Supplementary Material for

Catalytic hydrothermal deoxygenation of lipids and fatty acids to diesel-like hydrocarbons: A review

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Text S1 Definition of conversion and selectivity in the SI

In the following Tables, the conversion was calculated as mole percent, as shown in eq. S1:

$$\text{Conversion (mol\%)} = \left(1 - \frac{n(feedstock\ after\ reaction)}{n(feedstock\ before\ reaction)}\right) \times 100\% \quad \text{(S1)}$$

Hydrocarbon yields are divided into three categories, namely mass yield, molar yield and carbon mass/mole yield. For greater clarity, wt%, mol% and C% are used to refer to them respectively. The mass yield was calculated by weight percent (eq. S2):

$$\text{Mass yield (wt\%)} = \frac{\sum m(product)}{m(feedstock)} \times 100\% \quad \text{(S2)}$$

The molar yield was calculated by mole percent (eq. S3):

$$\text{Molar yield (\%)} = \frac{\sum n(product)}{n(feedstock)} \times 100\% \quad \text{(S3)}$$

The carbon mass/molar yield was calculated based on the eq. S4:

$$\text{Carbon mass/molar yield (C\%)} = \frac{\sum n(carbon\ in\ products)}{n(total\ carbon\ in\ feedstocks)} \times 100\% \quad \text{(S4)}$$

The selectivity of products is also divided into three categories, namely mass selectivity, molar selectivity and carbon mass/mole selectivity. For greater clarity, wt%, mol% and C% are used to refer to them respectively. The mass selectivity was calculated by weight percent (eq. S5):

$$\text{Mass selectivity (wt\%)} = \frac{m(product)}{m(total\ products)} \times 100\% \quad \text{(S5)}$$

The molar selectivity was calculated based on the eq. 21:

$$\text{Molar Selectivity (mol\%)} = \frac{n(product)}{n(total\ products)} \times 100\% \quad \text{(S6)}$$

The carbon mass/molar selectivity was calculated based on the eq.23:

$$\text{Carbon mass/molar Selectivity (C\%)} = \frac{n(carbon\ in\ product)}{n(total\ carbon\ in\ products)} \times 100\% \quad \text{(S7)}$$

Table S1. Pentadecane yields from palmitic acid after HTDO with different homogeneous catalyst at 370 °C [S1] .

Catalyst	Catalyst loading/mg	Time/h	Molar yield (mol%)
None	—	17	0.67
NaCl	2.5	17	1.3
$MnCl_2$	5.4	17	0.77
$ZnCl_2$	5.9	17	0.99
$CoCl_2$	5.6	17	2.1
$CoCl_2$	50	18	6.6
$CuSO_4$	6.9	17	1.8
$MgSO_4$	5.2	17	1.1
NaOH	3.9	18	7.1
KOH	5.5	18	5.5

Table S2. HTDO process of fatty acids involving AC as catalyst

Entry	Feedstock	Reactor	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion	Selectivity	Reference
1	Stearic acid	Micro-batch	AC-1[a]	370 °C 3 h	50-144:10:3 15 mg catalyst	24 mol%	38 mol% C_{17}	[S2]
2	Stearic acid	Micro-batch	AC-2[b]	370 °C 3 h	50-144:10:3 15 mg catalyst	33 mol%	58 mol% C_{18}	[S2]
3	Oleic acid	Batch	AC	400 °C 2 h	4:1:- 5 g catalyst	97 mol%	81 mol% C_{17}	[S3]
4	Oleic acid	Continuous	AC	400 °C 2 h	4:1:- 0.4 g/mL catalyst	91 mol%	89.3 mol% C_{17}	[S4]
5	Oleic acid	Continuous	AC	370 °C formic acid 0.35 h	5:1:- 18.2 g catalyst	99.4 mol%	80.6 mol% C_{17}	[S5]

a.AC-1 is an activated charcoal made via washing with phosphoric acid.

b.AC-2 was made from peat and was steam activated.

Table S3. HTDO process of lipids and fatty acids involving Pd-based catalyst

Entry	Feedstock	Reactor type	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion	Selectivity	Reference
1	Palmitic acid	Micro-batch	5 wt% Pd/C	370 °C 3 h autogenous pressure	-:10:1 5 mg catalyst	-	63 mol% C_{15}	S1
2	Stearic acid	Batch	4.3 wt% Pd/C	250 °C 20 h autogenous pressure	100:4:1 0.25 g catalyst	13 mol%	100 mol% heptadecane	S6
3	Tristearin	Batch	4.3 wt% Pd/C	250 °C 20 h autogenous pressure	100:4:1 0.26 g catalyst	100 mol%	18 mol% heptadecane 82 mol% stearic acid	S6
4	Oleic acid	Batch	4.3 wt% Pd/C	250 °C 20 h autogenous pressure	100:4:1 0.27 g catalyst	41 mol%	12.2 mol% heptadecane 7.3 mol% heptadecene	S6
5	Oleic acid	Batch	4.3 wt% Pd/C	250 °C glycerol 20 h autogenous pressure	100:4:1 0.28 g catalyst	63 mol%	11.1 mol% heptadecane 11.1 mol% heptadecene	S6

6	Triolein	Batch	4.3 wt% Pd/C	250 °C 20 h autogenous pressure	100:4:1 0.29 g catalyst	100 mol%	9 mol% heptadecane 7 mol% heptadecene	S6
7	Triolein	Batch	4.3 wt% Pd/C	250 °C methanol 20 h autogenous pressure	100:4:1 0.30 g catalyst	100 mol%	59 mol% heptadecane	S6
8	Crude Jatropha oil	Batch	5 wt% Pd/C	340 °C 1 g formic acid 4 h atmospheric pressure N_2	10:10:1 0.3 g catalyst	~ 58 wt%	~ 75 wt% paraffins ~ 10 wt% aromatic hydrocarbons	S7
9	Crude Jatropha oil	Batch	5 wt% Pd/C	340 °C 3 g formic acid 4 h atmospheric pressure N_2	10:10:1 0.3 g catalyst	99.5 wt%	97 wt% hydrocarbons	S7
10	Crude Jatropha oil	Continuous	5 wt% Pd/C	340 °C 20 ml/min N_2 feed rate 0.3 ml/min	3:2:- 5 g catalyst	99.5 wt%	97 wt% hydrocarbon yield ~99 wt% n-heptadecane	S7

11	Crude Jatropha oil	Batch	5 wt% Pd/C	260 °C biphasic solvent:cycloalkane/water=2:22 28 bar H_2 6 h	440:3:1 0.05 g catalyst	~97.1 C%	99 C% n-heptadecane n-heptadecane carbon yield 91.7%	S8

Table S4. HTDO process of lipids and fatty acids involving Pt-based catalyst

Entry	Feedstock	Reactor type	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion	Selectivity	Reference
1	Palmitic acid	Micro-batch	5 wt% Pt/C	370 °C autogenous pressure 1 h	-:10:1 5 mg catalyst	-	C_{15} molar yield 76%	[S1]
2	Stearic acid	Micro-batch	5 wt% Pt/C	330 °C autogenous pressure 0.5 h	-:5:1 10 mg catalyst	52.4 mol%	57 mol%	[S9]
3	Stearic acid	Micro-batch	5 wt% Pt/MWCNTs	330 °C autogenous pressure 0.5 h	-:5:1 10 mg catalyst	52.4 mol%	97 mol%	[S9]
4	Palm oil	Batch	Pt-Re/CNT	285 °C 1 MPa N_2 24 h	87:22:1 0.92 g catalyst	-	n-paraffin carbon yield 72%	[S10]
5	Palm oil	Batch	Pt-Re/oCNT	285 °C 1 MPa N_2	87:22:1 0.92 g catalyst	-	n-paraffin carbon yield ~ 58%	[S10]

				24 h				
6	Palm oil	Batch	Pt-Re/AC	285 °C 1 MPa N_2 24 h	87:22:1 0.92 g catalyst	-	n-paraffin carbon yield ~ 40%	S10
7	Palm oil	Batch	Pt-Re/oAC	285 °C 1 MPa N_2 24 h	87:22:1 0.92 g catalyst	-	n-paraffin carbon yield ~ 10%	S10
8	Jatropha oil	Batch	1 wt% Pt/H-ZSM-5	270 °C H_2/N_2 = 85/15 (vol %), 6.5 MPa. 12 h	9:1:1 1 g catalyst	103.4 C%	79.0 C% C_{15}-C_{18} 8.68 C% gas products	S11
9	Jatropha oil	Batch	1 wt% Pt/USY	270 °C H_2/N_2 = 85/15 (vol %), 6.5 MPa. 12 h	9:1:1 1 g catalyst	31.2 C%	68.15 C% C_{15}-C_{18} 11.53 C% gas products	S11
10	Jatropha oil	Batch	1 wt% Pt/CNTs	270 °C H_2/N_2 = 85/15 (vol %), 6.5 MPa. 12 h	9:1:1 1 g catalyst	13.6 C%	23.73 C% C_{15}-C_{18} 5.43 C% gas products	S11

11	Stearic acid	Micro-batch	Pt3Sn/C	350 °C 2 h	185:5680:1 5.4 mg catalyst	~ 97 mol%	~ 95 mol% C_{17}	S12
12	Oleic acid	Micro-batch	Pt3Sn/C	350 °C 2 h	185:5640:1 5.4 mg catalyst	~ 98 mol%	~ 53 mol% C_{17}	S12
13	Oleic acid	Batch	Pt-Ni/Al_2O_3	275 °C 0.1 MPa N_2 glycerol 4 h	100 g oleic acid	100 mol%	69 mol% C_{17}	S13
14	Jatropha Oils	Batch	Pt/HZSM-5	270 °C H_2/N_2 = 91/9 (vol %), 6.0 MPa. 12 h	9:1:1 1 g catalyst	~ 14 C%	~ 13 C% C_{18} ~ 27 C% C_{19+} ~ 54 C% C_1-C_{13}	S11
15	Jatropha Oils	Batch	Pt-Re/HZSM-5	270 °C H_2/N_2 = 91/9 (vol %), 6.0 MPa. 12 h	9:1:1 1 g catalyst	~ 78 C%	~ 6 C% C_{19+} ~ 72 C% C_{18}	S11

16	Oleic acid	Batch	Pt/C	300 °C 0.35MPa N_2 5 g glycerol 9 h	160:40:1 0.5 g catalyst	100 mol%	75 mol% stearic acid 24 mol% C_{17}	S14
17	Oleic acid	Batch	Pt-Re/C	300 °C 0.35MPa N_2 5 g glycerol 9 h	160:40:1 0.5 g catalyst	92 mol%	53 mol% stearic acid 37 mol% C_{17}	S14
18	Waste vegetable oil	Batch	Pt-Re/C	300 °C 1.72 MPa H_2 6 h	40:10:1 2 g catalyst	100 wt%	81.3 wt% C_{17} 12.4 wt% C_{15}	S15
19	Animal fat	Batch	Pt-Re/C	300 °C 1.72 MPa H_2 6 h	40:10:1 2 g catalyst	100 wt%	56.3 wt% C_{17} 28.8 wt% C_{15}	S15
20	Coffee oil	Batch	Pt-Re/C	300 °C 1.72 MPa H_2 6 h	40:10:1 2 g catalyst	49.20 wt%	30.7 wt% C_{17} 15.5 wt% C_{15}	S15

Table S5. HTDO process of lipids and fatty acids involving Ru-based catalyst

Entry	Feedstock	Reactor type	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion	Selectivity	Reference
1	Stearic acid	Batch	5 wt% Ru/C	330 °C 2 MPa N_2 1 h	160:10:1 0.5 g catalyst	37.5 mol%	31.4 mol% liquid alkanes 3.4% carbon distribution in gas	S16
2	Commercial lipid	Batch	5 wt% Ru/C	330 °C 2 MPa N_2 1 h	160:10:1 0.5 g catalyst	100 mol%	50.9 mol% liquid alkanes 7.7% carbon distribution in gas	S16
3	Stearic acid	Batch	5 wt% Ru/C	330 °C 2 MPa N_2 glycerol 1 h	160:10:1 0.5 g catalyst	89.1 mol%	66.0 mol% liquid alkanes 24.7% carbon distribution in gas	S16
4	Stearic acid	Batch	5 wt% Ru/C	330 °C 2 MPa H_2 1 h	160:10:1 0.5 g catalyst	95.6 mol%	67.3 mol% liquid alkanes 41.6% carbon distribution in gas	S16

5	Methyl stearate	Batch	1 wt% Ru/HZSM-5	200 °C 3 Mpa H_2 8 h	200:4:3 0.15 g catalyst	90.8 mol%	64.3 mol% C_{17} 13.0 mol% C_{18}	S17
6	Stearic acid	Batch	1.7 wt% Ru/HAP	180 °C 2 MPa H_2 1h	750:14:5 0.1 g catalyst	95.8 mol%	60 mol% C_{17} 20.7 mol% C_{18}	S18
7	Stearic acid	Batch	Ru/AC	180 °C 2 MPa H_2 1h	375:7:- 0.005 g Ru	26.9 mol%	3.1 mol% C_{17} 0.6 mol% C_{18}	S18
8	Stearic acid	Batch	Ru/HBEA	180 °C 2 MPa H_2 1h	375:7:- 0.005 g Ru	27.9 mol%	0.4 mol% C_{17} 0.1 mol% C_{18}	S18
9	Stearic acid	Batch	Ru/SiO_2	180 °C 2 MPa H_2 1h	375:7:- 0.005 g Ru	42.7 mol%	1 mol% C_{17} 0.1 mol% C_{18}	S18
10	Stearic acid	Batch	Ru/ZrO_2	180 °C 2 MPa H_2 1h	375:7:- 0.005 g Ru	41.7 mol%	4.5 mol% C_{17} 0.3 mol% C_{18}	S18
11	Stearic acid	Batch	Ru/TiO_2	180 °C 2 MPa H_2	375:7:- 0.005 g Ru	51.3 mol%	38.4 mol% C_{17} 9.8 mol% C_{18}	S18

				1h				
12	Stearic acid	Batch	$Ru/La(OH)_3$	180 °C 2 MPa H_2 1h	375:7:- 0.005 g Ru	31.9 mol%	6.5 mol% C_{17} 0.3 mol% C_{18}	[S18]

Table S6. HTDO process of lipids and fatty acids involving Ni-based catalyst

Entry	Feedstock	Reactor type	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion	Product yield	Reference
1	Palmitic acid	Mini-batch reactor	5 wt% Ni/ZrO_2	300 °C 0.69 MPa H_2 total pressure 5.52 MPa 6 h	9:1:1 0.5 g catalyst	78 C%	44 C% paraffin 5.8 C% palmitone	S19
2	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	300 °C 0.69 MPa H_2 total pressure 5.52 MPa 6 h	9:1:1 0.5 g catalyst	88 C%	66 C% paraffin 0.15 C% palmitone 30.8 C% C_8-C_{14} 16.1 C% CH_4	S19
3	Canola oil		20 wt% Ni/C	305 °C 2.76 MPa H_2 6 h		~32 wt%	~15 wt% hydrocarbons	S20
4	Palmitic acid	Mini-batch reactor	20 wt% Ni/ZrO_2	300 °C 0.69 MPa H_2 total pressure 5.52 MPa 6 h	9:1:1 0.5 g catalyst	100 C%	66 C% paraffin	S20
5	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	250 °C 5.52 MPa H_2 6 h	9:1:1 0.5 g catalyst	~5 C%	2.8 C% C_{15}	S20

6	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	270 °C 5.52 MPa H_2 6 h	9:1:1 0.5 g catalyst	~22 C%	18.9 C% C_{15} 0.8 C% C_{16}	S20
7	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	290 °C 5.52 MPa H_2 6 h	9:1:1 0.5 g catalyst	~97 C%	34.6 C% C_{15} 4.0 C% C_{16} 21.4 C% C_8-C_{14}	S20
8	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	300 °C 5.52 MPa H_2 6 h	9:1:1 0.5 g catalyst	100 C%	23.8 C% C_{15} 0.77 C% C_{16} 36.2 C% C_8-C_{14} ~18.2 C% CH_4	S20
9	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	300 °C 1.72 MPa H_2 total pressure 5.52 MPa 6 h	9:1:1 0.5 g catalyst	~92 C%	30.2 C% C_{15} 2.8 C% C_{16} 26.0 C% C_8-C_{14} ~18.3 C% CH_4	S20
10	Palmitic acid	Mini-batch reactor	10 wt% Ni/ZrO_2	300 °C 5.52 Mpa N_2 6 h	9:1:1 0.5 g catalyst	~63 C%	16.1 C% C_{15} 0.4 C% C_{16} 22.1 C% C_8-C_{14} ~11 C% CH_4	S20

11	Stearic acid	Mini-batch reactor	20 wt% Ni/ZrO_2	300 °C 6 h	45:5:2	67.08%	43.63 C% paraffin 29.90 C% C_8-C_{16} 19.91 C% n-C_{17} 0.45 C% n-C_{18}	S21
12	Oleic acid	Mini-batch reactor	20 wt% Ni/ZrO_2	300 °C 6 h	45:5:2	-	28 C% stearic acid 42 C% paraffin	S21
13	Bio-oil	Mini-batch reactor	20 wt% Ni/ZrO_2	300 °C 6 h	45:5:2	55.39 wt%	31.33 wt% liquid paraffin 8.78 wt% total gas	S21
14	Octanoic acid	Batch reactor	10 wt% Ni/Z450	260 °C water and decane system 3 MPa H_2 12 h	6:2:1	99.10 mol%	87.3 mol% heptane 8.3 mol% octane	S22
15	Oleic acid	Micro-batch reactor	10 wt% NiMoC/Al-SBA-15 Ni:Mo=2:1	400 °C 4 h	321:22:5	32.80 mol%	62.5 mol% heptadecene 3.1 mol% octadecene	S23
16	Oleic acid	Micro-batch reactor	10 wt% NiNbC/Al-SBA-15 Ni:Nb=2:1	400 °C 4 h	321:22:5	30.70 mol%	67.6 mol% heptadecene 1.9 mol% octadecene	S23

17	Oleic acid	Micro-batch reactor	10 wt% NiWC/Al-SBA-15 Ni:W=2:1	400 °C 4 h	321:22:5	30.70 mol%	0.72 mol% heptadecane 53.6 mol% heptadecene 1.8 mol% octadecene	[S23]
18	Oleic acid	Micro-batch reactor	10 wt% NiZrC/Al-SBA-15 Ni:Zr=2:1	400 °C 4 h	321:22:5	30.10 mol%	67.7 mol% heptadecene 1.1 mol% octadecene	[S23]
19	Oleic acid	Micro-batch reactor	10 wt% NiNbC/Al-SBA-15 Ni:Nb=2:1	400 °C glycerol 4 h	321:22:5	~ 80 mol%	~ 0.3 mol% heptadecane ~ 43 mol% heptadecene ~ 33 mol% stearic acid	[S23]
20	Oleic acid	Micro-batch reactor	10 wt% NiWC/Al-SBA-15 Ni:W=2:1	400 °C glycerol 4 h	321:22:5	97.30 mol%	5.2 mol% heptadecane ~ 12 mol% heptadecene ~ 73 mol% stearic acid	[S23]
21	Soybean oil	Micro-batch reactor	10 wt% NiWC/Al-SBA-15 Ni:W=2:1	400 °C 4 h	321:22:5	>95 mol%	2.1 mol% heptadecane 19.7 mol% heptadecene 39.6 mol% stearic acid 15 mol% linoleic acid	[S23]
21	Oleic acid	Micro-batch reactor	60 wt% Cu-Ni / Al_2O_3 Cu:Ni=1:2	330 °C methanol 1 h	100:10:3	100 mol%	92.7 mol% heptadecane	[S24]
22	Oleic acid	Micro-batch reactor	30% Cu-Ni/ZrO_2	370 °C methanol 5 h	100:10:3	100 mol%	92.5 mol% heptadecane	[S25]

Table S7. HTDO process of lipids and fatty acids over other catalysts.

Entry	Feedstock	Reactor type	Catalyst	Conditions	H_2O:Feedstock:Catalyst	Conversion/performance	Selectivity	Reference
1	Oleic acid	Continue	10 wt% MgO/Al_2O_3	375 °C 4 h	5:1:- 5 g catalyst	67% degree of DCX 65% liquid product yield 35% gas product yield	-	S26
2	Oleic acid	Continue	10 wt% Ni/Al_2O_3	375 °C 4 h	5:1:- 5 g catalyst	65% degree of DCX 30% liquid product yield 70% gas product yield	-	S26
3	Oleic acid	Continue	10 wt% Mo/Al_2O_3	375 °C 4 h	5:1:- 5 g catalyst	92% degree of DCX 71% liquid product yield 29% gas product yield	34.8% tetradecane 24% pentadecane 22.9% hexadecane 18.3% heptadecane	S26
4	Bio-oil	Mini-batch	Al-SBA-15	300 °C 1 h	50:10:1	-	4.30 wt% aliphatic hydrocarbons 20.62 wt% aromatic hydrocarbons	S27
5	Bio-oil	Mini-batch	CuO/Al-SBA-15	300 °C 1 h	50:10:1	-	64.64 wt% aliphatic hydrocarbons 1.07 wt% aromatic hydrocarbons	S27

6	Bio-oil	Mini-batch	ZnO/Al-SBA-15	300 °C 1 h	50:10:1	-	61.13 wt% aliphatic hydrocarbons 3.14 wt% aromatic hydrocarbons	[S27]
7	Bio-oil	Mini-batch	(CuO-ZnO)/Al-SBA-15	300 °C 1 h	50:10:1	-	50.77 wt% aliphatic hydrocarbons 3.44 wt% aromatic hydrocarbons	[S27]
8	Stearic acid	Batch	Ce/γ-Al_2O_3	300 °C 12 h	8:2:1	65 wt%	54 wt% hydrocarbons	[S28]
9	Stearic acid	Batch	Cu/γ-Al_2O_3	300 °C 12 h	8:2:1	92 wt%	72 wt% hydrocarbons	[S28]
10	Stearic acid	Batch	Cu-Ce/γ-Al_2O_3	300 °C 12 h	8:2:1	95 wt%	80 wt% hydrocarbons	[S28]

References

S1. J. Fu, X. Y. Lu and P. E. Savage, *Energy Environ Sci*, 2010, **3**, 311-317.

S2. J. Fu, F. Shi, L. T. Thompson, X. Y. Lu and P. E. Savage, *Acs Catal*, 2011, **1**, 227-231.

S3. M. Z. Hossain, A. K. Jhawar, M. B. I. Chowdhury, W. Z. Xu, W. Wu, D. V. Hiscott and P. A. Charpentier, *Energy Fuels*, 2017, **31**, 4013-4023.

S4. M. Z. Hossain, M. B. I. Chowdhury, A. K. Jhawar, W. Z. Xu and P. A. Charpentier, *Fuel*, 2018, **212**, 470-478.

S5. S. Popov and S. Kumar, *Energy Fuels*, 2015, **29**, 3377-3384.

S6. S. A. Hollak, M. A. Ariens, K. P. de Jong and D. S. van Es, *ChemSusChem*, 2014, **7**, 1057-1062.

S7. S. Idesh, S. Kudo, K. Norinaga and J. Hayashi, *Energy Fuels*, 2013, **27**, 4796-4803.

S8. S. Xie, C. Jia, A. Prakash, M. I. Palafox, J. Pfaendtner and H. Lin, *Acs Catal*, 2019, **9**, 3753-3763.

S9. C. Y. Yang, R. F. Nie, J. Fu, Z. Y. Hou and X. Y. Lu, *Bioresour. Technol.*, 2013, **146**, 569-573.

S10. M. Jin and M. Choi, *Mol Catal*, 2019, **474**, 1-9.

S11. K. Murata, Y. Liu, M. Inaba and I. Takahara, *Energy Fuels*, 2010, **24**, 2404-2409.

S12. T. M. Yeh, R. L. Hockstad, S. Linic and P. E. Savage, *Fuel*, 2015, **156**, 219-224.

S13. V. Dominguez-Barroso, C. Herrera, M. Angeles Larrubia and L. J. Alemany, *Fuel Process. Technol.*, 2019, **190**, 21-28.

S14. D. R. Vardon, B. K. Sharma, H. Jaramillo, D. Kim, J. K. Choe, P. N. Ciesielski and T. J. Strathmann, *Green Chem.*, 2014, **16**.

S15. D. Kim, D. R. Vardon, D. Murali, B. K. Sharma and T. J. Strathmann, *ACS Sustain Chem Eng*, 2016, **4**, 1775-1784.

S16. J. Zhang, X. Huo, Y. Li and T. J. Strathmann, *ACS Sustain Chem Eng*, 2019, **7**, 14400-14410.

S17. J. Z. Chen and Q. Y. Xu, *Catal Sci Technol*, 2016, **6**, 7239-7251.

S18. G. Xu, Y. Zhang, Y. Fu and Q. Guo, *Acs Catal*, 2017, **7**, 1158-1169.

S19. C. Miao, O. Marin-Flores, S. D. Davidson, T. Li, T. Dong, D. Gao, Y. Wang, M. Garcia-Pérez and S. Chen, *Fuel*, 2016, **166**, 302-308.

S20. R. U. Ndubuisi, S. Sinichi, Y. H. Chin and L. L. Diosady, *J. Am. Oil Chem. Soc.*, 2019, **96**, 535-543.

S21. C. Miao, O. Marin-Flores, T. Dong, D. Gao, Y. Wang, M. Garcia-Perez and S. Chen, *ACS Sustain Chem Eng*, 2018, **6**, 4521-+.

S22. H. Chen, Y. L. Wu, S. T. Qi, Y. Chen and M. D. Yang, *Appl Catal A-Gen*, 2017, **529**, 79-90.

S23. B. Al Alwan, S. O. Salley and K. Y. S. Ng, *Appl Catal A-Gen*, 2015, **498**, 32-40.

S24. Z. Zhang, Q. Yang, H. Chen, K. Chen, X. Lu, P. Ouyang, J. Fu and J. G. Chen, *Green Chem.*, 2018, **20**, 197-205.

S25. Z. Zhang, H. Chen, C. Wang, K. Chen, X. Lu, P. Ouyang and J. Fu, *Fuel*, 2018, **230**, 211-217.

S26. M. Z. Hossain, M. B. I. Chowdhury, A. K. Jhawar, W. Z. Xu, M. C. Biesinger and P. A. Charpentier, *Acs Omega*, 2018, **3**, 7046-7060.
S27. J. Li, X. Fang, J. Bian, Y. Guo and C. Li, *Bioresour. Technol.*, 2018, **266**, 541-547.
S28. Q. Yu, Z. Zhang, Z. Yin, S. Kong, Z. Yang, J. Chen and J. Zhang, *Chin J Chromatogr*, 2019, **37**, 454-461.