

Supplementary Material

Simulation and Evaluation of Processing Technologies for the Valorization of Sargassum

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Table S1: Technical report for the production of sodium alginate

1. OVERALL PROCESS DATA

Annual Operating Time	336	day
Unit Production Ref. Rate	4,205,414.8	kg sodium alginate/yr
Batch Size	16,491.82	kg sodium alginate
Recipe Batch Time	175.38	h
Recipe Cycle Time	31.00	h
Number of Batches per Year	255	

2. RAW MATERIALS

Material	Amount (kg/yr)	Amount (kg/batch)
Air	32,707,184	128,263
Hydrochloric acid (26%)	4,597,140	18,028
Sargassum	19,999,905	78,431
Sodium carbonate	2,250,630	8,826
Water	367,959,837	1,442,980
TOTAL	427,514,696	1,676,528

3. OVERALL COMPONENT BALANCE

COMPONENT	INPUT (kg/yr)	OUTPUT (kg/yr)
Ash	14,900	14,900
Calcium chloride	0	1,281,490
Calcium alginate	4,599,978	688
Carbon dioxide	0	0
Cellulose	2,229,989	2,085,040
Galactan	537,997	134,499
Galactose	0	448,335
Glucose	0	161,056

Hydrochloric acid	1,195,256	0
Hemicellulose	327,998	82,000
Lignin	1,919,991	1,919,991
Mannan	483,998	120,999
Mannose	0	403,335
Nitrogen	25,090,265	25,090,265
Other solids	9,885,053	9,885,053
Oxygen	7,616,918	7,616,918
Sodium alginate	0	4,205,415
Sodium carbonate	2,250,630	674
Sodium Chloride	0	1,240,609
Water	371,361,72	371,609,334
Xylose	0	279,545
TOTAL	427,514,69	426,580,146

4. PROCESS STREAM SPECIFICATIONS

Source	SR-101	VS-101	VS-101	R-201
Destination	VS-101	MX-101	R-201	RVF-201
Temperature (°C)	1.01	1.01	25.00	30.00
Pressure (bar)	4,491.42	4,718.53	1.01	10.26
Total flow rate (kg/batch)	79,182.159	751.159	78,431.000	790,663.051
Component Flowrates (kg/batch)				
Alginic acid	0.000	0.000	0.000	14,661.981
Calcium alginate	18,221.343	182.213	18,039.130	2.699
Calcium chloride	0.000	0.000	0.000	5,025.450
Cellulose	8,833.390	88.334	8,745.056	8,176.628
Galactan	2,109.794	0.000	2,109.794	527.448
Galactose	0.000	0.000	0.000	1,758.176
Glucose	0.000	0.000	0.000	631.592
Heavy metals	58.431	0.000	58.431	58.431
Hemicellulose	1,299.261	12.993	1,286.268	321.567
Lignin	7,605.430	76.054	7,529.376	7,529.376
Mannan	1,898.030	0.000	1,898.030	474.508
Mannose	0.000	0.000	0.000	1,581.705
Other solids	39,156.479	391.565	38,764.914	38,764.914
Water	0.000	0.000	0.000	710,052.322
Xylose	0.000	0.000	0.000	1,096.255

Source	RVF-201	RVF-201	R-202	RVF-301
Destination	R-202	OUTPUT	RVF-301	HX-401
Temperature (°C)	29.99	29.99	80.00	76.97
Pressure (bar)	1.01	1.01	27.64	1.01
Total flow rate (kg/batch)	77,209.997	714,453.054	759,927.924	30.936
Component Flowrates (kg/batch)				
Alginic acid	14,661.981	0.000	0.000	78,127.847
Calcium alginate	0.025	2.674	0.025	0.000
Calcium chloride	46.624	4,978.826	46.624	0.000
Cellulose	8,176.628	0.000	8,176.628	8,176.628
Galactan	4.893	522.555	4.893	4.893

Galactose	16.312	1,741.864	16.312	0.000
Glucose	5.860	625.733	5.860	0.000
Heavy metals	58.431	0.000	58.431	58.431
Hemicellulose	321.567	0.000	321.567	321.567
Lignin	7,529.376	0.000	7,529.376	7,529.376
Mannan	4.402	470.105	4.402	4.402
Mannose	14.675	1,567.030	14.675	0.000
Sodium alginate	0.000	0.000	16,491.823	0.000
Sodium carbonate	0.000	0.000	1.211	0.000
Other solids	38,764.914	0.000	38,764.914	38,764.914
Water	7,594.138	703,458.184	688,481.012	23,267.635
Xylose	10.171	1,086.084	10.171	0.000

Source	RVF-301	R-301	RVF-302	RVF-302
Destination	R-301	RVF-302	HX-301	OUTPUT
Temperature (°C)	76.97	80.00	79.04	79.04
Pressure (bar)	1.01	27.10	1.01	1.01
Total flow rate (kg/batch)	723,805.033	739,063.155	23,559.562	728,459.389
Component Flowrates (kg/batch)				
Calcium alginate	0.025	0.025	0.000	0.025
Calcium chloride	46.624	46.624	0.000	46.624
Galactan	0.000	16.312	0.000	0.000
Galactose	16.312	5.860	0.000	16.312
Glucose	5.860	0.000	0.000	5.860
Mannose	14.675	14.675	0.000	14.675
Sodium alginate	16,491.823	16,491.823	16,491.823	0.000
Sodium carbonate	1.211	2.642	0.000	2.642
Sodium Chloride	0.000	4,865.134	0.000	0.000
Other solids	0.000	0.000	0.000	4,865.134
Water	707,218.334	717,609.890	7,067.739	723,497.948
Xylose	10.171	10.171	0.000	10.171

Source	HX-301	SDR-301
Destination	SDR-301	OUTPUT
Temperature (°C)	30.00	70.00
Pressure (bar)	1.01	1.01
Total flow rate (kg/batch)	23,559.562	18,847.741
Component Flowrates (kg/batch)		
Sodium alginate	16,491.823	16,491.823
Water	7,067.739	2,355.918

Table S2: Economic report for the production of sodium alginate

EQUIPMENT SPECIFICATION AND COST

Quantity	Name	Description	Unit Cost (\$)	Cost (\$)
1	VS-101	Vibrating Screen	7,000	7,000
		Rated Throughput = 13200 kg/h		
1	SR-101	Shredder	148,000	148,000
		Rated Throughput = 13200 kg/h		
2	R-201	Stirred Reactor	476,000	952,000
		Vessel Volume = 405 m ³		
2	RVF-201	Rotary Vacuum Filter	191,000	382,000
		Filter Area = 50 m ²		
2	RVF-301	Rotary Vacuum Filter	188,000	376,000
		Filter Area = 45 m ²		
2	R-202	Stirred Reactor	466,000	932,000
		Vessel Volume = 400 m ³		
2	R-301	Stirred Reactor	476,000	952,000
		Vessel Volume = 400 m ³		
2	RVF-302	Rotary Vacuum Filter	192,000	384,000
		Filter Area = 50 m ²		
1	SDR-301	Spray Dryer	204,000	204,000
		Dryer Volume = 10 m ³		
1	HX-301	Heat Exchanger	18,000	18,000
		Heat Exchange Area = 3 m ²		
1	SDR-401	Spray Dryer	267,000	267,000
		Dryer Volume = 35 m ³		
1	HX-401	Heat Exchanger	41,000	41,000
		Heat Exchange Area = 10 m ²		
		Unlisted Equipment		845,000
		TOTAL		5,508,000

ESTIMATED FIXED CAPITAL

Plant Direct Cost (USD)	
Equipment Purchase Cost	5,508,000
Installation	2,187,000
Process Piping	1,800,000
Instrumentation	1,690,000
Insulation	165,000
Electrical	551,000
Buildings	1,838,000
Yard Improvement	826,000
Auxiliary Facilities	1,434,000
Total	15,998,000

Plant Indirect Cost	
Engineering	3,688,000
Construction	5,288,000
total	8,975,000
Other fees	
Contractor's Fee	1,249,000
Contingency	2,497,000
total	3,746,000
Direct Fixed Capital Cost	
TOTAL	28,719,000

ESTIMATED LABOR COST

Labor Type	Unit Cost (\$/h)	Annual Amount (h)	Annual Cost (\$)
Operator 1	2.07	383	792
Operator 2	22.80	46,821	1,067,523
Operator 3	27.60	1,275	35,190
TOTAL		48,479	1,103,505

MATERIALS COST

Bulk Material	Unit Cost (\$)	Annual amount (kg)	Annual Cost (\$)
Air	0.000	32,707,184	0
Hydrochloric acid	0.027	4,597,140	122,928
Sargassum	0.050	19,999,905	999,995
Sodium carbonate	0.200	2,250,630	450,126
Water	0.001	367,959,837	367,960
TOTAL			1,941,009

WASTE DISPOSAL COST

Waste Category	Unit Cost (\$)	Annual amount (kg)	Annual Cost (\$)
Solid Waste	0.200	14,582,679	2,916,536
TOTAL			2,916,536

UTILITIES COST

Utility	Unit Cost (\$)	Annual Amount	Annual Cost (\$)
Electricity	0.100	2,563,130 kW-h	256,313
Cooled water	0.025	1,704,327 MT	42,608
Chilled Water	0.175	163,067 MT	28,537
Steam	0.012	49,962,559 kg	599,551
TOTAL			927,009

ANNUAL OPERATING COST

Cost Item	Annual cost (\$)
Raw Materials	1,941,000
Labor-Dependent	1,104,000
Facility-Dependent	4,640,000
Quality control	134,000
Waste Disposal	2,917,000
Utilities	927,000
TOTAL	11,662,000

Table S3: Execute summary for the production of sodium alginate

Total investment		
Direct Fixed Capital	28,719,000	\$
Working Capital	616,000	\$
Startup Cost	1,436,000	\$
Total Investment	30,772,000	\$
Revenue/Savings Rates		
Sodium alginate	4,205,415	kg /yr
Revenue/Savings Price		
Sodium alginate	20.0	\$/kg
Revenues/Savings		
Sodium alginate	84,108,297	\$/yr
Total Revenues	84,108,297	\$/yr
Annual Operating Cost		
Total annual operating cost	11,662,000	\$/yr
Unit Production Cost /Revenue		
Gross Profit	72,446,297	\$/yr
Taxes (30%)	21,733,889	\$/yr
Net Profit (including depreciation)	52,627,008	\$/yr
Return On Investment	170.71	%
Payback Time	0.59	years