

# Supporting Information

## Surface-Modified Filter-Based Continuous Recovery of Microalgal Lipid-in-Solvent with High Recovery Efficiency, Long-Term Stability, and Cost Competitiveness

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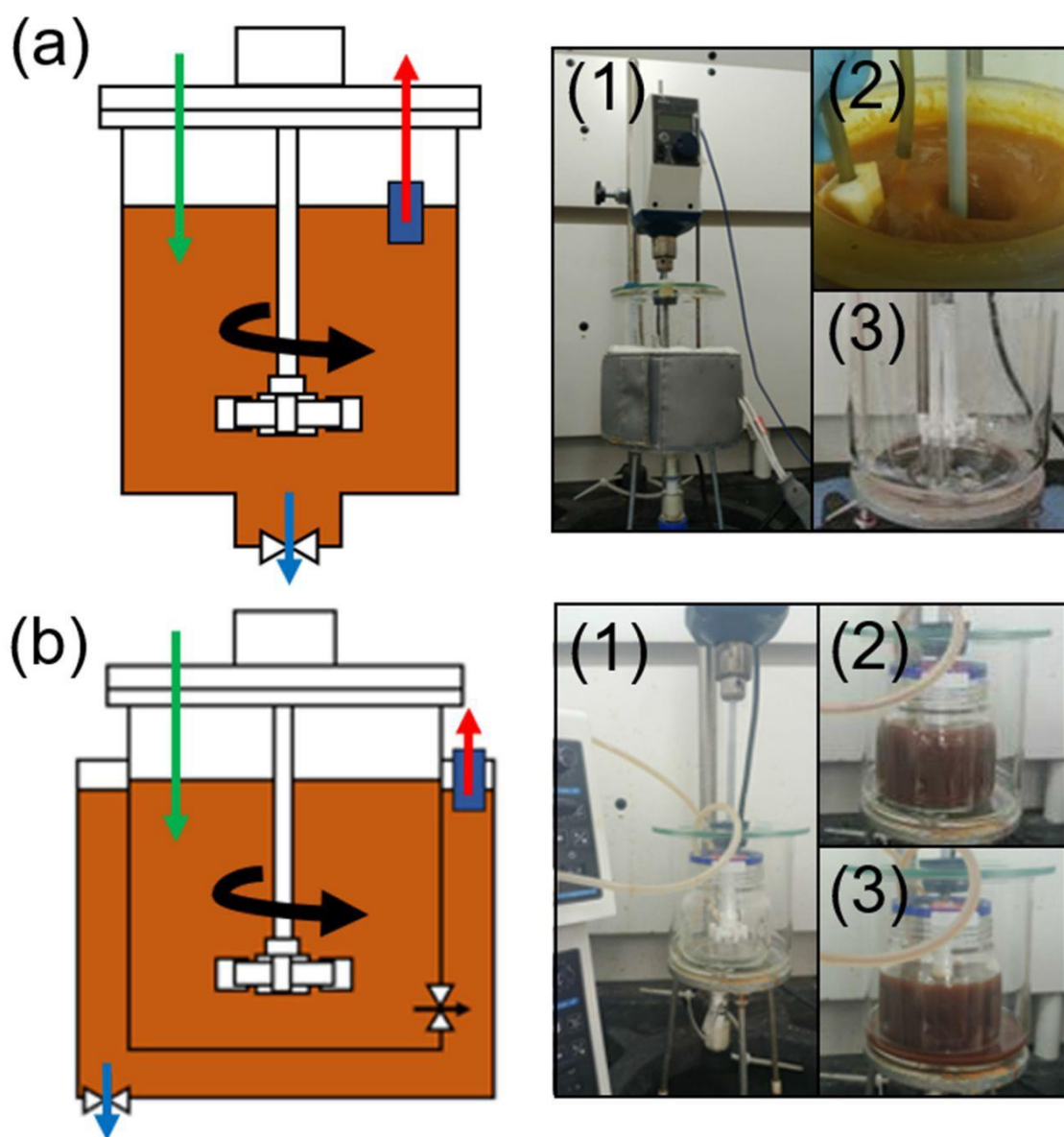
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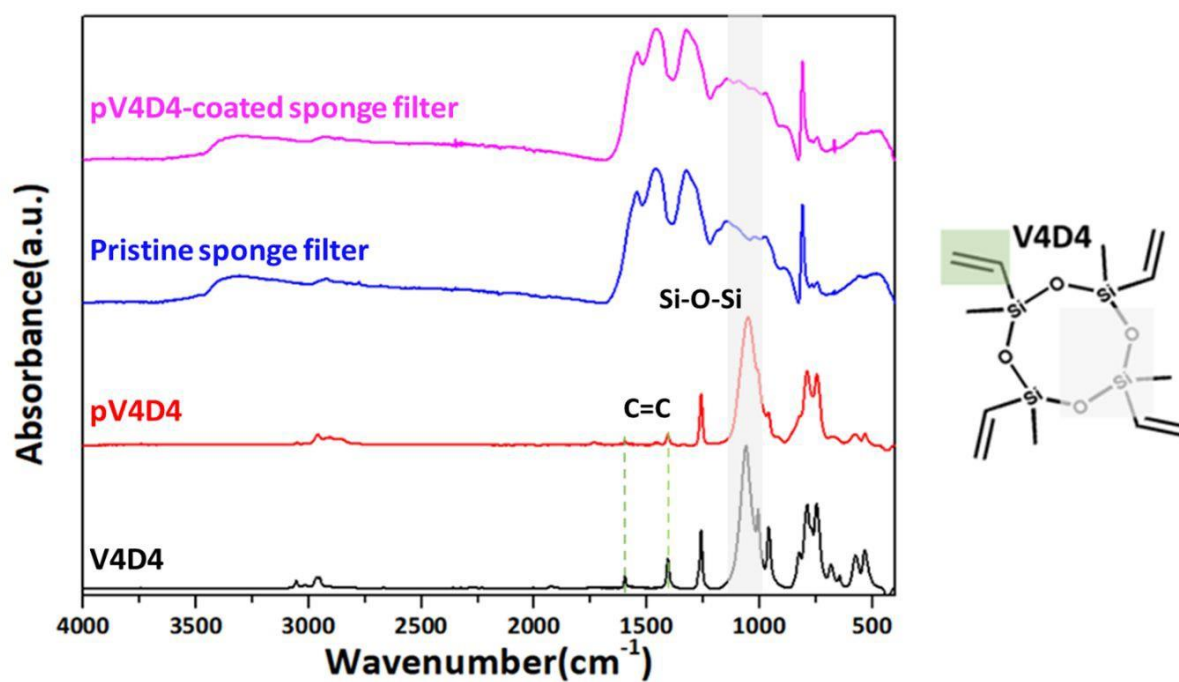
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**Figure S1.** Diagrams and images of the experimental apparatus used for lipid extraction and recovery system of (a) *in situ* filtering method: (1) equipment exterior, (2) *in situ* recovery and (3) inner mixer, and (b) *ex situ* filtering Method: (1) equipment exterior, (2) mixture during lipid extraction and (3) the extraction mixture pooled out to the outer vessel.



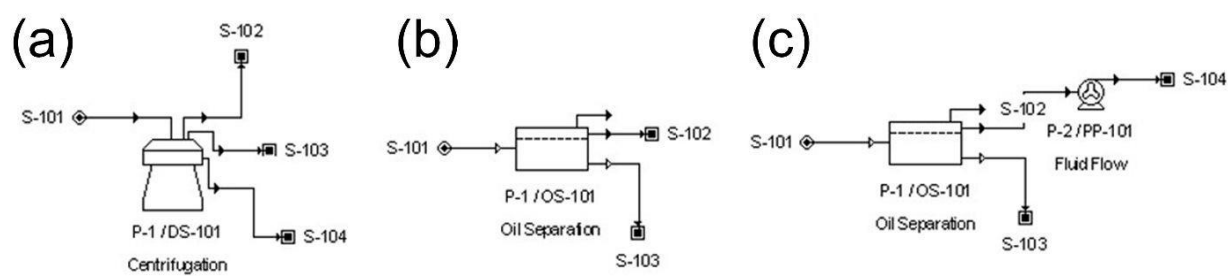
**Figure S2.** FT-IR spectra of V4D4, pV4D4, pristine sponge filter, and pV4D4-coated sponge filter. The green dashed line at 1650  $\text{cm}^{-1}$  represents C=C vinyl bond and the gray area represents characteristic cyclic Si-O-Si bond in V4D4 monomer.

**Table S1.** Porosimeter data of pV4D4 sponge filter (0.20 to 61000.00 psia)

Total pore area at 32,995.86 psia:	4.365 m <sup>2</sup> /g
Median pore diameter (volume) at 1.35 psia and 69.263 mL/g:	133.67986 μm
Median pore diameter (area) at 2.24 psia and 2.182 m <sup>2</sup> /g:	80.62778 μm
Average pore diameter (4V/A):	126.95504 μm
Bulk density at 0.23 psia:	0.0065 g/mL
Apparent (skeletal) density at 32,995.86 psia:	0.0669 g/mL
Porosity	90.2610 %



**Figure S3.** Images of extraction mixture during the gravity settling recovery (a) after extraction and (b) after 48 h of settling.



**Figure S4.** Diagrams of unit operations in Superpro designer program chosen as basis for cost analysis (a) disk-stack centrifugation (b) gravity settling (c) this study.

**Table S2.** List of items included in the total capital cost estimation

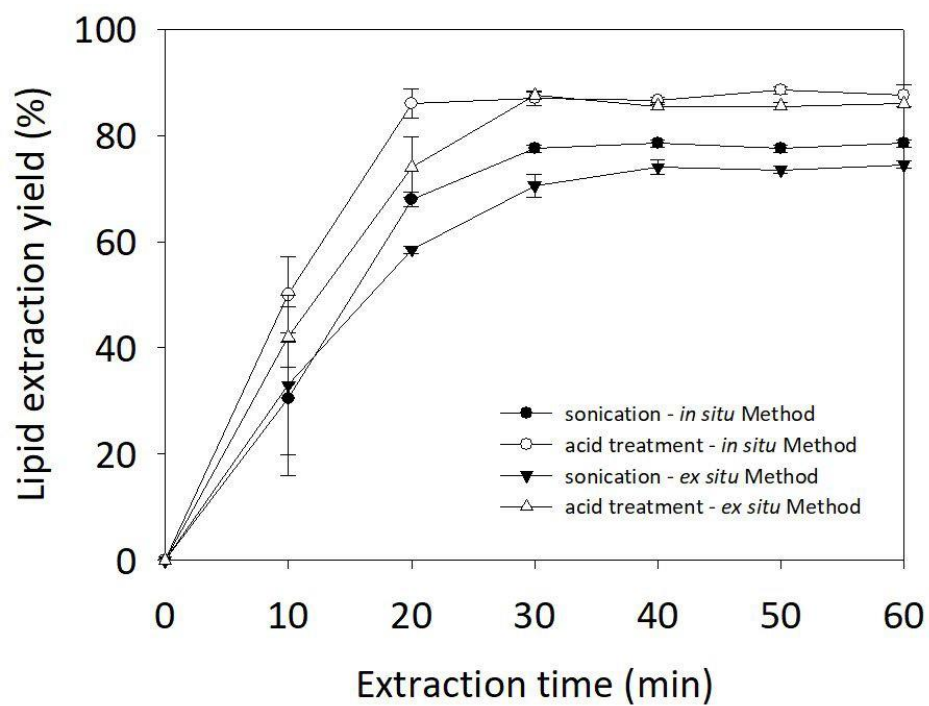
Item	Value
<b>Direct cost (DC)</b>	
Equipment purchase cost (EPC)	Estimation from Super designer
Installation	Estimation from Super designer
Piping	$0.31 \times \text{EPC}$
Instrumentation	$0.43 \times \text{EPC}$
Electrical	$0.10 \times \text{EPC}$
Buildings	$0.15 \times \text{EPC}$
Yard improvement	$0.12 \times \text{EPC}$
Service facilities	$0.55 \times \text{EPC}$
<b>Indirect cost (IC)</b>	
Engineering	$0.34 \times \text{EPC}$
Construction	$0.04 \times \text{EPC}$
Contractor's fee	$0.19 \times \text{EPC}$
Contingency	$0.37 \times \text{EPC}$
<b>Fixed capital investment (FCI)</b>	DC+IC
<b>Working capital</b>	$0.15 \times \text{FCI}$

**Table S3.** List of items included in the annual operating cost estimation\*

Item	Value
<b>Utility</b>	
Standard electricity power	0.1 \$/Kw-h
<b>Facility-Dependent Cost*</b>	
Maintenance	$0.06 \times \text{ECI}$
Miscellaneous	$0.08 \times \text{FCI}$
<b>Labor cost**</b>	$1.82 \times 10^4 \text{ DC}^{0.2}$
<b>Maintenance cost</b>	$0.1 \times \text{EPC}$

\* Material costs and depreciation were excluded

\*\* [reference 34]



**Figure S5.** Lipid extraction yields according to cell disruption – extraction methods at 500 rpm of stirring speed and 50°C of extraction temperature



**Table S4.** Fatty acid composition of extracted lipid\*

	<b>Sonication</b>	<b>Acid-treatment</b>
Total lipid (wt%)	42.2 ± 1.3	47.9 ± 0.8
Esterifiable lipid	38.6 ± 1.2	40.3 ± 0.9
Myristic acid (C14:0)	0.8 ± 0.0	1.0 ± 0.0
Palmitic acid (C16:0)	15.2 ± 0.8	17.5 ± 0.6
Stearic acid (C18:0)	0.2 ± 0.0	0.4 ± 0.0
EPA (C20:5,3)	0.4 ± 0.0	0.5 ± 0.0
DPA (C22:5n3)	3.9 ± 0.2	4.1 ± 0.4
DHA (C22:6n3)	13.9 ± 1.5	14.5 ± 1.8
Other Fatty acid and Non-esterifiable lipid	7.8 ± 3.1	9.9 ± 2.3

\* Samples of both *in situ* and *ex situ* Method were taken after 60 minutes of extraction

**Table S5.** Performance comparison of three recovery methods for lipid-in-solvent

	Centrifugation	Gravity settling	This study
<b>1. Recovery Yield (%)</b>	95*	26*	95
<b>2. Recovery rate (ml/min) *</b>	50*	0.70*	31
- EPC (\$) **	$2.9 \times 10^5$	$1.1 \times 10^4$	$1.5 \times 10^4$
- Installation (\$) **	$1.5 \times 10^5$	$5.5 \times 10^3$	$7.2 \times 10^3$
- Total capital cost (\$)	$4.5 \times 10^5$	$1.7 \times 10^4$	$2.1 \times 10^4$
<b>3. Annualized capital cost/throughput (\$/(kg/h))</b>	$8.8 \times 10^3$	$1.0 \times 10^3$	$1.2 \times 10^3$
-Power consumption (W) **	2500	0	977
<b>4. Annual Operating cost/throughput (\$/(kg/h)) ***</b>	$3.9 \times 10^5$	$1.3 \times 10^5$	$1.5 \times 10^5$

\* These values were measured based on the 100% of purity

\*\* based on the feed throughput (4.085 kg/h)

\*\*\* based on the annual operating time (7920h)

Selective hexane absorption from hexane/water mixture by surface- modified sponge filter (Movie 1) (MP4)

Selective solvent recovery from oil-in-hexane/water mixture by surface-modified sponge filter (Movie 2) (MP4)

Selective solvent recovery from lipid-in-hexane/medium with cell debris mixture by surface-modified sponge filter (Movie3) (MP4)

*In-situ* filtering method (Movie 4) (MP4)

*Ex-situ* filtering method (Movie 5) (MP4)