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APPENDIX

APPENDIX A.

EXTRACTION EQUILIBRIUM

Part 1. Extraction Equilibrium of Synthetic Berberine Solution

Experimental Conditions

Aqueous Phase	:	0.05 g/l of synthetic berberine solution
Organic Phase	:	a) n-hexane
		b) kerosene
		c) paraffin
Volume ratio	:	1:1 (aqueous:organic)
Agitation Speed	:	240 rpm
Temperature	:	at 25 ^{o}c
Time	:	0 - 96 hours

Table A.1 Calculation of the Synthetic Berberine Concentration Ratio on Extraction Equilibrium at pH 8

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BS}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BS}/C_{BH}	C_{BS}/C_{BK}	C_{BS}/C_{BP}
0	0.0500	0.0512	0.0450	0	0	0	0	0	0
6	-	-	-	0.0478	0.0501	0.0443	0.0460	0.0220	0.0158
24	-	-	-	0.0458	0.0466	0.0441	0.0917	0.0987	0.0204
48	-	-	-	0.0450	0.0465	0.0439	0.1111	0.1011	0.0251
96	-	-	-	0.0452	0.0465	0.0437	0.1062	0.1011	0.0297

Table A.2 Calculation of the Synthetic Berberine Concentration Ratio on Extraction Equilibrium at pH 9

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BS}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BS}/C_{BH}	C_{BS}/C_{BK}	C_{BS}/C_{BP}
0	0.0500	0.0512	0.0450	0	0	0	0	0	0
6	-	-	-	0.0478	0.0501	0.0443	0.0460	0.0220	0.0158
24	-	-	-	0.0451	0.0466	0.0442	0.1086	0.0987	0.0181
48	-	-	-	0.0451	0.0465	0.0439	0.1086	0.1010	0.0251
96	-	-	-	0.0450	0.0465	0.0437	0.1111	0.1010	0.0297

Table A.3 Calculation of the Synthetic Berberine Concentration Ratio on Extraction Equilibrium at pH 10

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BS}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BS}/C_{BH}	C_{BS}/C_{BK}	C_{BS}/C_{BP}
0	0.0510	0.0526	0.0520	0	0	0	0	0	0
6	-	-	-	0.0490	0.0488	0.0496	0.0408	0.0753	0.0113
24	-	-	-	0.0462	0.0479	0.0486	0.1039	0.0987	0.0321
48	-	-	-	0.0453	0.0476	0.0490	0.1258	0.1039	0.0237
96	-	-	-	0.0452	0.0475	0.0486	0.1283	0.1040	0.0321

Table A.4 Calculation of the Synthetic Berberine Concentration Ratio on Extraction Equilibrium at pH 11

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BS}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BS}/C_{BH}	C_{BS}/C_{BK}	C_{BS}/C_{BP}
0	0.0557	0.0562	0.0500	0	0	0	0	0	0
6	-	-	-	0.0543	0.0550	0.0480	0.0249	0.0218	0.0417
24	-	-	-	0.0499	0.0512	0.0460	0.1152	0.0971	0.1110
48	-	-	-	0.0500	0.0510	0.0470	0.1130	0.1029	0.0438
96	-	-	-	0.0495	0.0509	0.0489	0.1242	0.1045	0.0225

Table A.5 Calculation of the Synthetic Berberine Concentration Ratio on Extraction Equilibrium at pH 12

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BS}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BS}/C_{BH}	C_{BS}/C_{BK}	C_{BS}/C_{BP}
0	0.0500	0.0500	0.0500	0	0	0	0	0	0
6	-	-	-	0.0470	0.0430	0.0466	0.0639	0.1628	0.0730
24	-	-	-	0.0452	0.0450	0.0498	0.1056	0.1110	0.0040
48	-	-	-	0.0438	0.0447	0.0488	0.1416	0.1186	0.0246
96	-	-	-	0.0434	0.0447	0.0486	0.1520	0.1186	0.0288

Part 2. Extraction Equilibrium of Crude Berberine Solution

Experimental Conditions

Aqueous Phase	: 0.11 g/l of crude berberine solution (Extracted Khamin Khruea)
Organic Phase	: a) n-hexane b) kerosene c) paraffin
Volume ratio	: 1:1 (aqueous:organic)
Agitation Speed	: 240 rpm
Temperature	: at 25 ^{o}c
Time	: 0 - 96 hours

Table A.6 Calculation of the Crude Berberine Concentration Ratio on Extraction Equilibrium at pH 8

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BC}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BC}/C_{BH}	C_{BC}/C_{BK}	C_{BC}/C_{BP}
0	0.1100	0.1147	0.1245	0	0	0	0	0	0
6	-	-	-	0.1044	0.1098	0.1228	0.0536	0.0446	0.0138
24	-	-	-	0.1004	0.1048	0.1233	0.0986	0.0945	0.0097
48	-	-	-	0.1000	0.1045	0.1226	0.1000	0.0976	0.0154
96	-	-	-	0.1002	0.1043	0.1221	0.9780	0.0997	0.0195

Table A.7 Calculation of the Crude Berberine Concentration Ratio on Extraction Equilibrium at pH 9

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BC}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BC}/C_{BH}	C_{BC}/C_{BK}	C_{BC}/C_{BP}
0	0.1100	0.1135	0.1148	0	0	0	0	0	0
6	-	-	-	0.1032	0.1082	0.1131	0.0659	0.0489	0.1414
24	-	-	-	0.1004	0.1034	0.1126	0.0956	0.0977	0.0187
48	-	-	-	0.0997	0.1033	0.1131	0.1033	0.0987	0.0141
96	-	-	-	0.0990	0.1033	0.1124	0.1111	0.0987	0.0205

Table A.8 Calculation of the Crude Berberine Concentration Ratio on Extraction Equilibrium at pH 10

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BC}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BC}/C_{BH}	C_{BC}/C_{BK}	C_{BC}/C_{BP}
0	0.1120	0.1140	0.1140	0	0	0	0	0	0
6	-	-	-	0.1032	0.1084	0.1130	0.0948	0.0517	0.0089
24	-	-	-	0.0987	0.1041	0.1116	0.1347	0.0951	0.0215
48	-	-	-	0.0992	0.1014	0.1113	0.1290	0.1243	0.0243
96	-	-	-	0.0992	0.1018	0.1118	0.1290	0.1198	0.0197

Table A.9 Calculation of the Crude Berberine Concentration Ratio on Extraction Equilibrium at pH 11

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BC}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BC}/C_{BH}	C_{BC}/C_{BK}	C_{BC}/C_{BP}
0	0.1145	0.1130	0.1148	0	0	0	0	0	0
6	-	-	-	0.1053	0.1033	0.1137	0.0874	0.0939	0.0097
24	-	-	-	0.1011	0.1011	0.1119	0.1325	0.1177	0.0259
48	-	-	-	0.1021	0.1023	0.1122	0.1213	0.1038	0.0218
96	-	-	-	01021	0.1024	0.1123	0.1210	0.1030	0.0220

Table A.10 Calculation of the Crude Berberine Concentration Ratio on Extraction Equilibrium at pH 12

Time (h)	Initial Concentration in Aqueous Phase (g/l)			Equilibrium Concentration in Aqueous Phase (g/l)			Concentration Ratio C_{BC}/C_{BO}		
	n-Hexane	Kerosene	Paraffin	n-Hexane	Kerosene	Paraffin	C_{BC}/C_{BH}	C_{BC}/C_{BK}	C_{BC}/C_{BP}
0	0.1130	0.1140	0.1145	0	0	0	0	0	0
6	-	-	-	0.1051	0.1046	0.1109	0.0752	0.8987	0.0325
24	-	-	-	0.1002	0.1031	0.1118	0.1277	0.1038	0.0239
48	-	-	-	0.0993	0.1031	0.1118	0.1379	0.1038	0.0239
96	-	-	-	0.0996	0.1032	0.1117	0.1345	0.1040	0.0247

APPENDIX B.
EXTRACTION EXPERIMENTAL DATA FOR SYNTHETIC BERBERINE SOLUTION

Part 1. Surfactant Concentration Variables

Experimental Conditions.

External Phase	: 0.05 g/l of synthetic berberine solution at pH 9
Membrane Phase	: Span-80 at various concentrations and kerosene at various volume (% of kerosene due to % of Span-80)
Internal Phase	: 0.1 M of HCl Solution
Membrane Preparation	: at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	: 240 rpm
Temperature	: room temperature

Table B.1 Experimental Data on ELM Extraction of Synthetic Berberine Solution at Various Surfactant Concentrations

Time (min)	Concentration of Aqueous Berberine Solution in the External Phase (g/l)			
	1% Span-80	3% Span-80	5% Span-80	7% Span-80
0	0.0501	0.0570	0.0480	0.0470
1	0.0244	0.0419	0.0385	0.0400
2	0.0187	0.0364	0.0347	0.0382
3	0.0168	0.0353	0.0326	0.0368
4	0.0174	0.0315	0.0345	0.0380
5	0.0163	0.0303	0.0306	0.0373
6	-	0.0295	0.0331	0.0378
7	-	0.0273	0.0300	0.0359
8	-	0.0245	0.0288	0.0359
9	-	0.0236	0.0293	0.0341
10	0.0138	0.0236	0.0281	0.0341
15	0.0143	0.0225	0.0258	0.0310
20	0.0099	0.0205	0.0215	0.0273
25	0.0110	0.0177	0.0199	0.0252
30	0.0096	0.0148	0.0180	0.0259
35	0.0096	-	-	0.0226
40	0.0090	0.0124	0.0144	0.0227
50	0.0089	0.0114	0.0123	0.0153
60	0.0084	0.0109	0.0154	0.0153

Table B.2 Calculation of C/Co on ELM Extraction of Synthetic Berberine Solution at Various Surfactant Concentrations

Time (min)	C/Co			
	1% Span-80	3% Span-80	5% Span-80	7% Span-80
0	1	1	1	1
1	0.4880	0.7350	0.8030	0.8520
2	0.3740	0.6380	0.7230	0.8130
3	0.3350	0.6200	0.6790	0.7830
4	0.3470	0.5520	0.7180	0.8080
5	0.3250	0.5320	0.6380	0.7930
6	-	0.5180	0.6900	0.8039
7	-	0.4790	0.6260	0.7647
8	-	0.4290	0.6000	0.7647
9	-	0.4140	0.6110	0.7254
10	0.2760	0.4140	0.5860	0.7254
15	0.2860	0.3940	0.5380	0.6587
20	0.1970	0.3600	0.4480	0.5800
25	0.2200	0.3100	0.4140	0.5370
30	0.1920	0.2600	0.3740	0.5520
35	0.1920	-	-	0.4800
40	0.1800	0.2170	0.3000	0.4830
50	0.1770	0.2000	0.2560	0.3250
60	0.1670	0.1920	0.3200	0.3250

Table B.3 Calculation of Initial Rate on ELM Extraction of Synthetic Berberine Solution at Various Surfactant Concentrations (at first 1 minute)

Surfactant Concentration (% v/v)	Initial Rate (g/l min)
1	0.5120
3	0.2650
5	0.1970
7	0.1500

Table B.4 Calculation of Internal Berberine Concentration on ELM of Synthetic Berberine Solution at Various Surfactant Concentrations (at first 1 minute)

Surfactant Concentration (% v/v)	Internal Berberine Concentration (g/l)
1	0.1542
3	0.0906
5	0.0570
7	0.0420

Part 2. Initial External Phase pH Variables

Experimental Conditions.

External Phase	:	0.05 g/l of synthetic berberine solution at various pH of initial external phase
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	0.01 M HCl solution.
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table B.5 Experimental Data on ELM Extraction of Synthetic Berberine Solution at Various pH of Initial External Phase

Time (min)	Concentration of Synthetic Berberine Solution in the External Phase (g/l)				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.0514	0.0512	0.0480	0.0560	0.0507
1	0.0510	0.0420	0.0280	0.0150	0.0189
2	0.0477	0.0374	0.0160	0.0020	0.0118
3	0.0466	0.0369	0.0050	0.0020	0.0033
4	0.0508	0.0340	0.0030		0.0023
5	0.0463	0.0305	0.0020		0.0033
6	0.0454	0.0259			
7	0.0439	0.0268			
8	0.0435	0.0245			
9	0.0430	0.0233			
10	0.0401	0.0190			
15	0.0375	0.0123			
20	0.0338	0.0107			
25	0.0300	0.0080			
30	0.0299	0.0053			
40	0.0238				
60	0.0223				

Table B.6 Calculation of C/Co on ELM Extraction of Synthetic Berberine Solution at Various pH of Initial External Phase

Time (min)	C/Co				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	1.0000	1.0000	1.0000	1.0000	1.0000
1	0.9922	0.8199	0.5683	0.2643	0.3729
2	0.9280	0.7308	0.3208	0.0319	0.2334
3	0.9072	0.7210	0.1069	0.0296	0.0641
4	0.9819	0.6640	0.0532		0.0462
5	0.9000	0.5948	0.0380		0.0651
6	0.8829	0.5054			
7	0.8530	0.5228			
8	0.8465	0.4788			
9	0.8354	0.4552			
10	0.7792	0.3718			
15	0.7296	0.2409			
20	0.6579	0.2098			
25	0.5832	0.1569			
30	0.5820	0.1043			
40	0.4622				
60	0.4341				

Table B.7 Calculation of Initial Rate on ELM Extraction of Synthetic Berberine Solution at Various pH of Initial External Phase (at first 1 minute)

External phase pH	Initial Rate (g/l min)
8	0.0078
9	0.1801
10	0.4317
11	0.7358
12	0.6271

Table B.8 Calculation of Internal Berberine Concentration on ELM Extraction of Synthetic Berberine Solution at Various pH of Initial External Phase (at first 1 minute)

External phase pH	Internal Berberine Concentration (g/l)
8	0.0024
9	0.0553
10	0.1200
11	0.2460
12	0.1907

Part 3. Internal Phase Concentration Variables

Experimental Conditions.

External Phase	: 0.05 g/l of synthetic berberine solution at pH 11
Membrane Phase	: 1 % Span-80 and 99% kerosene
Internal Phase	: HCl solution at various concentrations
Membrane Preparation	: at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	: 240 rpm
Temperature	: room temperature

Table B.9 Experimental Data on ELM Extraction of Synthetic Berberine Solution at Internal Phase Concentration Variables

Time (min)	Concentration of Synthetic Berberine Solution in the External Phase (g/l)		
	0.01 M HCl	0.02 M HCl	0.03 M HCl
0	0.0560	0.0540	0.0500
1	0.0148	0.0108	0.0079
2	0.0018	0.0012	0.0005
3	0.0017	0.0001	0.0005
4		0.0005	

Table B.10 Calculation of C/Co on ELM Extraction of Synthetic Berberine Solution at Internal Phase Concentration Variables.

Time (min)	C/Co		
	0.1 M HCl	0.2 M HCl	0.3 M HCl
0	1.0000	1.0000	1.0000
1	0.2643	0.2000	0.1589
2	0.0319	0.0225	0.0100
3	0.0296	0.0200	0.0100
4		0.0100	

Table B.11 Calculation of Initial Rate on ELM Extraction of Synthetic Berberine Solution at Internal Phase Concentration Varibles (at first 1 minute)

Internal Concentration (M)	Initial Rate (g/l min)
0.01	0.7350
0.02	0.8000
0.03	0.8411

Table B.12 Calculation of Internal Berberine Concentration on ELM Extraction of Synthetic Berberine Solution at Internal Phase Concentration Variables (at first 1 minute)

Internal Concentration (M)	Internal Berberine Concentration (g/l)
0.01	0.2472
0.02	0.2592
0.03	0.2526

APPENDIX C.
EXTRACTION EXPERIMENTAL DATA FOR CRUDE BERBERINE SOLUTION

Part 1. Initial External Phase pH Variables

1.1 Experimental Conditions.

External Phase	:	0.11 g/l of crude berberine solution at various pH of initial external phase
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	0.01 M HCl solution.
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table C.1 Experimental Data on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.01 M HCl Solution)

Time (min)	Concentration of Crude Berberine Solution in the External Phase (g/l)				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.1407	0.1408	0.1178	0.1147	0.1159
1	0.1399	0.1153	0.0825	0.0681	0.0531
2	0.1174	0.0932	0.0618	0.0355	0.0276
3	0.1104	0.0645	0.0391	0.0231	0.0211
4	0.0911	0.0447	0.0241	0.0118	0.0176
5	0.0785	0.0323	0.0173	0.008	0.0145
6	0.0749	0.0239	0.013	0.0044	0.0127
7	0.0688	0.0193	0.0106	0.0032	0.0113
8	0.0636	0.0175	0.0094	0.0026	0.009
9	0.0555	0.0164	0.0094		
10	0.054	0.0175			
15	0.0499	0.0136			
20	0.0426				
30	0.0376				

Table C.2 Calculation of C/Co on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.01 M HCl Solution)

Time (min)	C/Co				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	1.0000	1.0000	1.0000	1.0000	1.0000
1	0.9943	0.8190	0.7000	0.5941	0.4581
2	0.8347	0.6621	0.5250	0.3095	0.2381
3	0.7843	0.4583	0.3321	0.2013	0.1821
4	0.6480	0.3175	0.2046	0.1030	0.1519
5	0.5579	0.2294	0.1467	0.0700	0.1251
6	0.5327	0.1695	0.1000	0.0380	0.1096
7	0.4895	0.1374	0.0897	0.0280	0.0975
8	0.4523	0.1246	0.0800	0.0230	0.0975
9	0.3946	0.1167	0.0800		
10	0.3842	0.1246			
15	0.3547	0.0963			
20	0.3028				
30	0.2675				

Table C.3 Calculation of Initial Rate on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.01 M HCl Solution)

External Phase pH	Initial Rate (g/l min)
8	0.0057
9	0.1810
10	0.3000
11	0.4059
12	0.5419

Table C.4 Calculation of Internal Berberine Concentration on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.01 M HCl Solution)

External Phase pH	Internal Berberine Concentration (g/l)
8	0.0048
9	0.1108
10	0.2118
11	0.2796
12	0.3768

1.2 Experimental Conditions

External Phase	:	0.11 g/l of crude berberine solution at various pH of initial external phase
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	0.02 M HCl solution.
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table C.5 Experimental Data on ELM Extraction of Crude Berberine Solution at Various Initial External Phase pH (0.02 M HCl Solution)

Time (min)	Concentration of Crude Berberine Solution in the External Phase (g/l)				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.1308	0.1428	0.1178	0.1242	0.1069
1	0.1141	0.1050	0.0766	0.0596	0.0377
2	0.0975	0.0823	0.0505	0.0281	0.0156
3	0.0928	0.0649	0.0297	0.0122	0.0121
4	0.0809	0.0421	0.0170	0.0075	0.0104
5	0.0690	0.0305	0.0100	0.0067	0.0084
6	0.6420	0.0235	0.0063	0.0018	0.0071
7	0.0547	0.0195	0.0039		
8	0.0476	0.0162			
9	0.0428				
10	0.0404				
20	0.0324				
30	0.0290				

Table C.6 Calculation of C/Co on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.02 M HCl Solution)

Time (min)	C/Co				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	1.0000	1.0000	1.0000	1.0000	1.0000
1	0.8727	0.7352	0.6500	0.4800	0.3527
2	0.7455	0.5762	0.4283	0.2260	0.1459
3	0.7091	0.4548	0.2525	0.0980	0.1132
4	0.6182	0.2949	0.1439	0.0600	0.0973
5	0.5273	0.2136	0.0849	0.0539	0.0786
6	0.4909	0.1367	0.0531	0.0145	0.0664
7	0.4182	0.1135	0.0327		
8	0.3636				
9	0.3273				
10	0.3090				
20	0.2480				
30	0.2220				

Table C.7 Calculation of Initial Rate on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.02 M HCl Solution)

External Phase pH	Initial Rate (g/l min)
8	0.1273
9	0.2648
10	0.3500
11	0.5200
12	0.6473

Table C.8 Calculation of Internal Berberine Concentration on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.02 M HCl Solution)

External Phase pH	Internal Berberine Concentration (g/l)
8	0.1002
9	0.2268
10	0.2472
11	0.3876
12	0.4152

1.3 Experimental Conditions.

External Phase	:	0.11 g/l of crude berberine solution at various pH of initial external phase
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	0.03 M HCl solution
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table C.9 Experimental Data on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.03 M HCl Solution)

Time (min)	Concentration of Crude Berberine Solution in the External Phase (g/l)				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.1398	0.1424	0.1195	0.1147	0.1189
1	0.1208	0.0996	0.0755	0.0420	0.0358
2	0.1034	0.0690	0.0444	0.0200	0.0121
3	0.0972	0.0562	0.0165	0.0087	0.0090
4	0.0842	0.0418	0.0089	0.0074	0.0095
5	0.0718	0.0262	0.0060	0.0053	0.0071
6	0.0684	0.0169	0.0032		
7	0.0559	0.0103			
8	0.0498	0.0076			
9	0.0419	0.0067			
10	0.0402	0.0067			
15	0.0280				
20	0.0266				
30	0.0201				

Table C.10 Calculation of C/Co on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.03 M HCl Solution)

Time (min)	C/Co				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	1.0000.	1.0000	1.0000	1.0000	1.0000
1	0.8642	0.6994	0.6321	0.3660	0.3015
2	0.7395	0.4843	0.3715	0.1740	0.1021
3	0.6954	0.3947	0.1380	0.0759	0.0759
4	0.6025	0.2938	0.0742	0.0642	0.0800
5	0.5137	0.1837	0.0500	0.0465	0.0600
6	0.4895	0.1185	0.0264	0.0000	
7	0.4000	0.0721			
8	0.3565	0.0532			
9	0.3000	0.0473			
10	0.2875	0.0473			
15	0.2000				
20	0.1900				
30	0.1440				

Table C.11 Calculation of Initial Rate on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.03 M HCl Solution)

External Phase pH	Initial Rate (g/l min)
8	0.1358
9	0.3006
10	0.3679
11	0.6340
12	0.6985

Table C.12 Calculation of Internal Berberine Concentration on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (at first 1 minute) (0.03 M HCl Solution)

External Phase pH	Internal Berberine Concentration (g/l)
8	0.1140
9	0.2668
10	0.2910
11	0.4362
12	0.4986

Part 2. Internal Phase Concentration Variables

2.1 Experimental Conditions.

External Phase	:	0.11 g/l of crude berberine solution at pH 11
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	HCl solution at various concentrations
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table C.13 Experimental Data on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (pH 11)

Time (min)	Concentration of Crude Berberine Solution in the External Phase (g/l)		
	0.01 M HCl	0.02 M HCl	0.03 M HCl
0	0.1147	0.1242	0.1147
1	0.0681	0.0596	0.0420
2	0.0355	0.0281	0.0200
3	0.0231	0.0122	0.0087
4	0.0118	0.0075	0.0074
5	0.0080	0.0067	0.0053
6	0.0044	0.0018	0.0000
7	0.0032		
8	0.0026		

Table C.14 Calculation of C/Co on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (pH 11)

Time (min)	C/Co		
	0.01 M HCl	0.02 M HCl	0.03 M HCl
0	1.0000	1.0000	1.0000
1	0.5941	0.4800	0.3660
2	0.3095	0.2260	0.1740
3	0.2013	0.0980	0.0759
4	0.1030	0.0600	0.0642
5	0.0700	0.0539	0.0465
6	0.0380	0.0145	0
7	0.0280		
8	0.0230		

Table C.15 Calculation of Initial Rate on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (at first 1 minute) (pH 11)

Internal Phase Concentration (M)	Initial Rate (g/l min)
0.01	0.4063
0.02	0.5200
0.03	0.6338

Table C.16 Calculation of Internal Berberine Concentration on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (at first 1 minute) (pH 11)

Internal Phase Concentration (M)	Internal Berberine Concentration (g/l)
0.01	0.2796
0.02	0.3876
0.03	0.4362

2.2 Experimental Conditions.

External Phase	:	0.11 g/l of crude berberine solution at pH 12
Membrane Phase	:	1 % Span-80 and 99% kerosene
Internal Phase	:	HCl solution at various concentrations
Membrane Preparation	:	at 8000 rpm homogenizing speed for 30 minutes
Agitation Speed	:	240 rpm
Temperature	:	room temperature

Table C.17 Experimental Data on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (pH 12)

Time (min)	Concentration of Crude Berberine Solution in the External Phase (g/l)		
	0.01 M HCl	0.02 M HCl	0.03 M HCl
0	0.1159	0.1069	0.1189
1	0.0531	0.0377	0.0358
2	0.0276	0.0156	0.0121
3	0.0211	0.0121	0.0090
4	0.0145	0.0104	0.0095
5	0.0127	0.0084	0.0071
6	0.0113	0.0071	
7	0.0090		

Table C.18 Calculation of C/Co on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (pH 12)

Time (min)	C/Co		
	0.01 M HCl	0.02 M HCl	0.03 M HCl
0	1.0000	1.0000	1.0000
1	0.4581	0.3527	0.3015
2	0.2381	0.1459	0.1021
3	0.1821	0.1132	0.0759
4	0.1519	0.0973	0.0800
5	0.1251	0.0786	0.0600
6	0.1096	0.0664	
7	0.0975		
8	0.0975		

Table C.19 Calculation of Initial Rate on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (at first 1 minute) (pH 12)

Internal Phase Concentration (M)	Initial Rate (g/l min)
0.01	0.5419
0.02	0.6473
0.03	0.6985

Table C.20 Calculation of Internal Berberine Concentration on ELM Extraction of Crude Berberine Solution at Internal Phase Concentration Variables (at first 1 minute) (pH 12)

Internal Phase Concentration (M)	Internal Berberine Concentration (g/l)
0.01	0.3768
0.02	0.4152
0.03	0.4986

Table C.21 Calculation of Swelling on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.01 M HCl Solution)

Time (min)	% Swelling				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.9000	0.9350	0.8730	0.8520	0.9430
2	4.5900	3.8700	1.3700	1.0430	1.0000
3	8.7000	7.4500	1.6800	1.3450	2.3500
4	10.9200	9.8000	2.5400	2.5400	2.3600
5	15.4300	13.0000	2.8700	2.5300	2.3600
6	17.2700	14.3500	3.0600	2.5700	
7	17.4300	16.0300	3.0600	2.6100	
8	20.0000	17.4900	4.4800	2.6800	
9	20.7800	18.2000	5.1000		
10	24.3500	20.3500			
20	48.7300				
30	48.7300				

Table C.22 Calculation of Swelling on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.02 M HCl Solution)

Time (min)	% Swelling				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.9420	0.9270	0.9740	0.9720	0.9100
2	4.2600	1.3450	0.9800	0.9980	0.9000
3	7.9500	5.4200	1.5840	1.1540	2.1900
4	10.9400	8.6000	2.4380	2.3490	2.2900
5	14.1500	9.6000	2.5700	2.3520	2.7000
6	15.4000	10.6000	3.5900	2.3520	2.2700
7	16.0300	13.1000	5.5000		
8	17.2100	13.6000			
9	18.4900				
10	20.6200				
20	44.9300				
30	44.9300				

Table C.23 Calculation of Swelling on ELM Extraction of Crude Berberine Solution at Various pH of Initial External Phase (0.03 M HCl Solution)

Time (min)	% Swelling				
	pH 8	pH 9	pH 10	pH 11	pH 12
0	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.8940	0.8790	0.8650	0.8790	0.8020
2	4.4200	1.0200	1.0300	0.9470	0.8130
3	6.9800	4.3000	1.7600	2.0400	1.5800
4	11.4800	6.0000	1.9500	2.3500	1.6700
5	11.9500	8.9000	2.4700	2.4300	1.9400
6	13.2000	9.3000	2.3800		
7	14.0200	9.7000			
8	15.3700	10.9000			
9	16.3900	12.4000			
10	18.0700	13.6000			
20	38.4500				
30	38.4800				

APPENDIX D

PHYSICAL PROPERTIES OF PURE SUBSTANCES

D1. Physical Properties of n-Hexane

Formula :	$CH_3(CH_2)_4CH_3$
Formula weight :	86.17
Form and color :	Colorless liquid
Specific gravity :	$0.659^{20/4}$
Melting point ($^{\circ}C$) :	-94
Boiling point ($^{\circ}C$) :	69
Solubility in 100 parts ;	
water :	0.014^{15}
alcohol :	50^{33}
ether :	∞

D2. Physical Properties of Kerosene

Formula :	light distillate
Formula weight :	157.97
Form and color :	Colorless liquid
Degree API :	45
Specific gravity :	0.8013
Solubility in water :	non

APPENDIX E
SIMPLE CALCULATION

E.1 Theory for Unfacilitated Transport

The main assumption can be summarised as follows: the emulsion globules are an uniform size, either breakage or leakage is negligible; berberine partitions into the solvent and diffuses to internal phase where it is removed by an instantaneous stripping reaction; the reaction front recedes into the emulsion as stripping occurs, the shrinking core assumption. The rate of removal of berberine from the external phase can be represented by Equation (E.1)

$$\frac{dC_B}{dt} = -\frac{kAC_B}{V_E}\left(1-\frac{k}{k+\frac{r_c D_B k_D}{RL}}\right) \qquad \text{..... (E.1)}$$

E.2 Estimation of the External Phase Mass Transfer Coefficient

The external mass transfer coefficient (k) was estimated from a correlation for mass transfer in dispersions (Calderbank and Moo-Young, 1961)

$$Sh = 2.0 + 0.31\ Ra^{1/3} \qquad \text{..... (E.2)}$$

$$\frac{kd}{D_E} = \left[2.0 + 0.31 \left(\frac{d^3 \Delta \rho g}{\mu_E D_E} \right)^{\frac{1}{3}} \right]$$

Where Sh is the Sherwood Number equal to kd/D_E

Ra is the Raleigh Number equal to $d^3 \Delta \rho g / \mu_E D_E$

k is the mass transfer coefficient of berberine, cm/s

D_E is the diffusion coefficient of berberine in the external phase, cm^2/s

d is the emulsion globule diameter, cm

$\Delta \rho$ is the density different between the emulsion and the external phase, g/cm^3

g is the acceleration due to gravity, cm/s^2

μ_E is the external phase viscosity, cP

The diffusion coefficient of berberine in the external phase was estimated by the Wilke-Chang correlation (Wilke and Chang, 1955),

$$D_E = \frac{7.4 * 10^{-8} \left(\phi M_S \right)^{1/2} T}{\mu_S \left(\bar{V}_B \right)^{0.6}} \quad \text{..... (E.3)}$$

Where ϕ is the association factor of the solvent which in the case of water is equal to 2.6

M_S is the molecular weight of the solvent; 18 g/g mol

T is the absolute temperature; 298 K

μ_S is the viscosity of water; 1 cP at 298 K

$\overline{V}_B$ is partial molar volume of the berberine; 318.437 cm^3/g mol

Therefore the diffusion coefficient of berberine in bulk external phase (D_E) was equal to 4.7506 * 10^{-6} cm^2/s. From the value of diffusion coefficient of berberine in external phase and the globule radius, the mass transfer coefficient (k) of berberine can be defined, where the density of berberine solution is equal to 0.9980 g/cm^2, the density of kerosene is equal to 0.8013 g/cm^2 and the acceleration due to gravity is equal to 980 cm/s^2. The globule radius is equal to 0.04 cm. Therefore k is equal to 7.4359*10^{-4} cm/s

E.3 Estimation of the Membrane Phase Diffusion Coefficient

The diffusion coefficient of berberine in membrane phase (D_B) was estimate using the Wilke-Chang correlationis, where μ_S is the viscosity of kerosene; 0.42 cP at 298K, ϕ is the association factor of the solvent which in the case of unassociated solvent; 1, and M_S is the molecular weight of kerosene; 157.97 g/g mol. So that the diffusion coefficient of berberine in membrane phase (D_B) was found to be 2.078*10^{-5} cm^2/s

E.3 Surface Area of Internal Phase Droplets

The initial globule radius in this modle is 0.04 cm, then the volume of single globule is given by;

$$V = \frac{4}{3}\pi R^3 \qquad \text{.....(E.4)}$$

Then the volume of single globule (V) is $2.679*10^{-4}$ cm^3 and the total volume of emulsion is 100 cm^3, therefore assuming that the globules are spherical and monodisperse, the number of globules in the emulsion is

$$N = \frac{100}{V_{emul}} \qquad \text{.....(E.5)}$$

Therefore the number of blobules in the emulsion is $3.7327*10^5$. The surface area of the globule is assumed to be the same as that of sphere, then equal to $2.0096*10^{-2}$ cm^2

$$\text{Surface area} = 4\pi R^2 \qquad \text{.....(E.6)}$$

The total surface area of 100 cm^3 of emulsion is $(3.7327*10^5)(2.0096*10^{-2}) = 6.8983*10^3$ cm^3

The data from this appendix were used to calculate the model of berberine transported mechanism in Q Basic in Appendix F.

APPENDIX F

COMPUTER PROGRAM LISTINGS (Q BASIC)

In this Appendix contains the program written to solve the differential equation for unfacilitated transport (non swelling and swelling). All of this program is written in Q Basic.

```
DECLARE SUB COMP (Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT,
LTOT, N, VI())
REM UNFACILITATED EXTRACTION FROM EXTERNAL PHASE: NON
SWELLING AND SWELLING
REM ************************************************************
REM RUNGE-KUTTA SOLUTION MODEL
REM INPUT INITIAL VALUES
CLS
DIM VI(0 TO 100)
    PRINT "  COMPUTE UNFACILITATED EXTRACTION  "
    INPUT "                ENTER pH    "; PH
    INPUT "Enter diffusion Coefficient (cm^2/s) "; DIFF
    INPUT "Enter diff. coef.of External (cm^2/s)"; DIFE
    INPUT "   Enter radius of globule (cm)    "; RAD0
    INPUT "              Enter partition     "; PART
    INPUT "       Enter initial time (min)    "; MINS
    INPUT "        Enter final time (min)     "; MINX
    INPUT "      Enter time interval (min)    "; HMIN
```

```
        INPUT "  Enter initial concentration (M)    "; C0
        VEXT = 300
        LPRINT "++++++++++++++++++++++++++++++++++++++++"
        LPRINT " START AT 0 MIN C/C0 = 1.0 C0 ="; C0, "M": LPRINT

  REM CONVERT TIME INTO SECONDS, SET COUNTER
        SEC = MINS * 60: SECX = MINX * 60: HSEC = HMIN * 60
         M = INT((SECX - SEC) / HSEC)
        FOR J = 0 TO M
             PRINT "VOLUME OF INTERNAL DROPLET("; J; ")=",
             INPUT VI(J)
             VI(J) = VI(J) + 50
        NEXT J
    MASS = DIFE / (2 * RAD0) * (2 + .31 * ((RAD0 * 2) ^ 3 * .1967 * 980 / 1 / DIFE) ^
(1 / 3))
     LPRINT "       ****************  "
     LPRINT "    AT "; SEC / 60; " MIN C/C0 = ",
     REM.....
     LPRINT C0, C1
     LPRINT USING "###,###.####"; CONC / C0
     LPRINT "L=0"
     LPRINT "RC="; RAD0
     LPRINT "K0="; MASS
     N = 1: X = 0
FOR N = 1 TO M
REM RUNGE-KUTTA ALGORITHM TO INTEGRATE FUNCTION
```

```
REM ****************************************
  Y = CONC
CALL COMP(Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT, LTOT, N, VI())
      IF A2 < 1 THEN
   K1 = HSEC * FUNCT
   SEC = SEC + .5 * HSEC
   Y = CONC + .5 * K1
   CALL COMP(Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT, LTOT, N,
VI())
         IF A2 < 1 THEN
      K2 = HSEC * FUNCT
      Y = CONC + .5 * K2
   CALL COMP(Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT, LTOT, N,
VI())
         IF A2 < 1 THEN
      K3 = HSEC * FUNCT
      SEC = SEC + .5 * HSEC
      Y = CONC + K3
  CALL COMP(Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT, LTOT, N,
VI())
         IF A2 < 1 THEN
      K4 = HSEC * FUNCT
     CONC = CONC + (K1 + 2 * K2 + 2 * K3 + K4) / 6
      END IF
   END IF
 END IF
```

```
END IF
        IF X = 10 THEN
    LPRINT "     AT "; SEC / 60, "min C/C0 = "; CONC / C0
    X = -1
  END IF
    X = X + 1
K0 = 1 / (1 / MASS + RAD0 * LTOT / (RC * DIFF * PART))

REM PRINT FINAL RESULT AND PARAMETER VALUES
    LPRINT "       ***************** "
    LPRINT "    AT "; SEC / 60; "min C/C0 = ",
    LPRINT USING "###,###.####"; CONC / C0
    LPRINT "CONC="; CONC
    LPRINT "     L = "; LTOT
    LPRINT "    RC = "; RC
    LPRINT "    K0 = "; K0
NEXT N
REM PRINT FINAL RESULT AND PARAMETER VALUES
    LPRINT "-------------------------------------"
    LPRINT "                  THE VALUE OF pH = "; PH
    LPRINT "          Initial Concentration = "; C0, "M"
    LPRINT "       Mass Transfer Coefficient = "; MASS; "cm/s"
    LPRINT "          Diffusion Coefficient = "; DIFF; "cm^2/s"
    LPRINT "                Globule Radius = "; RAD; "cm"
    LPRINT "          Partition Coefficient = "; PART
    LPRINT
```

```
END
SUB COMP (Y, C0, MASS, DIFF, DIFE, RAD, RAD0, PART, RC, FUNCT, LTOT, N, VI())
REM ********************************
'SUBROUTINE TO EVALUATE FUNCTION
' ********************************
'SOLVE EQUATION FOR DIFFUSION DISTANCE, L
'EXTRACTION PARAMETERS: R = STOICHIOMETRIC COEFF., PV = PHASE VOLUME
'RATIO, HCl = HYDROCHLORIC ACID CONC.(M)

  R = 1: HCl= .01: PV = 6: VEXT = 300: PI = 22 / 7
 MASS = DIFE / (2 * RAD0) * (2 + .31 * ((RAD0 * 2) ^ 3 * .1967 * 980 / 1 / DIFE) ^
(1 / 3))
      A1! = 1 - (Y / C0)
      A2! = R * PV * C0 * A1 / NA
        IF A2 < 1 THEN
      A3 = 1 - (1 - A2) ^ (1 / 3)
  REM FURTHER PARAMETERS: RAD = GLOBULE RADIUS (cm), PART =
PARTITION
REM COEFFICIENT
      NEM = .75 * 100 / (PI * RAD0 ^ 3)
      RAD = (.75 * VI(N) / (PI * NEM)) ^ (1 / 3)
      L = RAD * A3
      AREA = 4 * PI * NEM * RAD ^ 2
      LTOT = L + (RAD - RAD0)
      RC = RAD - LTOT
REM CONTANTS
```

```
      IF LTOT <= 0 THEN
        I = 0
      ELSE
REM SOLVE FOR INTERFACIAL CONCENTRATIOM
        B1 = RC * DIFF * PART / (RAD * LTOT)
        B2 = MASS / (MASS + B1)
        I = Y * B2
      END IF
REM EVALUATE DIFFERENTIAL EQUATION FUNCTION
        FUNCT = -MASS * AREA * (Y - I) / VEXT
   ELSE
        LPRINT
        LPRINT "ALL INTERNAL PHASE REAGENT CONSUMED"
  END IF
END SUB
```

VITA

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