

Supporting Information

Conceptual Process Design to produce bio-acrylic acid via gas phase dehydration of lactic acid produced from carob pod extracts

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S1. Determination of invertase kinetics

C _{glucose} (mol/L)	Ln C	r (mol glucose/L min)	Ln r
0.04	-3.22	0.0027	-5.91
0.066	-2.72	0.00472	-5.35
0.097	-2.33	0.00652	-5.03
0.126	-2.07	0.00719	-4.93
0.177	-1.73	0.00862	-4.75
0.285	-1.25	0.0103	-4.57

Table S1. Rate of sucrose hydrolysis by invertase.

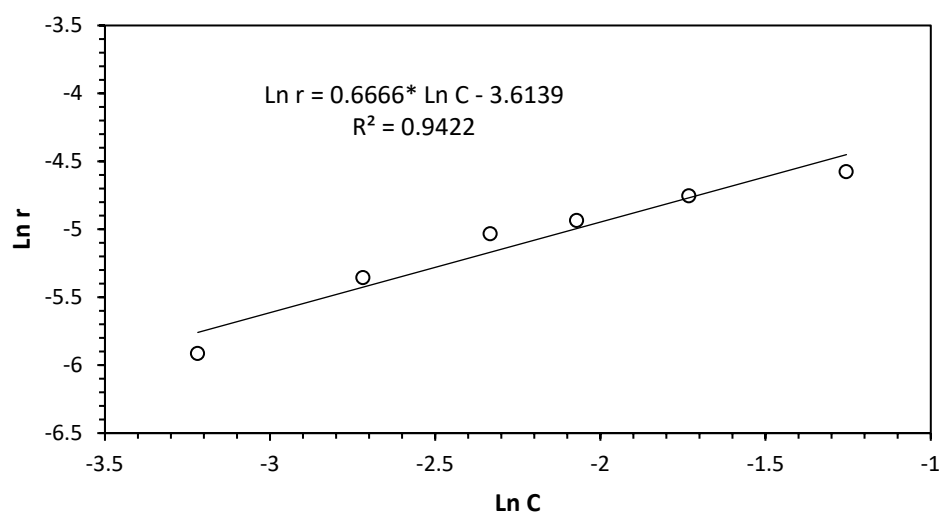


Figure S1. Kinetic model fitting to experimental data

From the general expression $\ln r = \ln k + n * \ln C$, it can be seen that $n \approx 0.66$ and $k = 0.027$. So the kinetic expression takes the form:

$$r = 0.027 C_{glucose}^{0.66}$$

S2. Equipment summary

Area-000			Carob Pod Storage		
			Install factor	Number of Units	Installed Cost (€)
ST-000					1720591
Total A-000					1720591
Area-100			Sugars Extraction		
Equipment ID	Equipment Title	Description	Install factor	Number of Units	Installed Cost (€)
C-101	Roller Crusher	Roll gap 1 mm, Capacity 8.5 Tn/h, Power: 3.15 kWh, carbon steel	1.7	1	24413
EX-101	Stirred reactor	V: 35 m ³ , Power: 6.5kWh, carbon steel	1.5	1	489030
EX-102	Stirred reactor	V: 35 m ³ , Power: 6.5kWh, carbon steel	1.5	1	489030
D-101	Rotary Dryer	D: 2 m, L: 15 m, Power: 30kWh, carbon steel	1.7	1	177757
F-101	Plate & Frame filter	A: 27 m ² , Power: 2.2 kWh, carbon steel	1.7	1	31174
HX-101	Shell and Tube heat exchanger	A: 33 m ² , Heat duty: 235 kWh, carbon steel	2.0	1	25788
HX-102	Shell and Tube heat exchanger	A: 48 m ² , Heat duty: 1156 kWh, carbon steel	2.0	1	32943
HX-103	Shell and Tube heat exchanger	A: 40 m ² , Heat duty: 300 kWh, carbon steel	2.0	1	29174
P-101 A/B	Centrifugal Pump	Q: 59.2 m ³ /h, Head: 6.91 m, Power: 17 kW, carbon steel	2.8	2	41384
P-102 A/B	Centrifugal Pump	Q: 59.40 m ³ /h, Head: 9.3 m, Power: 17 kWh, carbon steel	2.8	2	45162
MX-101	In line mixer	Q: 143 m ³ /h, Power: 97 kWh, stainless steel	1.0	1	51145
MX-102	In line mixer	Q: 74 m ³ /h, Power: 51 kWh, stainless steel	1.0	1	26575
MX-103	In line mixer	Q: 148 m ³ /h, Power: 100kWh, stainless steel	1.0	1	52832
MX-104	In line mixer	Q: 1.5 m ³ /h, Power: 2.5 kWh, stainless steel	1.0	1	852
T-101	Process Water Tank	Vertical, V: 1463 m ³ , D: 7.75 m, H: 31.0 m, carbon steel	1.7	1	765817
ST-102	DDG's storage section	Capacity: 2500 Tn, carbon steel	1.7	1	48878
Total A-100					2331955
Area-200			Lactic Acid Fermentation		
Equipment ID	Equipment Title	Description	Install factor	Number of Units	Installed Cost (€)
ST-201	Seed Fermentor	V: 6 m ³ , Power: 2 kWh, stainless steel	1.5	1	175153
ST-202	Urea and culture ingredients storage	V: 84 m ³ , stainless steel	1.8	1	399199
ST-203	Sulfuric acid storage	V: 196 m ³ , stainless steel	1.8	1	531432
ST-204	Ca(OH) ₂ storage	V: 112 m ³ , stainless steel	1.8	1	306625
R-201	Fixed Bed enzymatic reactor	V: 80 m ³ , carbon steel	1.5	1	3778000
FX-201	Lactic Acid Fermentor	V: 310 m ³ , Power: 55kWh, stainless steel	1.5	1	3347791
P-201	Calcium Lactate Precipitation	V: 310 m ³ , Power: 55kWh, stainless steel	1.5	1	3347791
N-201	Lactic acid recovery	V: 95 m ³ , Power: 15kWh, stainless steel	1.5	1	1267011
C-201	Centrifugal Separator	D: 1 m, Speed: 900 rpm, Power: 75 kWh stainless steel	1.7	1	432798
F-201	Plate & Frame filter	A: 73 m ² , Power: 2.2 kWh, stainless steel	1.7	1	54333
F-202	Plate & Frame filter	A: 13.5 m ² , Power: 2.2 kWh, stainless steel	1.7	1	21490
EX-201	Stirred reactor	V: 2 m ³ , Power: 1kWh, stainless steel	1.5	1	97689
T-201	Transit Vessel	Vertical, V: 4 m ³ , D: 1.08 m, H: 4.34 m, stainless steel	1.5	1	44974

T-202	Transit Vessel	Vertical, V: 228 m ³ , D: 4.2 m, H: 16.7 m, stainless steel	1.5	1	298144
P-201 A/B	Centrifugal Pump	Q: 116.1 m ³ /h, Head: 4.9 m, Power: 33kWh, stainless steel	2.8	2	45012
P-202 A/B	Centrifugal Pump	Q: 2.2 m ³ /h, Head: 0.7 m, Power: 1.5kWh, stainless steel	2.8	2	93681
MX-201	In line mixer	Q: 3.0 m ³ /h, Power: 3.5kWh, stainless steel	1.0	1	1430
MX-202	In line mixer	Q: 16.0 m ³ /h, Power: 12.5kWh, stainless steel	1.0	1	6161
Total A-200					14248714
Area-300 Lactic acid dehydration and Acrylic acid recovery section					
Equipment ID	Equipment Title	Description	Install factor	Number of Units	Installed Cost (€)
P-301 A/B	Centrifugal Pump	Q: 13.4 m ³ /h, Head: 1.00 m, Power:6kWh, stainless steel	2.8	2	45669
P-302 A/B	Centrifugal Pump	Q:8.5 m ³ /h, Head: 8,4 m, Power:2kWh, stainless steel	2.8	2	65288
P-303 A/B	Centrifugal Pump	Q: 0.04 m ³ /h, Head: 7.22 m, Power:0.5kWh, stainless steel	2.8	2	66973
H-301	Fired Heater	Heat duty: 2648 kWh, stainless steel	1.3	1	1468666
R-301	Fixed Bed reactor	V: 2 m ³ , stainless steel	1.5	1	363737
HX-301	Shell and Tube heat exchanger	A: 288 m ² , Heat duty: 9843 kWh, stainless steel	2.0	1	286200
HX-302	Shell and Tube heat exchanger	A: 55 m ² , Heat duty: 708 kWh, stainless steel	2.0	1	84922
HX-303	Shell and Tube heat exchanger	A: 10.0 m ² , Heat duty: 67 kWh, stainless steel	2.0	1	118556
HX-304	Shell and Tube heat exchanger	A: 1.0 m ² , Heat duty: 5.6 kWh, stainless steel	2.0	1	9177
HX-305	Shell and Tube heat exchanger	A: 224 m ² , Heat duty: 2215 kWh, carbon steel	2.0	1	109883
TW-301	Absorption column	D: 0.3 m, H: 12.0 m, H _{packing} : 9.5, stainless steel	3.0	1	66816
TW-302	Distillation Colum	D: 0.76 m, H: 14 m, N: 13, stainless steel	3.0	1	1081498
TW-303	L-L extraction Colum	D: 1.25 m, H: 22 m, N: 25, stainless steel	3.0	1	532224
TW-304	Distillation Colum	D: 3.2 m, H: 38 m, N: 50, stainless steel	3.0	1	6838272
TW-305	Distillation Colum	D: 0.9 m, H: 14 m, N: 50, stainless steel	3.0	1	783360
MX-301	In line mixer	Q: 24.0 m ³ /h, 18 kWh, stainless steel	1.0	1	8925
CP-301	Centrifugal Compressor	Power: 358 kWh, stainless steel	1.3	1	1061626
ST-301	Toluene storage	V: 164m ³ , carbon steel	1.8	1	158722
ST-302	Acetaldehyde storage	V: 53 m ³ , stainless steel	1.8	1	271091
ST-303	Acrylic acid storage	V: 335 m ³ , stainless steel	1.8	1	429226
ST-304	Lactic acid storage	V: 7 m ³ , stainless steel	1.8	1	62545
Total A-300					13913374
Installed Equipment					32145811

Table S2. Equipment specification for bio-acrylic acid production from carob pod process at a capacity of 68 kton carob pod per year.

S3. Estimation of the TCI

Components of the TCI

Component	Value	Base Case (x10 ⁶ €)
<i>Direct Investment</i>		
a) Equipment Cost (EC)		23.13
b) Installed equipment		32.14
c) Piping	0.22*EC	5.09
d) Instrumentation	0.09* EC	2.08
e) Electrical Installation	0.07* EC	1.62
f) Land	0.07* EC	1.62
g) Buildings	0.21* EC	4.86
h) Utilities	0.28* EC	6.48
<i>Indirect Investment</i>		
a) Construction engineering	0.38* EC	8.79
b) Contractors fee	0.13* EC	3.01
c) Contingency	0.26* EC	6.01
Fixed Capital Investment		62.70
<i>Working capital</i>	0.28*FCI	17.55
Total Capital Investment		80.22

Table S3. Factors applied for the calculation of the TCI.