

Co-liquefaction of sewage sludge with wheat straw in supercritical water - Potentials for integrating hydrothermal liquefaction with wastewater treatment plant

Swanand Bhatwadekar ^a, Federica Conti ^a, Kamaldeep Sharma ^a, Eliana Maria Lozano ^a, Saqib Sohail Toor ^a, Thomas Helmer Pedersen ^{a*}

^a AAU Energy, Aalborg University, Pontoppidanstræde 111, 9220 Aalborg, Denmark

*Corresponding author: Thomas Helmer Pedersen (email: thp@energy.aau.dk address: Pontoppidanstræde 111, 9220 Aalborg, Denmark)

Supplementary material:

Table S1: Experimental and theoretical yields, synergistic effect (SE), elemental compositions, higher heating values (HHV), carbon and energy recoveries (C_{rec} and E_{rec}) of the biocrudes obtained from supercritical HTL of sewage sludge (SS), straw (S), and mixtures of the two (3:1, 1:1, and 1:3 ratios) without and with a catalyst. Results are reported on dry ash-free basis (daf).

	$Y_{experimental}$ (%) _{daf}	$Y_{theoretical}$ (%) _{daf}	SE (-)	C (%)	H (%)	N (%)	O (%)	HHV (MJ kg ⁻¹)	C_{rec} (%)	E_{rec} (%)
SS	40.8 ± 3.4	-	-	72.6 ± 0.1	9.6 ± 0.0	6.1 ± 0.0	11.7	35.3	61.9	65.0
SS3:S1	35.9 ± 2.2	38.0	0.95	72.9 ± 0.4	8.4 ± 0.1	6.4 ± 0.1	12.3	34.0	56.4	57.8
SS1:S1	35.7 ± 0.2	35.2	1.02	73.7 ± 0.2	7.9 ± 0.2	5.0 ± 0.1	13.4	33.6	58.4	59.9
SS1:S3	33.5 ± 2.0	32.3	1.04	73.8 ± 0.0	7.9 ± 0.0	3.7 ± 0.0	14.6	33.5	56.7	59.3
S	29.5 ± 0.7	-	-	73.1 ± 0.0	7.7 ± 0.1	1.2 ± 0.4	18.0	32.7	51.2	54.1
SS - KOH	47.8 ± 0.4	-	-	76.0 ± 0.6	9.7 ± 0.0	5.3 ± 0.2	9.0	37.0	75.9	79.6
SS3:S1 - KOH	34.9 ± 0.3	42.2	0.83	74.3 ± 0.0	9.0 ± 0.0	4.5 ± 0.4	12.2	35.2	55.8	58.3
SS1:S1 - KOH	28.6 ± 0.8	36.5	0.78	75.1 ± 0.0	8.5 ± 0.0	4.2 ± 0.2	12.2	34.9	47.7	49.9
SS1:S3 - KOH	26.9 ± 2.7	30.9	0.87	75.3 ± 0.7	8.1 ± 0.1	3.4 ± 0.3	13.2	34.4	46.5	49.0
S - KOH	25.2 ± 1.5	-	-	76.3 ± 0.2	7.7 ± 0.1	0.7 ± 0.2	15.3	34.1	45.6	48.3
SS3:S1 - K ₂ CO ₃	40.9 ± 2.2	-	-	74.0 ± 0.2	8.9 ± 0.2	5.6 ± 0.4	11.5	35.1	65.2	68.0
SS3:S1 - NH ₃	36.9 ± 2.0	-	-	74.1 ± 0.4	8.7 ± 0.0	5.5 ± 0.3	11.7	34.9	58.9	61.0
SS3:S1 - NH ₃ +KOH	34.7 ± 1.1	-	-	75.6 ± 0.3	9.4 ± 0.0	5.3 ± 0.2	9.7	36.4	56.5	59.9
SS3:S1 - NH ₃ (10%)	28.4 ± 0.6	-	-	72.3 ± 0.0	9.2 ± 0.0	6.2 ± 0.6	12.3	34.7	44.2	46.7

Table S2: Ash contents, yields, elemental analysis (C, H, N, O mass fractions) and main inorganic elements (Al, Ca, Fe, K, Mg, Mn, Na, P, S, Si, Zn) relative to the solids obtained from HTL of sewage sludge (SS), straw (S), and mixtures of the two feedstocks (3:1, 1:1, and 1:3 ratios) without and with catalyst. Yields and elemental analysis are reported on dry ash-free basis (daf).

Ash (%)	Yield (%) _{daf}	C (%) _{daf}	H (%) _{daf}	N (%) _{daf}	O (%) _{daf}	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (%)	Na (%)	P (%)	(%)
73.6 ± 8.5	19.4 ± 4.5	43.5 ± 7.8	3.0 ± 2.9	5.2 ± 1.8	48.3	1.33	6.77	5.07	0.53	0.93	0.05	<0.3	5.15	0
68.8 ± 2.1	21.1 ± 3.7	61.2 ± 9.7	2.8 ± 0.7	5.2 ± 0.7	30.8	1.44	7.39	5.77	1.24	1.11	0.06	<0.3	5.84	0
61.4 ± 0.1	16.9 ± 1.5	66.6 ± 0.6	3.3 ± 0.4	4.3 ± 0.1	25.9	1.14	5.85	4.56	1.73	0.87	0.04	<0.3	4.43	0
50.9 ± 1.5	14.5 ± 0.2	75.3 ± 0.6	4.1 ± 0.0	3.9 ± 0.6	16.7	0.6	4.14	2.88	1.51	0.62	<0.03	<0.3	2.9	0
11.3 ± 2.0	15.9 ± 1.1	70.8 ± 0.2	4.5 ± 0.0	1.4 ± 0.1	23.4	<0.3	1.74	0.41	0.75	0.24	<0.03	0.33	<0.6	0
77.7 ± 5.6	19.5 ± 4.0	51.4 ± 0.5	5.1 ± 0.2	4.5 ± 1.2	39.0	1.48	6.04	6.06	5.96	0.88	0.04	<0.3	4.59	0
72.1 ± 7.4	17.0 ± 3.9	59.6 ± 1.2	5.1 ± 0.1	4.5 ± 0.4	30.9	1.24	6.46	5.37	5.71	0.99	0.05	<0.03	5.26	0
62.4 ± 2.9	20.8 ± 3.0	59.9 ± 3.7	4.2 ± 0.1	3.4 ± 0.2	32.4	0	4.53	3.32	7.60	0.74	0.04	<0.3	3.36	0
50.8 ± 1.0	21.2 ± 1.3	65.1 ± 6.5	4.5 ± 0.4	2.8 ± 0.1	27.6	0.52	3.63	2.73	7.08	0.57	<0.03	<0.3	2.78	0
25.6 ± 0.6	18.7 ± 1.0	68.3 ± 1.9	4.1 ± 0.5	1.2 ± 0.2	26.4	0.51	0.91	0.31	4.88	0.23	<0.03	<0.3	0.61	0
75.7 ± 1.2	17.6 ± 0.4	69.9 ± 0.8	4.2 ± 0.9	5.7 ± 0.2	16.8	<0.3	6.72	5.37	3.68	1.04	0.07	<0.3	5.43	0
62.3 ± 2.1	25.9 ± 2.8	76.9 ± 3.1	3.7 ± 0.9	4.5 ± 0.1	24.4	1.24	6.47	5.31	1.01	0.99	0.07	0.3	5.37	0
72.1 ± 4.1	18.8 ± 1.9	48.1 ± 6.0	5.4 ± 2.5	2.8 ± 0.6	21.7	1.28	5.76	4.62	7.26	0.98	0.05	1.21	4.90	0
67.1 ± 0.3	19.3 ± 1.2	71.8 ± 0.4	3.2 ± 0.1	7.6 ± 0.1	17.4	1.31	6.80	5.65	1.12	1.07	0.05	<0.3	5.64	0

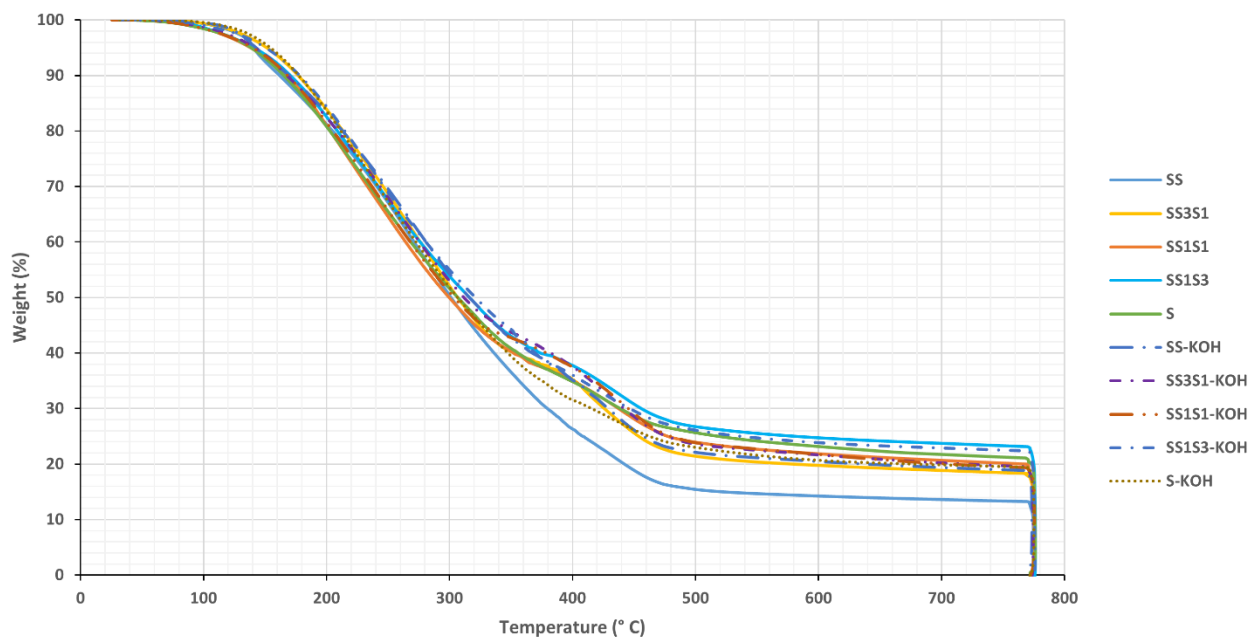


Figure S1: Thermogravimetric curves of the biocrudes obtained from liquefaction of sewage sludge (SS), straw (S), and mixtures of the two (3:1, 1:1, and 1:3 ratios) without and with KOH catalyst. The analysis was performed in N₂ until 775 °C, where the gas was switched to air to establish the ash content of the biocrudes.