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Production factors controlling the physical characteristics of biochar derived from phytoremediated willow for agricultural applications

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Supplementary Information

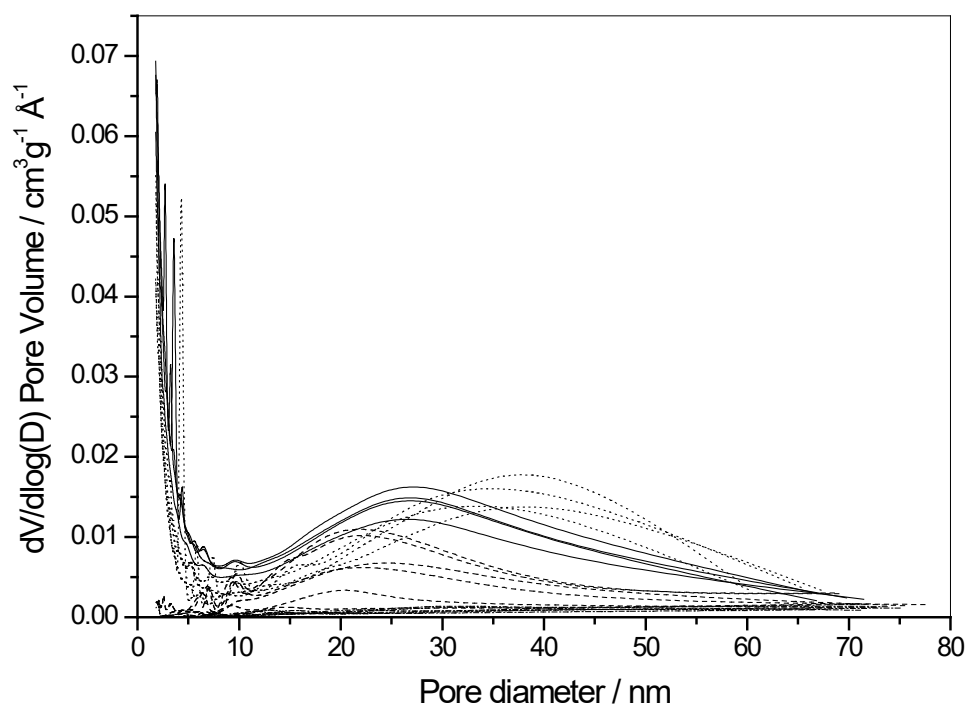


Figure SA1: pore size distributions for chars produced in this study. Dash-dot line: 350 °C; dashed: 450 °C; solid line: 550 °C; dotted: 650 °C.

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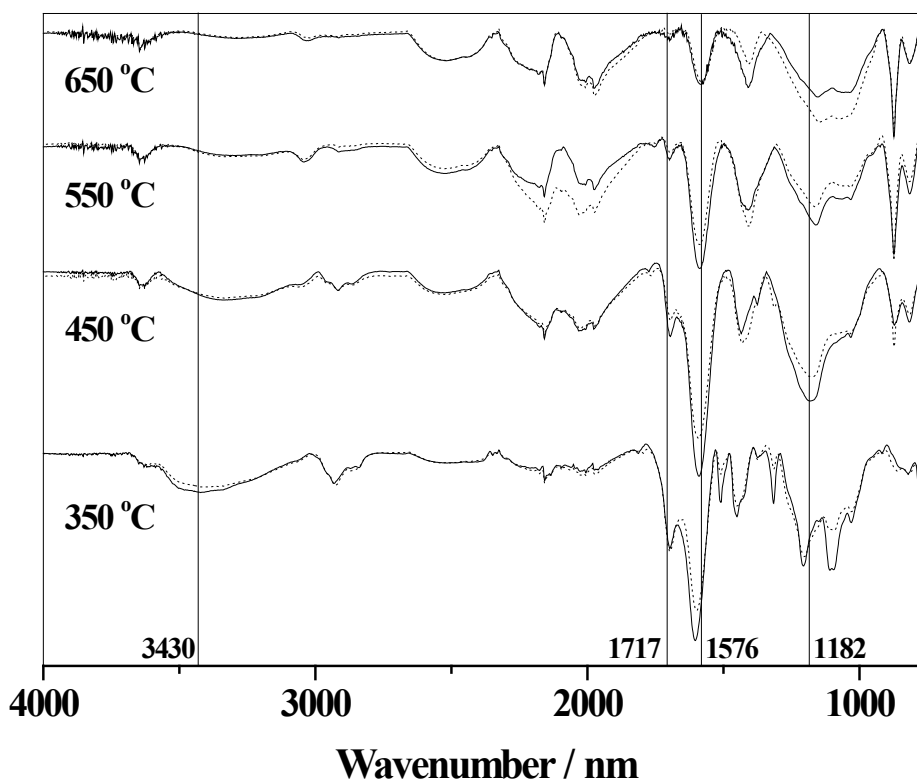


Figure SA2: FTIR spectra obtained for chars produced at the HTT used in this study.

Table SA1: proximate analyses of feed materials used in this study.

Material	Volatile Carbon %	Fixed Carbon %	Ash %
Twig (3-4 mm \varnothing) bark	75.1	21.3	3.6
Branch (10-12 mm \varnothing) bark	71.4	25.2	3.4
Trunk (~20 mm \varnothing) bark	72.3	24.0	3.7
Twig (3-4 mm \varnothing) wood	79.5	18.8	1.6
Branch (10-12 mm \varnothing) wood	83.6	15.6	0.8
Trunk (~20 mm \varnothing) wood	84.9	14.4	0.5

Table SA2: elemental analyses of chars produced in this study. Calculated average of elemental contributions of chars prepared in 100 mL min⁻¹ argon flow, at hold times of 5 and 30 min for each HTT.

HTT °C	C %#	H %#	N %#	Other %†
350	65.34 ± 1.40	5.19 ± 0.20	1.14 ± 0.08	28.33 ± 1.15
450	72.39 ± 0.14	3.30 ± 0.10	0.81 ± 0.05	23.51 ± 0.04
550	70.61 ± 1.17	2.32 ± 0.11	1.05 ± 0.06	26.04 ± 1.00
650	81.26 ± 1.89	1.87 ± 0.02	0.46 ± 0.04	16.42 ± 0.69

† Calculated from difference remaining after C, H and N accounted

Table SA3: percentage material burn off (n = 1); pH (n = 3); BET surface area (n = 1); pore volume (n = 1) and average pore diameter (n = 1) for willow biochar as a function of HTT, sweep gas flow rate and time at HTT.

HTT °C	Flow rate mL min ⁻¹	Hold time min	Percentage burn-off	Surface area m ² g ⁻¹	External surface area (S _{ext}) m ² g ⁻¹	pH	Pore volume cm ³ g ⁻¹	Average pore diameter nm
350	100	5	63.74	0.527 ± 0.026	-	7.17 ± 0.03	0.0004	29.78
350	100	10	63.73	0.468 ± 0.034	-	7.37 ± 0.04	0.0004	32.66
350	100	15	61.78	0.445 ± 0.032	-	6.68 ± 0.02	0.0004	34.62
350	100	20	62.65	0.569 ± 0.030	-	7.38 ± 0.05	0.0004	33.46
350	100	25	61.57	0.656 ± 0.030	0.030	5.58 ± 0.04	0.0003	31.13
350	100	30	62.22	0.655 ± 0.027	0.084	5.73 ± 0.03	0.0003	34.16
350	500	5	63.08	0.403 ± 0.033	-	7.42 ± 0.04	0.0005	34.16
350	500	5	62.99	0.358 ± 0.032	-	7.39 ± 0.04	0.0004	34.21
350	500	10	63.59	0.519 ± 0.032	-	7.61 ± 0.05	0.0004	31.13
350	500	15	64.49	0.739 ± 0.032	0.140	7.61 ± 0.06	0.0003	30.58
350	500	20	64.66	0.749 ± 0.035	0.045	7.52 ± 0.07	0.0004	31.30
350	500	25	64.17	0.808 ± 0.032	0.165	7.33 ± 0.03	0.0004	31.16
350	500	30	64.58	0.740 ± 0.032	0.052	7.16 ± 0.05	0.0004	31.17
350	500	30	64.27	0.897 ± 0.056	0.076	7.06 ± 0.06	0.0006	32.01
450	100	5	70.99	0.977 ± 0.062	-	8.41 ± 0.06	0.0011	16.67
450	100	10	69.86	0.796 ± 0.049	-	8.42 ± 0.04	0.0008	19.19
450	100	15	72.18	6.217 ± 0.138	2.164	9.42 ± 0.05	0.0021	13.43
450	100	20	71.63	8.645 ± 0.221	2.517	9.70 ± 0.04	0.0032	16.38
450	100	25	71.97	6.911 ± 0.196	2.036	9.11 ± 0.07	0.0037	16.56
450	100	30	70.97	1.843 ± 0.069	0.263	7.73 ± 0.03	0.0029	13.38
450	500	5	71.63	2.268 ± 0.079	0.253	9.17 ± 0.05	0.0011	15.49
450	500	5	71.24	2.546 ± 0.079	0.270	9.26 ± 0.04	0.0012	16.26
450	500	10	74.92	2.594 ± 0.091	0.407	9.34 ± 0.06	0.0012	14.71

450	500	15	71.53	3.872 ± 0.138	0.380	9.56 ± 0.05	0.0019	12.22
450	500	20	71.60	4.693 ± 1.244	1.078	8.57 ± 0.05	0.0019	13.10
450	500	25	71.98	5.934 ± 0.129	1.608	9.17 ± 0.04	0.0022	18.38
450	500	30	73.18	5.918 ± 0.147	1.342	9.19 ± 0.09	0.0024	19.82
450	500	30	74.55	6.589 ± 0.112	1.526	9.21 ± 0.06	0.0026	20.18
550	100	5	74.22	175.4 ± 4.5	40.466	10.47 ± 0.10	0.0695	3.83
550	100	10	74.42	213.4 ± 5.5	47.927	9.63 ± 0.06	0.0873	3.79
550	100	15	74.42	210.3 ± 5.3	48.542	9.65 ± 0.05	0.0864	3.91
550	100	20	74.44	209.3 ± 5.5	45.922	9.23 ± 0.08	0.0862	3.94
550	100	25	74.75	206.9 ± 5.1	41.749	9.63 ± 0.10	0.0889	3.89
550	100	30	75.09	206.2 ± 4.7	42.476	9.70 ± 0.06	0.0901	3.83
550	500	5	74.39	208.5 ± 5.6	44.254	9.55 ± 0.05	0.0834	3.79
550	500	5	75.13	206.5 ± 6.0	46.550	9.61 ± 0.06	0.0812	3.87
550	500	10	74.73	217.5 ± 5.3	43.965	9.88 ± 0.04	0.0965	3.64
550	500	15	75.30	221.2 ± 5.3	42.879	9.48 ± 0.06	0.0932	3.87
550	500	20	75.66	240.4 ± 5.9	54.003	9.58 ± 0.05	0.0991	3.56
550	500	25	75.42	227.0 ± 5.6	46.574	9.72 ± 0.07	0.0965	3.65
550	500	30	74.23	211.7 ± 5.6	42.303	10.02 ± 0.09	0.0872	3.93
550	500	30	75.64	215.4 ± 5.7	43.256	10.09 ± 0.08	0.0894	3.98
650	100	5	75.76	200.1 ± 5.3	35.226	10.89 ± 0.12	0.0895	4.44
650	100	10	75.40	196.8 ± 5.4	29.153	11.33 ± 0.08	0.0863	5.83
650	100	15	76.22	205.1 ± 5.6	32.156	11.38 ± 0.11	0.0850	4.51
650	100	20	77.02	233.9 ± 6.3	34.432	11.49 ± 0.10	0.1032	4.91
650	100	25	76.84	218.8 ± 5.2	36.145	11.42 ± 0.09	0.0895	4.98
650	100	30	75.96	188.4 ± 5.0	35.743	11.45 ± 0.06	0.0862	6.12
650	500	5	75.79	247.4 ± 6.6	35.946	11.08 ± 0.06	0.1090	4.59
650	500	5	76.00	244.5 ± 5.8	36.798	11.12 ± 0.09	0.1054	4.89

650	500	10	76.06	242.6 ± 6.3	37.219	11.26 ± 0.08	0.1063	4.71
650	500	15	75.76	243.6 ± 4.3	37.125	11.45 ± 0.12	0.1056	5.12
650	500	20	75.14	226.0 ± 4.6	26.610	11.61 ± 0.10	0.0910	5.23
650	500	25	76.00	234.4 ± 5.8	28.410	11.58 ± 0.09	0.0962	5.47
650	500	30	76.78	240.7 ± 6.2	29.266	11.46 ± 0.11	0.1062	5.02
650	500	30	76.42	239.6 ± 6.1	28.989	11.51 ± 0.09	0.0999	5.09