Techno-economic evaluation and life cycle assessment for sustainable alternative biorefinery concepts using the organic fraction of municipal solid waste

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Supplementary Information

Table S1. Optimal bioreactor design parameters for lactic acid production in various annual capacities. The bioreactor design optimization was based on the methodology developed by Dheskali et al.[17]

Annual capacity (t)	**10,000**	**20,000**	**40,000**	**50,000**	**60,000**
Loading time, τ_l (h)	2	2	2	4	4
Uploading time, τ_{ul} (h)	5	5	5	3	3
Number of batches per year, N_b	1579	1579	1579	2631	2631
Number of bioreactors per batch, N_f	6	6	6	10	10
Working volume of each bioreactor V_b (m^3)	105.5	211.1	422.2	316.7	380.1

Table S2. Optimal bioreactor design parameters for succinic acid production in various annual capacities. The bioreactor design optimization was based on the methodology developed by Dheskali et al.[17]

Annual capacity (t)	**10,000**	**20,000**	**40,000**	**50,000**	**60,000**
Loading time, τ_l (h)	2	2	2	2	4
Uploading time, τ_{ul} (h)	6	4	2	2	2
Number of batches per year, N_b	1314	1971	3942	3942	3942
Number of bioreactors per batch, N_f	7	10	19	19	20
Working volume of each bioreactor, V_b (m^3)	258.8	345.1	345.1	431.4	517.7

Table S3. Unitary cost of raw materials.[30]

Raw Material	Unitary prices 2018 ($/t)
HCl	61
NaOH	400
Nutrients	950
Ethanol	680
Petroleum ether	1,000
Acetone	1,500
KOH (85%)	400
NPG	1,500
HXDO	3,500
Additives for HMAs	1,894
Additives for PUDs	5,500
Enzyme	1,000
Water	0.435

Table S4. Summary of the mass and energy balances inventory for all processes.

	Unit	SA	LA	Biosurfactants	HMAs	PP	PUDs
Sugars	$kg/kg_{product}$	1.78	1.43	-	-	-	-
Solid residues (dry)	$kg/kg_{product}$	-	-	11.9	-	-	-
1,6-hexanediol	$kg/kg_{product}$	-	-	-	-	0.44	-
Neopentyl glycol	$kg/kg_{product}$	-	-	-	-	0.26	-
Succinic acid	$kg/kg_{product}$	-	-	-	-	0.63	-
Lactic acid	$kg/kg_{product}$	-	-	-	0.96	-	-
Additives	$kg/kg_{product}$	-	-	-	0.41	-	0.14
Nutrients	$kg/kg_{product}$	0.29	-	-	-	-	-
HCl	$kg/kg_{product}$	1.34	-	1.84	-	-	-
NaOH	$kg/kg_{product}$	1.20	0.04	0.23	-	-	-
KOH (85%)	$kg/kg_{product}$	-	-	0.82	-	-	-
Ethanol	$kg/kg_{product}$	-	-	0.23	-	-	-
Petroleum ether	$kg/kg_{product}$	-	-	0.17	-	-	-
Acetone	$kg/kg_{product}$	-	-	-	-	-	0.67
Enzyme	$kg/kg_{product}$	-	-	0.048	-	-	-
Water	$kg/kg_{product}$	2.05	6.4	-	-	-	0.61
Electricity	$kWh/kg_{product}$	3.93	3.97	3.02	2.82	0.01	0.01
Steam	$kg/kg_{product}$	0.89	2.36	1.32	0.41	3.56	0.52
Cooling water	$kg/kg_{product}$	171.74	39.9	27.70	16.07	-	22.55

Table S5. Parameters of the DCF analysis taken from Humbird et al.[15]

Discount rate (or interest rate)	10 %
Plant life time	30 years
Equity financing	100 %
Depreciation via MACRS	200% declining balance and 7 year recovery period
Corporate tax rate	35 %
Plant construction duration	3 years
% of project cost in the 1st, 2nd and 3rd year of construction	8 % - 60% - 32 %
Working capital	5 % of FCI
Salvage value	0
Land costs	0

Table S6. Greenhouse gas emission of the fossil- and bio-based counterparts of the end-products derived from OFMSW

Fossil- and bio-based counterpart	GHG ($kg\ CO_2$-$eq/kg_{product}$)	Reference
Bio-based LA from corn-derived glucose	0.3-1.2	De Matos et al.[35]
Fossil-based SA	1.89	Dewulf et al.[37]
Bio-based SA from corn-derived glucose	0.88	Cok et al.[11]
Fossil-based surfactants	2.1	Schowanek et al.[38]
Fossil adhesives	5.0	McDevitt et al.[39]
Adipic acid based PUDs	3.4	EPDLA[40]

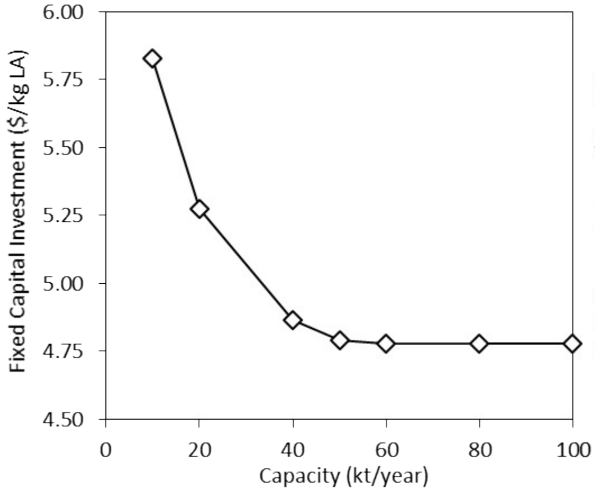

Figure S1. Fixed capital investment (a), cost of manufacture (b) per kg lactic acid as a function of lactic acid annual production capacity.

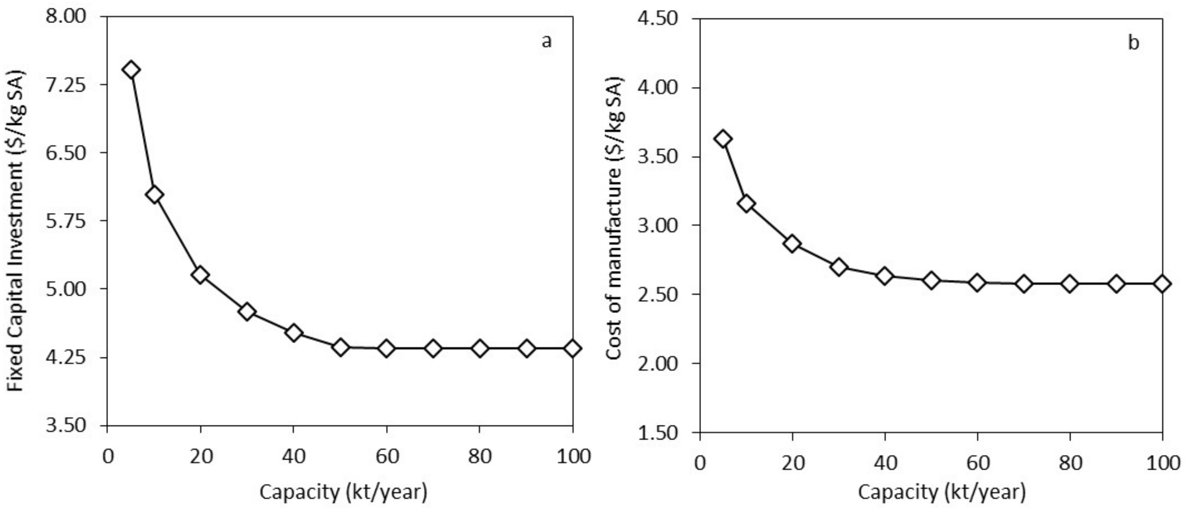

Figure S2. Fixed capital investment (a) and cost of manufacture (b) per kg succinic acid as a function of succinic acid annual production capacity.

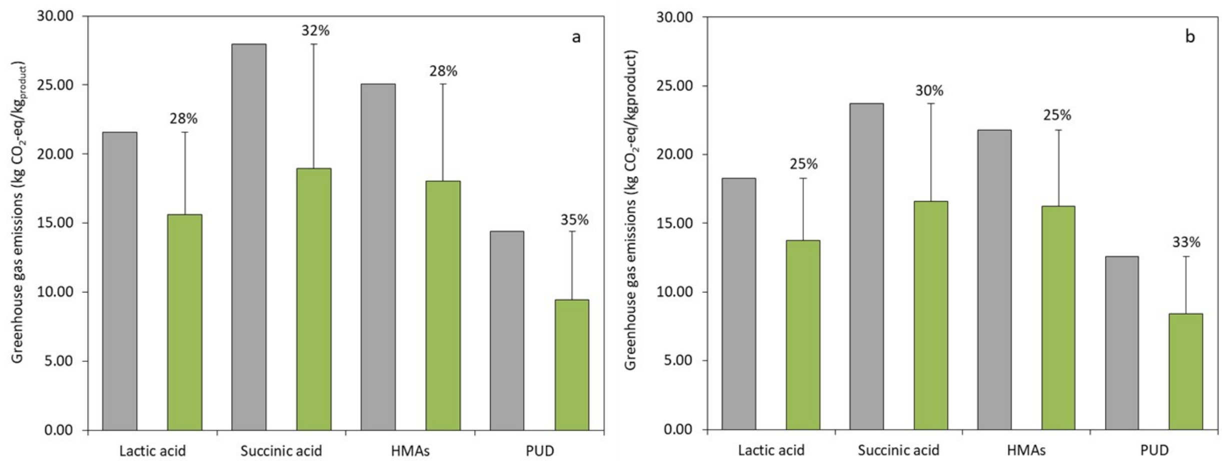

Figure S3. Environmental performance of all processes in GHG emissions for base case scenario and alternative approach having as OFMSW management 100% landfilling (a) and 37.45% recycling/62.55% landfilling (b).