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APPENDICES

Appendix A Experimental Data of Microemulsion Formation

1. Interfacial Tension (IFT)

The interfacial tension of each phase of microemulsion is interpreted by the following formulation:

$$IFT = e(Vd)^3 n^2 \Delta\rho \quad (A1)$$

where

σ = interfacial tension or IFT (mN/m, dyne/cm)

e = unity factor ($3.427 \cdot 10^{-7}$ mN cm³ min² /m g mm³)

V = enlargement factor (0.31 mm/sdv)

d = measured drop diameter (sdv)

n = number of revolution (1/min)

$\Delta\rho$ = density difference of two liquids (g/cm³)

2. Experimental Data of Interfacial Tension (IFT)

2.1 Interfacial Tension

Table A2 Interfacial tension of each phase in microemulsion formation with 0.3 wt% of Alfoterra at different NaCl concentrations and an initial oil-to-water ratio = 1:1

Alfoterra Conc. (wt%)	NaCl conc (wt%)	No.	Upper density (g/ml)	Lower density (g/ml)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.3	10	1	0.8506	1.0647	5.46	2.03	1174	0.1216
		2	0.8506	1.0647	5.49	1.98	1166	0.1285
		3	0.8506	1.0647	5.41	2.02	1201	0.1228
		ave						0.1243
	11	1	0.8566	1.0773	5.31	2.11	1098	0.0890
		2	0.8566	1.0773	5.37	2.10	1067	0.0897
		3	0.8566	1.0773	5.60	2.09	993	0.0961
		ave						0.0916
	12	1	0.8587	1.0814	5.35	2.22	992	0.0686
		2	0.8587	1.0814	5.51	2.14	901	0.0706
		3	0.8587	1.0814	5.20	2.12	1029	0.0703
		ave						0.0699
	13	1	0.8573	1.0899	5.17	2.09	855	0.0507
		2	0.8573	1.0899	5.13	2.04	862	0.0521
		3	0.8573	1.0899	5.09	2.02	886	0.0539
		ave						0.0522
	14	1	0.8532	1.1083	5.33	2.07	851	0.0653
		2	0.8532	1.1083	5.29	2.06	795	0.0555
		3	0.8532	1.1083	5.41	2.11	879	0.0723
		ave						0.0644
	15	1	0.8543	1.0988	5.34	2.03	1117	0.1129
		2	0.8543	1.0988	5.40	2.11	1127	0.1129
		3	0.8543	1.0988	5.35	2.08	1158	0.1170
		ave						0.1143

Table A3 Interfacial tension of each phase in microemulsion formation with 0.3 wt% of Alfoterra and 13 wt% NaCl at different oil-to-water ratio

Alfoterra Conc. (wt%)	NaCl Conc. (wt%)	Oil:Water	No.	Upper density (g/ml)	Lower density (g/ml)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.3	13	1:1	1	0.8558	1.0713	5.18	2.22	1010	0.0582
			2	0.8558	1.0713	5.18	2.44	1056	0.0505
			3	0.8558	1.0713	5.07	2.45	1126	0.0502
			ave						0.0529
		1:4	1	0.8659	1.0695	4.97	2.52	982	0.0295
			2	0.8659	1.0695	5.02	2.43	956	0.0330
			3	0.8659	1.0695	5.02	2.48	996	0.0338
			ave						0.0321
		1:9	1	0.8623	1.0673	5.04	2.48	848	0.0253
			2	0.8623	1.0673	5.04	2.40	815	0.0256
			3	0.8623	1.0673	4.96	2.54	993	0.0292
			ave						0.0267
		1:19	1	0.8629	1.0980	5.30	2.48	902	0.0438
			2	0.8629	1.0980	5.08	2.31	935	0.0446
			3	0.8629	1.0980	5.11	2.15	913	0.0519
			ave						0.0468

Alfoterra Conc. (wt%)	NaCl Conc. (wt%)	Time (min)	Upper density (g/ml)	Lower density (g/ml)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.3	14	0	0.854	1.0749	4.86	2.28	1466	0.0832
		5	0.854	1.0749	4.84	2.27	1463	0.0819
		10	0.854	1.0749	4.85	2.29	1463	0.0810
		15	0.854	1.0749	4.84	2.28	1464	0.0811
		20	0.854	1.0749	4.83	2.28	1464	0.0801
		25	0.854	1.0749	4.84	2.27	1465	0.0822
		30	0.854	1.0749	4.85	2.28	1466	0.0823
		ave						
	15	0	0.854	1.0803	5.13	2.24	1564	0.1364
		5	0.854	1.0803	5.12	2.25	1563	0.1334
		10	0.854	1.0803	5.13	2.26	1566	0.1339
		15	0.854	1.0803	5.12	2.25	1565	0.1338
		20	0.854	1.0803	5.11	2.25	1564	0.1322
		25	0.854	1.0803	5.12	2.26	1566	0.1325
30		0.854	1.0803	5.12	2.26	1565	0.1324	
ave							0.1335	



3. Experimental Data of Electrolytic Conductivity

Table A5 Electrolytic conductivity of each phase in microemulsion formation with 0.3 wt% of Alfoterra at different NaCl concentrations and an initial oil-to-water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)			
0.3	2	5	1159	26.5			
		10	1154	26.5			
		15	1155	26.6			
		20	1143	26.8			
		25	1151	26.8			
		30	1148	26.8			
		35	1147	26.9			
		40	1148	26.9			
		45	1141	26.9			
		50	1135	27.0			
		55	1140	27.0			
		60	1138	27.0			
		65	1134	27.1			
		70	1135	27.1			
		75	1139	27.1			
		80	1136	27.1			
		ave	1144	26.9			
	3	3	1	2460	27.0		
			2	2370	27.0		
			4	2250	27.0		
			5	2210	27.1		
			7	2170	27.1		
			10	2090	27.1		
			15	2010	27.2		
			20	2000	27.2		
			45	2090	27.4		
			50	2010	27.4		
			55	2290	27.4		
			60	2340	27.5		
			ave	2191	27.2		
			6	6	5	7180	26.5
					10	6550	26.6
					15	6060	26.6
20	5880	26.7					
25	5760	26.8					

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)
0.3	6	30	5680	26.8
		35	5600	26.9
		40	5550	26.9
		45	5550	26.9
		50	5553	26.9
		70	5390	26.9
		75	5360	27.0
		ave	5843	26.8
	8	10	9000	26.4
		20	7820	26.5
		30	7240	26.7
		35	7160	26.7
		45	7320	26.8
		50	8260	26.8
		55	8160	26.9
		60	8970	26.9
		65	9870	26.9
		70	9060	26.9
		75	11540	26.9
		85	12570	26.9
		90	6910	26.9
		95	5270	26.9
		100	4730	26.9
		105	4250	26.9
		110	3800	27.0
		115	3500	27.0
		120	3140	27.0
		125	3030	27.0
		130	2880	27.0
		135	2790	27.0
		140	2710	27.0
		145	2705	27.0
	150	2709	27.0	
ave	6216	26.9		
9	1	7960	26.9	
	3	7560	26.6	
	5	7370	26.6	
	7	7220	26.8	
	9	7220	26.6	
	11	7240	26.5	
	14	7190	26.5	
	20	7190	26.8	
25	7110	26.9		

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)
0.3	9	30	7070	26.9
		40	6900	28.4
		50	6920	28.1
		65	6780	28.6
		95	6770	28.8
		ave	7179	27.2
		10	15	26900
	25		23100	26.6
	35		22800	26.7
	40		23000	26.7
	45		23100	26.7
	50		22900	26.7
	55		22800	26.7
	60		22700	26.7
	65		22600	26.7
	70		22700	26.7
	75		22600	26.7
	80		22500	26.7
	85		22600	26.7
	90	22600	26.7	
	ave	23064	26.7	
	15	15	58.6	26.8
		20	74.4	26.8
		25	60.8	26.8
		30	67.2	26.9
		40	64.6	26.9
		50	61.2	26.9
		60	62.3	26.9
		70	63.5	26.9
		80	62.7	26.9
		150	62.1	26.9
	ave	63	26.9	
	16	20	0	26.3
30		0	26.3	
40		0	26.3	
50		0	26.3	
60		0	26.3	
70		0	26.3	
80		0	26.3	
90		0	26.3	
100		0	26.3	
ave		0	26.3	

Table A6 Electrolytic conductivity of each phase in microemulsion formation with 0.5 wt% of Alfoterra at different NaCl concentrations and an initial oil-to-water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μ S)	Temperatur e ($^{\circ}$ C)
0.5	2	10	5260	25.6
		15	4960	25.7
		20	4300	25.8
		25	4570	25.8
		30	3480	25.9
		35	3610	25.9
		40	3350	26.0
		45	3300	26.0
		50	3240	26.0
		55	3310	26.1
		60	3250	26.3
		65	3280	26.3
		70	3310	26.3
		75	3320	26.3
		80	3290	26.3
		120	3310	26.3
		ave	3337.5	26.1
	4	10	2120	26.3
		15	1830	26.4
		35	1314	26.8
40		1350	26.8	
48		1178	26.8	
52		1209	26.8	
55		1158	27.0	
60		1137	27.0	
66		1117	27.0	
70		1128	27.1	
75		1084	27.1	
80		1141	27.1	
85		1002	27.1	
86	1010	27.1		
87	1016	27.1		
88	1046	27.1		
89	1092	27.1		
90	1125	27.1		
92	1228	27.1		
93	1288	27.1		
94	1375	27.1		



Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μ S)	Temperature ($^{\circ}$ C)	
0.5	4	95	1494	27.1	
		96	1528	27.1	
		97	1560	27.1	
		98	1592	27.1	
		99	1652	27.1	
		100	1784	27.1	
		120	1816	27.1	
		140	1895	27.1	
		ave	1327	27.0	
	6	6	15	10720	27.2
			20	10960	27.3
			25	11050	27.3
			30	11150	27.3
			35	10950	27.3
			40	11090	27.3
			45	11040	27.3
			50	11340	27.3
			55	11290	27.4
			60	12830	27.6
			65	12970	27.9
			70	13060	28.0
			75	13270	28.2
			80	13620	28.2
			85	13540	28.0
			90	13480	27.9
			100	13870	27.6
			136	14040	27.6
			140	14150	27.7
			142	14220	27.7
			160	14340	27.7
	ave	12523	27.6		
	8	8	30	37100	27.3
			35	36300	27.3
40			35500	27.3	
45			34900	27.2	
50			34100	27.2	
55			33500	27.2	
60			32800	27.1	
65			32100	27.1	
70			31600	27.1	
75			31200	27.1	
80			30800	27.1	

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)
0.5	8	100	27600	27.1
		120	25700	27.1
		140	25000	27.1
		160	24900	27.3
		180	25100	27.3
		ave	25660	27.2
		10	30	30100
	35		28500	26.9
	40		26900	27.0
	45		24900	27.0
	50		23700	27.0
	60		23200	27.1
	70		21600	27.1
	80		20900	27.0
	85		18600	26.9
	90		16800	26.9
	100		15800	26.8
	110		16900	26.6
	120		16400	26.6
	ave		16783	26.7
	11	30	10340	26.7
		35	9970	26.8
		40	9850	26.9
		45	8900	26.9
		50	7970	27.0
		55	8040	27.0
		60	8120	27.0
		70	8880	27.1
		80	10040	27.1
		90	9050	27.1
		100	8940	27.1
		110	8590	27.1
		120	8730	27.1
		130	8540	27.1
		ave	8955	27.0
	12	5	0	26.1
10		0	26.1	
15		0	26.1	
20		0	26.1	
25		0	26.1	

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μ S)	Temperature ($^{\circ}$ C)
0.5	12	35	0	26.1
		40	0	26.1
		120	0	26.1
		ave	0	26.1

Table A7 Electrolytic conductivity of each phase in microemulsion formation with 0.7 wt% of Alfoterra at different NaCl concentrations and an initial oil-to-water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)	
0.7	2	15	4020	28.5	
		20	3970	28.5	
		25	2390	28.4	
		30	2360	28.4	
		35	2510	28.4	
		40	2420	28.4	
		45	2400	28.3	
		50	2290	28.3	
		55	2390	28.2	
		60	2420	28.1	
		70	2430	28.1	
		80	2400	28.1	
		90	2410	28.1	
	ave	2402	28.3		
	4	4	10	9500	27.8
			15	9470	27.8
			20	9670	27.8
			25	9800	27.9
			30	9980	27.9
			35	10100	27.9
			40	10200	27.9
			45	10240	27.8
			50	10270	27.8
			55	10240	27.8
			60	10680	27.8
			75	11020	27.5
			80	11040	27.5
			85	11010	27.4
			90	11040	27.4
			120	11080	27.4
			ave	10629	27.7
	6	6	25	7300	27.0
			30	7540	27.0
35			8150	27.1	
40			8670	27.1	
45			8840	27.1	
50			8590	27.2	
55			9340	27.2	

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)	
0.7	6	60	8790	27.3	
		65	8910	27.3	
		70	8870	27.4	
		80	8830	27.4	
		90	8840	27.4	
		100	8880	27.4	
		120	8820	27.4	
		ave	8853	27.3	
	8	8	20	24500	28.5
			25	23300	28.3
			30	21000	28.3
			35	18100	28.2
			40	17200	28.2
			45	15900	28.2
			50	14800	28.1
			55	18000	28.1
			60	18110	28.1
			65	17070	28.1
			70	16720	28.1
			75	15790	28.0
			80	15030	27.9
			85	14760	27.9
			90	14600	27.9
			95	14470	27.8
			100	14050	27.7
			105	13800	27.6
			110	13340	27.6
			115	12740	27.6
			120	12230	27.6
			125	10810	27.5
			130	10750	27.5
			135	10470	27.4
	140	10760	27.4		
180	10800	27.4			
ave	10718	27.4			
10	10	10	37000	26.8	
		20	34500	27.0	
		35	34600	27.2	
		45	32700	27.3	
		50	29900	27.5	
		60	27700	27.5	
		65	23500	27.6	
		70	21900	27.8	

Alfoterra conc. (wt%)	NaCl conc. (wt%)	Time (min)	Electrolytic conductivity (μS)	Temperature ($^{\circ}\text{C}$)
0.7	10	90	20500	27.9
		95	17200	28.1
		100	16600	28.2
		105	15900	28.3
		110	15500	28.4
		120	16100	28.4
		130	16200	28.4
		140	16000	28.4
		ave	16050	28.4
		12	70	110
	75		184	27.6
	80		206	27.6
	90		228	27.6
	95		310	27.6
	100		102	27.6
	105		65	27.6
	115		47	27.6
	120		39	27.6
	125		33	27.6
	135		41	27.6
	140		45	27.6
	150		48	27.6
	160		47	27.6
	ave	46	27.6	
	13	20	0	27.7
		25	0	27.7
		30	0	27.7
		35	0	27.7
		40	0	27.7
		50	0	27.7
100		0	27.7	
ave		0	27.7	

Appendix B Experimental Data of Froth Flotation Experiment

1. Oil Removal

The oil removal was calculated by the following formulation:

$$\text{Oil removal (\%)} = \frac{C_i F_i - C_e F_e}{C_i F_i} \times 100 \quad (\text{B1})$$

where C_e = concentration of oil in an effluent (wt.%)
 C_i = concentration of oil in an influent (wt.%)
 F_e = volumetric flow rate of an effluent (ml/min)
 F_i = volumetric flow rate of an influent (ml/min)

2. Surfactant Removal

The surfactant removal was interpreted by the following equation:

$$\text{Surfactant removal (\%)} = \frac{C_{s,i} F_i - C_{s,e} F_e}{C_{s,i} F_i} \times 100 \quad (\text{B2})$$

where $C_{s,e}$ = concentration of surfactant in an effluent (wt.%)
 $C_{s,i}$ = concentration of surfactant in an influent (wt.%)
 F_e = volumetric flow rate of an effluent (ml/min)
 F_i = volumetric flow rate of an influent (ml/min)

3. Enrichment ratio

The enrichment ratio was calculated by the following equation:

$$\text{Enrichment ratio} = \frac{C_f}{C_i} \quad (\text{B3})$$

where C_f = concentration of oil in the collapsed foam solution
 C_i = concentration of oil in an influent

Table B1 Summary results of froth flotation performance of all system in the surfactant concentration effects at 13 wt.% NaCl, 500 ppm oil content, 0.3 L/min air flow rate, 20 min HRT, and 31 cm foam height

Alfoterra concentration (wt.%)	Oil removal (wt.%)	Enrichment ratio of oil	Surfactant removal (wt.%)	Enrichment ratio of surfactant	Foam production rate (ml/min)	Foam wetness (g/ml)
0.1	52.12	1.05	49.64	1.07	21.23	1.0825
0.3	86.28	1.84	80.60	1.12	36.36	1.0851
0.5	84.74	1.74	78.43	1.08	43.60	1.0866

Table B2 Summary results of froth flotation performance of all system in the salinity effects at 0.3 wt.% Alfoterra, 500 ppm oil content, 0.3 L/min air flow rate, 20 min HRT, and 31 cm foam height

NaCl concentration (wt.%)	Oil removal (wt.%)	Enrichment ratio of oil	Surfactant removal (wt.%)	Enrichment ratio of surfactant	Foam production rate (ml/min)	Foam wetness (g/ml)
6	73.36	1.50	73.85	1.10	34.23	1.0350
10	83.27	1.90	76.81	1.14	34.92	1.0655
13	86.28	1.84	80.60	1.12	36.36	1.0851

Table B3 Summary results of froth flotation performance of all system in the HRT effects at 0.3 wt.% Alfoterra, 10 wt.% NaCl, 500 ppm oil content, 0.3 L/min air flow rate, and 31 cm foam height

HRT (min)	Oil removal (wt.%)	Enrichment ratio of oil	Surfactant removal (wt.%)	Enrichment ratio of surfactant	Foam production rate (ml/min)	Foam wetness (g/ml)
10	69.34	1.20	65.65	1.04	36.55	1.0680
15	78.56	1.32	68.87	1.05	35.32	1.0674
17.5	80.45	1.36	70.87	1.05	35.07	1.0666
20	83.27	1.45	76.81	1.07	34.92	1.0655

Appendix C Experimental Data of Foamability and Foam Stability Experiment

1. Foamability

The foamability was defined as the ratio of maximum foam height to initial solution height

$$\text{Foamability} = \frac{H_{\max}}{H_i} \quad (\text{C1})$$

where H_{\max} = Maximum foam height
 H_i = Initial solution height

2. Foam Stability ($t_{1/2}$)

The foam stability was defined as the time that was required for the foam volume to collapse by half.

Table C1 Summary results of foamability and foam stability of the system in the surfactant concentration effect at 13 wt.% NaCl, 500 ppm oil content, and 0.3 L/min air flow rate

Alfoterra concentration (wt.%)	Foamability	Foam stability (min)
0.1	7.51	6
0.3	15.69	15.61
0.5	9.35	7.93

Table C2 Summary results of foamability and foam stability of the system in the salinity effect at 0.3 wt.% Alfoterra, 500 ppm oil content, and 0.3 L/min air flow rate

NaCl concentration (wt.%)	Foamability	Foam stability (min)
6	10.82	15.30
10	17.57	16.26
13	15.69	15.61

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