Supporting Information

Streptothricin F biological production and simulated moving bed purification from food waste digestate

Xiaofang Zhou,[a] Peiyi Li,[b] Yuchen Sun,[b] Zeyang Zhang,[b] Chuanyi Yao,[b] Qingbiao Li*[b,c] and Yuanpeng Wang*[b]

[a] College of School of environment and ecology, Xiamen University, Xiamen, P. R. China

[b] Department of Chemical and Biochemical Engineering, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen, P. R. China

[c] College Food and Biological Engineering, Jimei University, Xiamen, P. R. China

* Corresponding Author:

Yuanpeng Wang, Department of Chemical and Biochemical Engineering, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005 Fujian, China.

Qingbiao Li, Department of Chemical and Biochemical Engineering, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005 Fujian, China; College Food and Biological Engineering, Jimei University, Xiamen 361021 Fujian, China.

1. Experimental Section

1.1 Greenhouse gas emissions (GHG)

The primary utility consumption in the process includes purchased low-pressure steam, circulating water, and electricity. Utility usage is converted to standard oil equivalents for calculation. In the life cycle evaluation, process energy is calculated based on standard oil and electricity as detailed in equations (**Formula S1-S4**). The converted values are provided in **Table S8, S10**.

$$GHG_{tCO2eq} = CO_2 + 25 \times CH_4 + 298 \times N_2O \quad (1)$$

$$IE_{CO2} = I_{CO2} \times LHV_{CO2} \times EC \times 44/12 \quad (2)$$

$$IE_{CH4} = I_{CH4} \times LHV_{CH4} \times EC \quad (3)$$

$$IE_{N2O} = I_{N2O} \times LHV_{N2O} \times EC \quad (4)$$

1.2 Non-renewable energy consumption (NEC)

In addition to utility consumption, three non-renewable energy sources (crude oil, raw coal, and natural gas) used in the separation process are analyzed for life cycle non-renewable energy consumption. The method for calculating energy consumption is detailed in equations (**Formula S5-S6**). The results of the non-renewable energy consumption calculations are provided in Table **S11**.

$$NED = NE_{crudeoil} + NE_{crudecoal} + NE_{natura\,lg\,a\,s} \quad (5)$$

$$NE_i = \sum (EC \times LHV \times PFCF_i) \quad (6)$$

1.3 Eutrophication potential (EP)

The life cycle assessment model for eutrophication potential is calculated using the characterization approach, which integrates input and output data from the life cycle inventory with various environmental impact categories. The quantitative calculation is detailed in equations (**Formula S7**). The results of the eutrophication potential calculations are presented in Table **S9, S12**.

$$EI_j = \sum_i EF_{i,j} \times E_i \quad (7)$$

2. Supplementary Figures and Tables

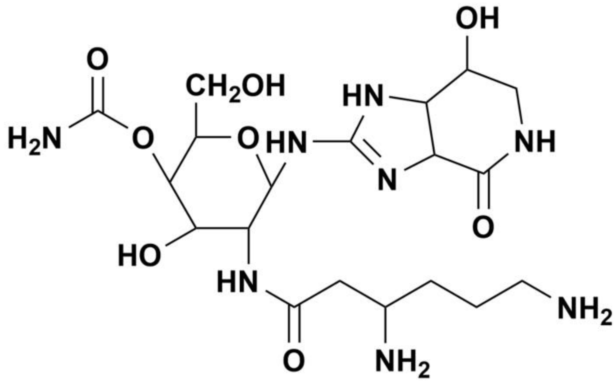

Figure S1 The Structure of Streptothricin F ($C_{19}H_{34}O_8N_8$，502 MV).

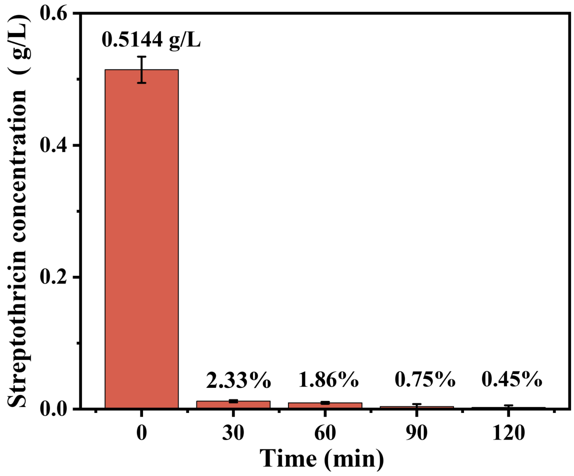

Figure S2 The concentration of Streptothricin F in the supernatant at different adsorption times.

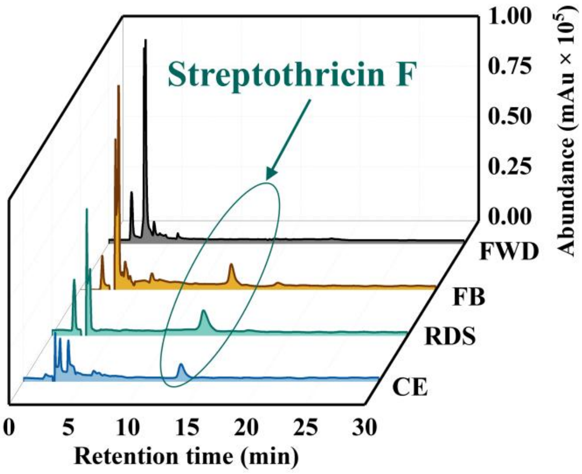

Figure S3 The liquid chromatogram of Streptothricin F during food waste digestate biological fermentation and crude extraction (Retention time is 13.29 min).

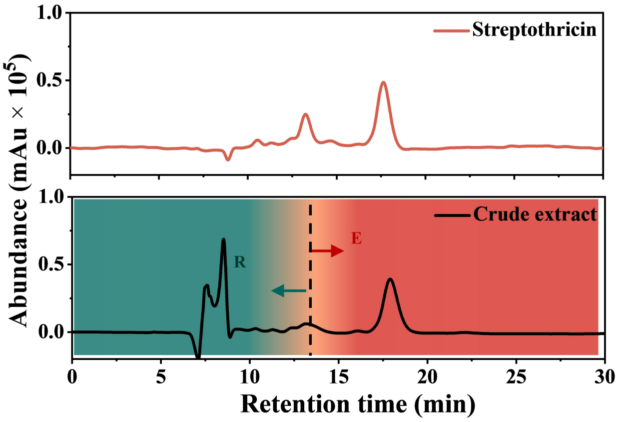

Figure S4 The liquid chromatogram of Streptothricin F standard and crude extract were analyzed in a simulated moving bed with C18 semi-preparative columns.

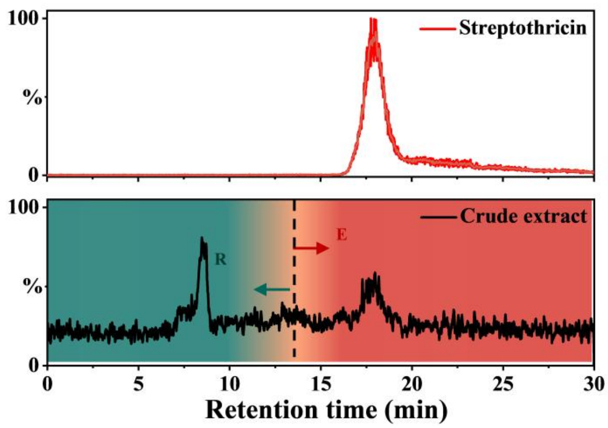

Figure S5 The total ion flow spectrum of Streptothricin F standard and crude extract by LC-MS (Retention time is 17.85 min).

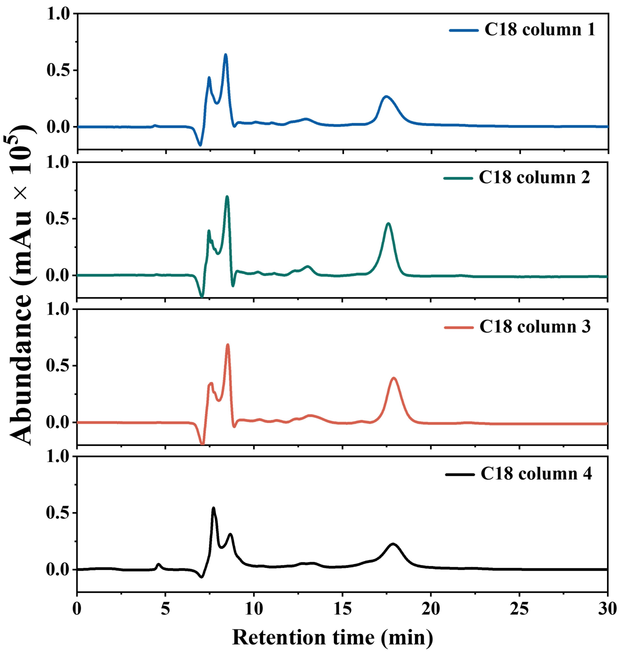

Figure S6 The liquid chromatogram of crude extract was analyzed using four C18 semi-preparative columns.

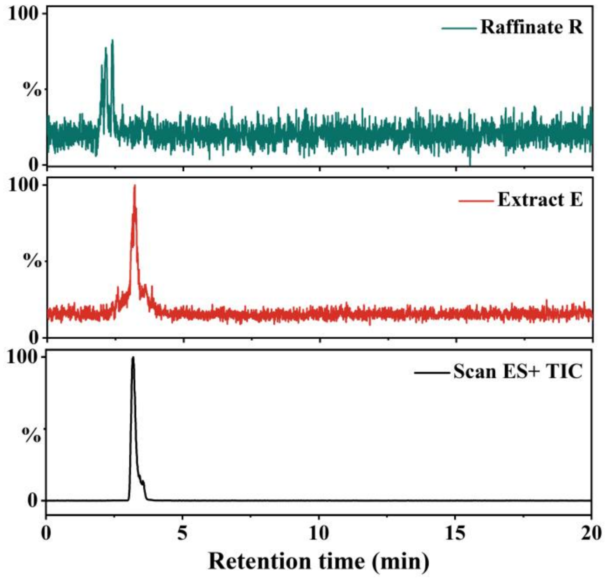

Figure S7 The total ion flow of extract E and extract R after the simulated moving bed separation and recrystallization using the C18 analysis column.

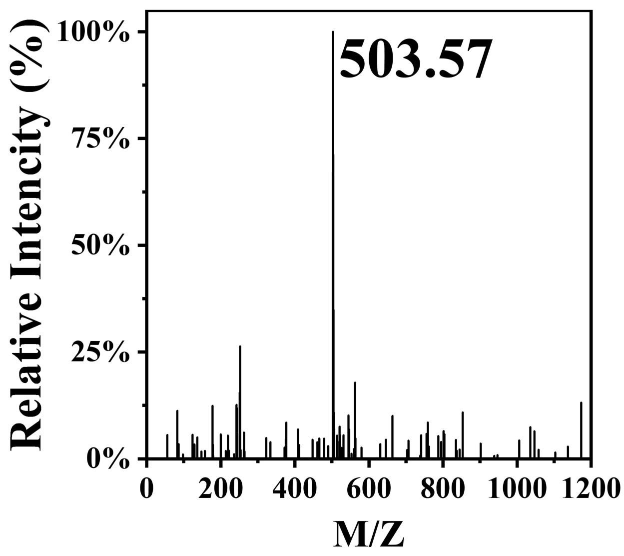

Figure S8 The Mass spectrum of extract E were examined after recrystallization.

Table S1 The ingredients of Gause no. 1 medium.

Ingredient	Medium
	/L
Soluble starch	20.0 g
KNO_3	1.0 g
NaCl	0.5 g
K_2HPO_4	0.5 g
$MgSO_4 \cdot 7\ H_2O$	0.5 g
$FeSO_4 \cdot 7\ H_2O$	10.0 mg
pH	7.4-7.6

Table S2 The composition of food waste digestate.

Operating parameter	Parameter value
pH	8.42±0.11
EC (ms/cm)	400 ± 37
TOC (mg/L)	5608 ± 48
COD (mg/L)	15860 ± 443
TN (mg/L)	3158 ± 37
TP (mg/L)	396 ± 27
NH_4^+-N (mg/L)	2743 ± 31
TS (%)	1.78 ± 0.21
VS (%)	0.74 ± 0.14

Table S3 The C/N/P changes after pre-treatment of food waste digestate.

	TOC (mg/L)	COD (mg/L)	TN (mg/L)	NH_4^+-N (mg/L)	TP (mg/L)
FWD	5608 ± 48	15860 ± 443	3158 ± 37	2743 ± 31	396 ± 27
FWD-MD	6421 ± 56	16155 ± 419	650 ± 17	228 ± 22	393 ± 34

Table S4 The comparison of different pretreatment methods for food waste digestate.

	COD (mg/L)	NH_4^+-N (mg/L)	TP (mg/L)	comparison
Food waste digestate	15860 ± 443	2743 ± 31	396 ± 27	——
Membrane distillation	16155 ± 419	228 ± 22	393 ± 34	High removal rate, high removal rate, simple to operate
Struvite precipitation	7598±189	1419±73	14±7	Adding chemical reagents, secondary pollution
Activated carbon adsorption	15139±477	2416±83	410±21	Low removal effect, generate solid waste
Reverse osmosis	5594±121	242±11	54±11	Nonselectivity, complicated operation

Table S5 The correlation analysis of Streptothricin F concentration in food waste digestate after fermentation under different treatments.

Index	FWD	FWD-MD	G-25%	G-50%	G-75%	G-100%	S-25%	S-50%	S-75%	S-100%
FWD	1	0.0498	0.0009	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.9078
FWD-MD	*	1	0.0734	<0.0001	<0.0001	<0.0001	0.0128	<0.0001	<0.0001	0.9996
G-25%	**	ns	1	<0.0001	0.0011	<0.0001	0.9967	<0.0001	<0.0001	0.0193
G-50%	**	**	**	1	<0.0001	0.0011	<0.0001	0.6977	0.0011	<0.0001
G-75%	**	**	**	**	1	0.4989	0.0067	0.0005	0.4905	<0.0001
G-100%	**	**	**	**	ns	1	<0.0001	0.0587	>0.9999	<0.0001
S-25%	**	*	ns	**	**	**	1	<0.0001	<0.0001	0.0031
S-50%	**	**	**	ns	**	ns	**	1	0.0604	<0.0001
S-75%	**	**	**	**	ns	**	**	ns	1	<0.0001
S-100%	ns	ns	*	**	**	**	**	**	**	1

An asterisk (*) represents a significant difference of $P < 0.05$, while two asterisks (**) represent a significant difference of $P < 0.01$.

Table S6 The retention time of thiourea.

Flow rates (mL/min)	Retention time (min)			
	Column #1	Column #2	Column #3	Column #4
0.5	15.901	15.633	15.681	15.71
1	7.884	7.826	7.765	7.776
2	4.053	4.146	4.028	4.031
3	2.793	2.803	2.778	2.783
4	2.087	2.078	2.077	2.076
5	1.682	1.66	1.65	1.656
R2	0.99982	0.99988	0.99983	0.99983
The overall porosity	0.70296	0.69943	0.6949	0.6961
The bed porosity	0.35809	0.35164	0.35173	0.35187

Table S7 The operating parameters of the simulated moving bed at different operating points.

Operating parameter	P1	P2	P3	P4	P5
m II, m III	1.62, 1.84	1.42, 1.61	1.22, 1.38	1.01, 1.15	0.81, 0.92
T_S (min)	140	140	140	140	140
Q_D (mL/min)	1.000	1.000	1.000	1.000	1.000
Q_E (mL/min)	0.528	0.572	0.616	0.661	0.705
Q_F (mL/min)	0.048	0.042	0.036	0.030	0.024
Q_R (mL/min)	0.519	0.469	0.419	0.369	0.319
Recovery rate (%)	81.27%	96.78%	98.64%	99.32%	99.12%
Purity (%)	99.05%	97.47%	95.26%	92.22%	78.07%

Table S8 Converted value of utility usage.

Utility usage (m^3/food waste digestate):	Aspen	Conversion value	Energy value (kgEO/m^3 food waste digestate)
Water	0.396	55	21.78
Electricity（kwh）	0.36	0.22	0.0792

Table S9 Environmental impact indicators and characterization factors.

Environmental impact indicators	Pollutants	Characterization factor
(EP) Kg PO_4^{3-} eq/kg	COD	0.02
	NO_3^-	0.42
	PO_4^{3-}	1.00
	NH_3	0.35
	NH_4^+	0.35
	NO_X	0.13
	N_2O	0.27

Table S10 Greenhouse gas emission ($tCO2\ eq/m^3$ food waste digestate).

	EC	LHV	I			IE CO_2	IE N_2O	IE CH_4	GHG_{tCO2eq}
			ICO_2	IN_2O	ICH_4				
Standard oil	0.02178	41868	0.00002533	4.1E-10	0.00000007	0.084692843	3.73873E-07	6.3832E-05	0.086400056
Electricity	0.36	10.89	0.00024802	6.2E-10	0.00000216	0.003565238	2.43065E-09	8.46806E-06	0.003777664
Total									0.09017772

Table S11 List of renewable energy consumption (MJ eq/m^3 ^{3} food waste digestate).

	EC	LHV	PFCF crude oil	PFCF raw coal	PFCF natural gas	NE crude oil	NE raw coal	NE natural gas	Total NE
Standard oil	0.02178	41868	1.06	0.14	0.03	966.598142	127.663905	0.004452	1094.2665
Electricity	0.36	10.89	0.37	2.86	0.03	1.450548	11.212344	0.031746	12.694638
Total									1106.96114

Table S12 List of eutrophication potential (KgSO_2 eq/kg food waste digestate).

	COD kg/m^3	characterization factor	(EP) Kg PO_4^{3-} eq/kg
Food waste digestate	15.228	0.022	0.335016
Biological Fermentation	1.372	0.022	0.030184
Crude extraction	0.364	0.022	0.008008
Separation and Purification	1.16	0.022	0.02552
Total			0.398728

Table S13 Life Cycle Emission Inventory Data.

Operating parameter	Food waste digestate	Biological Fermentation	Crude extraction	Separation and Purification
COD (mg/L)	18457	3229	1195	333
EP (KgPO_4^{3-} eq/kg)	_	0.3350	0.0380	0.0260
GHG (tCO2 eq/m^3)	_	_	0.0038	0.0860
NEC (MJ eq/m^3)	_	_	0.3600	0.3900

The primary sources of emissions and energy consumption include: ① Raw Material Acquisition: This refers to the energy and emissions associated with the extraction and processing of raw materials used in fermentation and purification; ② Waste Management: This pertains to emissions generated during the treatment and disposal of waste products.