

Supporting Information

For

Bio-cleaning improves mechanical properties of lignin-based carbon fibers

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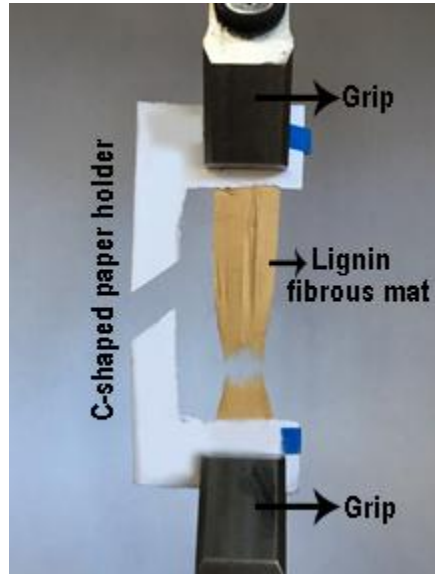


Figure S-1. Tensile Sample

Table S-1. Average fiber diameters and mechanical properties of electrospun lignin fibers at 22 wt% total solid concentration (n=10)

PEO MW (kDa)	Lignin /PEO	Electric Field (kV/m)	Spinning Behavior	Fiber Morphology	Fiber Diameter (nm)	Elastic Modulus (MPa)	Tensile Strength (MPa)	Strain at Failure (%)
1000	95/5	50	Uniform	Bead-free, no fusion	1000.48±97.48	229.79±69.21	2.08±0.80	15.39±7.20
		60	Uniform	Bead-free, no fusion	863.47±113.14	226.83±67.16	2.29±0.46	21.99±7.90
		70	Spitting	Bead-free, no fusion	749.85±102.64	111.30±38.79	1.26±0.46	12.33±3.64
	96/4	50	Uniform	Bead-free, no fusion	924.51±103.30	177.87±49.64	2.12±0.35	14.77±5.58
		60	Uniform	Bead-free, no fusion	840.95±102.26	182.08±52.73	2.29±0.34	13.49±4.34
		70	Spitting	Bead-free, no fusion	669.59±87.69	87.11±31.71	1.59±0.64	9.48±2.60
	97/3	50	Uniform	Bead-free, no fusion	721.45±89.28	201.56±55.27	2.43±0.67	10.77±4.37
		60	Uniform	BOAS, no fusion	718.09±91.25	194.59±65.85	2.54±0.80	9.22±2.15
		70	Uniform	bead-free, no fusion	543.86±103.58	121.64±36.70	1.64±0.46	9.50±1.75
2000	95/5	50	Uniform	BOAS, no fusion	714.36±103.65	167.53±45.82	2.10±0.70	14.28±4.87
		60	Uniform	Occasional beads, no fusion	741.10±102.90	175.11±56.61	2.16±0.62	14.56±5.13
		70	Uniform	Occasional beads, no fusion	699.23±90.10	173.62±58.62	1.79±0.26	13.96±5.68
	96/4	50	Uniform	Bead-free, no fusion	995.82±104.04	192.75±63.11	2.21±0.62	15.87±6.59
		60	Spitting	Bead-free, no fusion	901.54±115.58	124.26±38.84	1.40±0.37	13.67±2.53
		70	Spitting	Occasional bead, lumps, no fusion	569.31±88.18	229.35±60.42	3.66±0.74	13.92±4.89
	97/3	50	Uniform	Bead-free, no fusion	1032.47±140.37	110.71±28.98	1.47±0.40	20.09±6.36

		60	Uniform	Mostly bead-free, some fusion	961.74±183.26	93.02±25.90	1.27±0.35	13.82±3.23
		70	Spitting	Bead-free fiber, no fusion	778.89±82.65	112.21±40.73	1.60±0.47	13.40±4.34
5000	95/5	50	Uniform	Bead-free fiber, no fusion	722.42±93.92	130.88±35.53	2.26±0.40	14.71±3.87
		60	Uniform	Bead-free fiber, no fusion	710.23±85.50	172.32±46.88	2.70±0.85	15.42±6.89
		70	Uniform	BOAS, no fusion	584.93±99.34	139.66±24.80	2.31±0.45	12.04±0.47
	96/4	50	Uniform	Bead-free fiber, no fusion	829.21±122.11	170.16±51.54	2.01±0.56	12.90±8.13
		60	Uniform	Bead-free fiber, a little fusion	801.68±180.02	170.93±62.89	2.04±0.52	19.23±6.31
		70	Uniform	BOAS, a little fusion	665.41±89.13	100.83±72.84	1.11±0.46	18.36±6.46
	97/3	50	Uniform	Bead-free fiber, no fusion	971.57±118.03	155.77±38.86	2.51±0.68	19.34±6.72
		60	Spitting	Bead-free fiber, fusion	880.11±97.29	76.53±26.75	0.84±0.29	8.79±2.61
		70	Spitting	Mostly bead-free, some fusion	867.48±121.11	72.30±25.80	1.12±0.30	10.95±3.80

Table S-2. Average fiber diameters and mechanical properties of electrospun lignin fibers at 30 wt% total solid concentration (n=10).

PEO MW (kDa)	Lignin /PEO	Electric Field (kV/m)	Diameter (nm)	Morphology	Observations	Tensile Strength (MPa)	Elastic Modulus (MPa)	Strain at Failure (%)
1000	99.5/0.5	50	1327.31±217.78	Bead-free, no fusion, little ribbon	Uniform	1.63±0.47	185.73±33.91	24.13±2.93
		60	1335.10±251.83	Bead-free, no fusion, little ribbon	Uniform	1.64±0.31	245.54±78.52	15.26±6.44
		70	1190.89±219.95	Bead-free, no fusion, little ribbon	Uniform	1.74±0.74	258.91±97.89	15.74±3.80
	99.75/0.25	50	1334.81±229.69	Bead-free, no fusion, little ribbon	Uniform	1.35±0.17	91.46±33.34	30.17±4.46
		60	1276.09±192.62	Bead-free, no fusion, little ribbon	Uniform	1.44±0.58	99.76±36.01	26.94±6.45
		70	1202.89±194.93	Bead-free, no fusion, little ribbon	Uniform	2.19±0.63	237.95±100.88	24.30±5.10

Table S-3. Average fiber diameters and mechanical properties of electrospun lignin fibers at 35 wt% total solid concentration (n=10).

PEO Mv (kDa)	PEO/KL A	Electric Field (kV/m)	Diameter (nm)	Morphology	Observations	Tensile Strength (MPa)	Elastic Modulus (MPa)	Strain at Failure (%)
1000	0.5/99.5	50	1901.02±391.1 1	Bead-free, no fusion, ribbon-like	Uniform	1.59±0.53	235.41±79.13	18.46±7.89
		60	1842.56±332.2 5	Bead-free, no fusion, ribbon-like	Uniform	0.77±0.39	142.45±59.85	9.56±2.59
		70	1787.68±349.8 3	Bead-free, no fusion, ribbon-like	Uniform	0.42±0.17	97.49±47.26	8.70±1.91
	0.25/99.75	50	1573.16±276.8 1	Bead-free, no fusion, little ribbon	Uniform	1.89±0.21	235.83±38.85	>40
		60	1360.58±238.6 3	Bead-free, no fusion, little ribbon	Uniform	1.97±0.48	241.88±75.97	>40
		70	1250.26±203.2 2	Bead-free, no fusion, little ribbon	Uniform	2.05±0.86	177.45±66.98	26.06±6.27
	0.1/99.9	50	1520.30±219.5 9	Bead-free, no fusion, little ribbon	Uniform	1.74±0.36	185.79±53.65	>40
		60	1397.83±225.3 8	Bead-free, no fusion, little ribbon	Uniform	1.67±0.46	202.94±67.28	23.58±6.05
		70	1286.65±182.0 0	Bead-free, no fusion, little ribbon	Uniform	1.80±0.54	203.57±48.77	23.03±5.41
5000	0.1/99.9	50	1847.05±431.7 5	Bead-free, no fusion, little ribbon	Uniform	1.32±0.50	189.45±73.18	11.46±5.59
		60	1823.86±392.4 0	Bead-free, no fusion, little ribbon	Uniform	1.96±0.62	282.88±121.88	15.20±3.66
		70	1613.91±394.9 6	Bead-free, no fusion, little ribbon	Uniform	1.60±0.77	296.38±156.73	9.15±2.49