Optimizing Rubberwood Performance through Rapid Heated Platen Thermal Modification: A Sustainable Approach for Enhanced Dimensional Stability, Decay Resistance, and Mechanical Integrity

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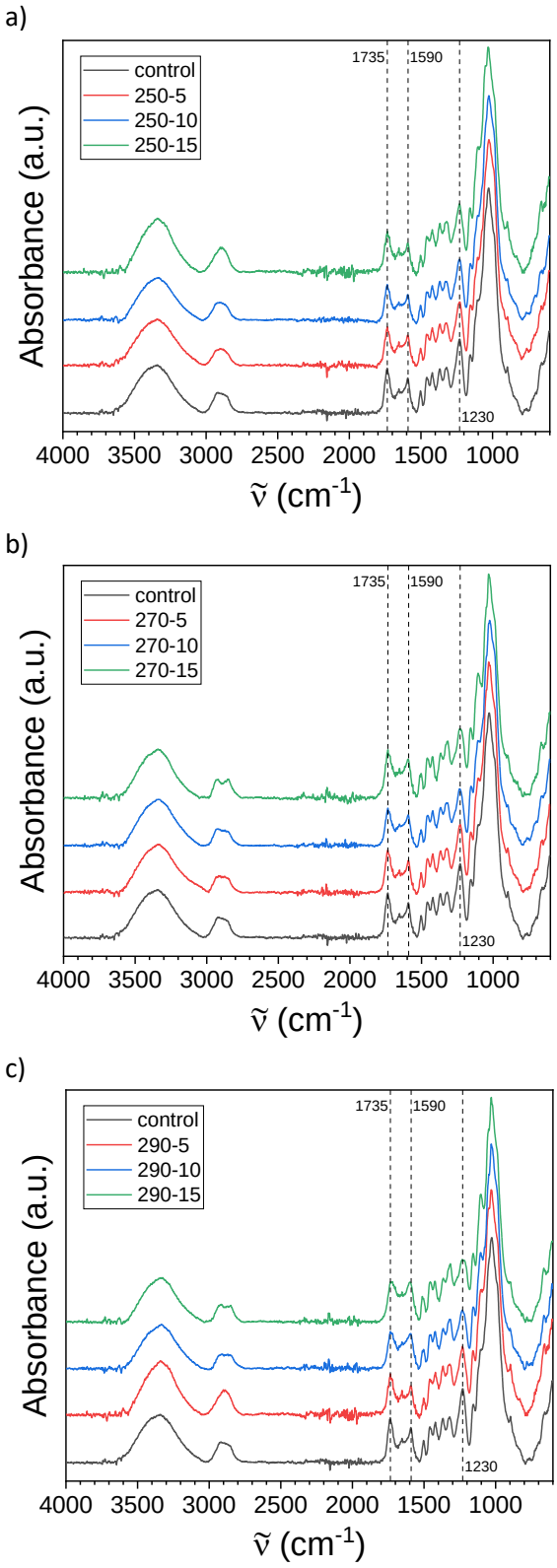

Fig. SI-1: FTIR spectra for the rubberwood samples at a) 250 °C, b) 270 °C, and c) 290 °C, from 5 to 15 min heat treatment. The control sample is shown as the black curve for comparison.

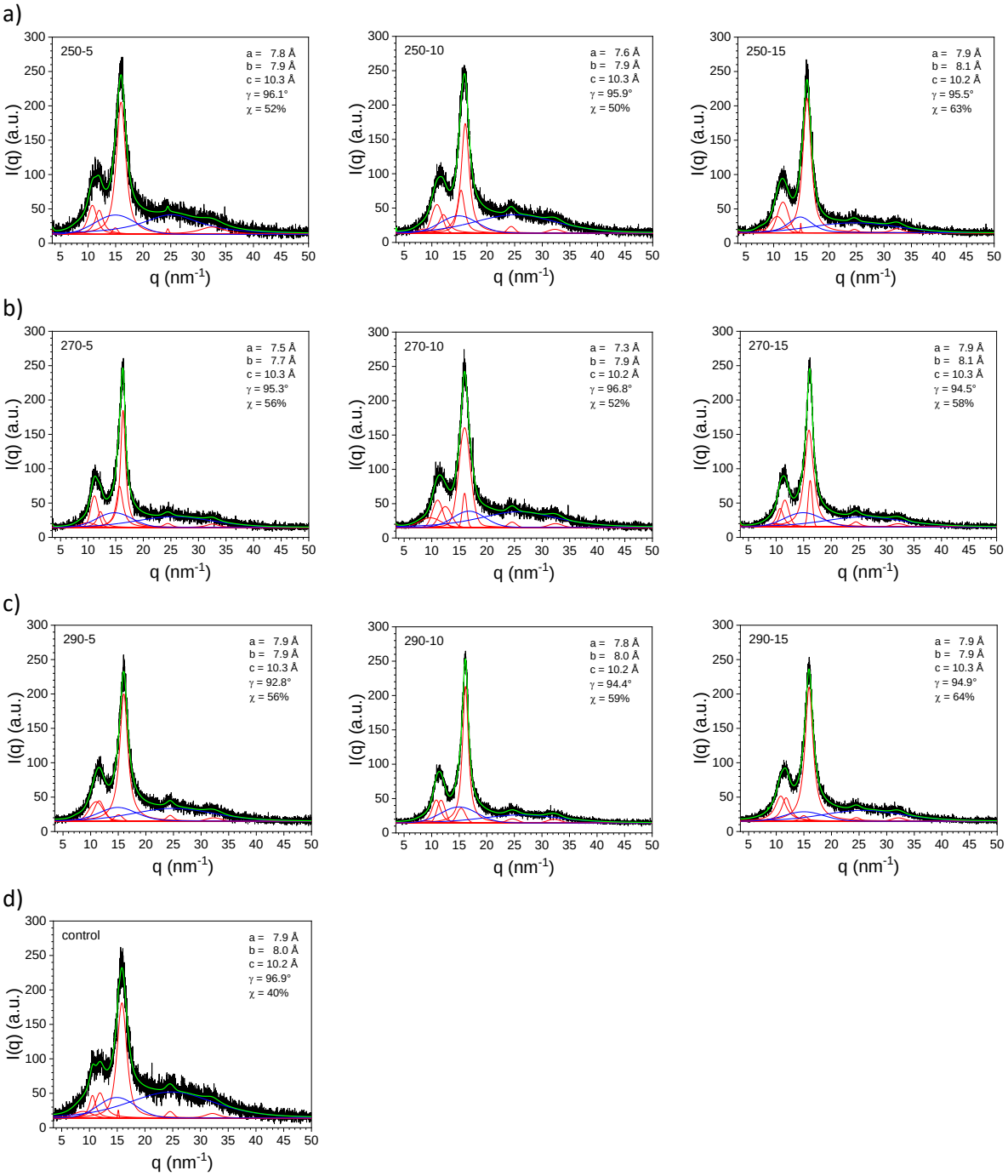

Fig. SI-2: WAXS scattering profiles with the corresponding fitting curve (green), crystalline (red) and amorphous (blue) peaks obtained by deconvolution for the rubberwood samples at a) 250 °C, b) 270 °C, and c) 290 °C, from 5 to 15 min heat treatment. The control sample is shown in d) for comparison.

Table SI-1. Lattice parameters (a, b, c and γ), and the degree of crystallinity (χ) obtained by WAXS analysis of the rubberwood samples at different temperatures and heating times

sample	t (min)	a (Å)	b (Å)	c (Å)	γ (deg)	χ (%)
control	0	7.9	8.0	10.2	96.9	40
250 °C	5	7.8	7.9	10.3	96.1	52
	10	7.6	7.9	10.3	95.9	50
	15	7.9	8.1	10.2	95.5	63
270 °C	5	7.5	7.7	10.3	95.3	56
	10	7.3	7.9	10.2	96.8	52
	15	7.9	8.1	10.3	94.5	58
290 °C	5	7.9	7.9	10.3	92.8	56
	10	7.8	8.0	10.2	94.4	59
	15	7.9	7.9	10.3	94.9	64

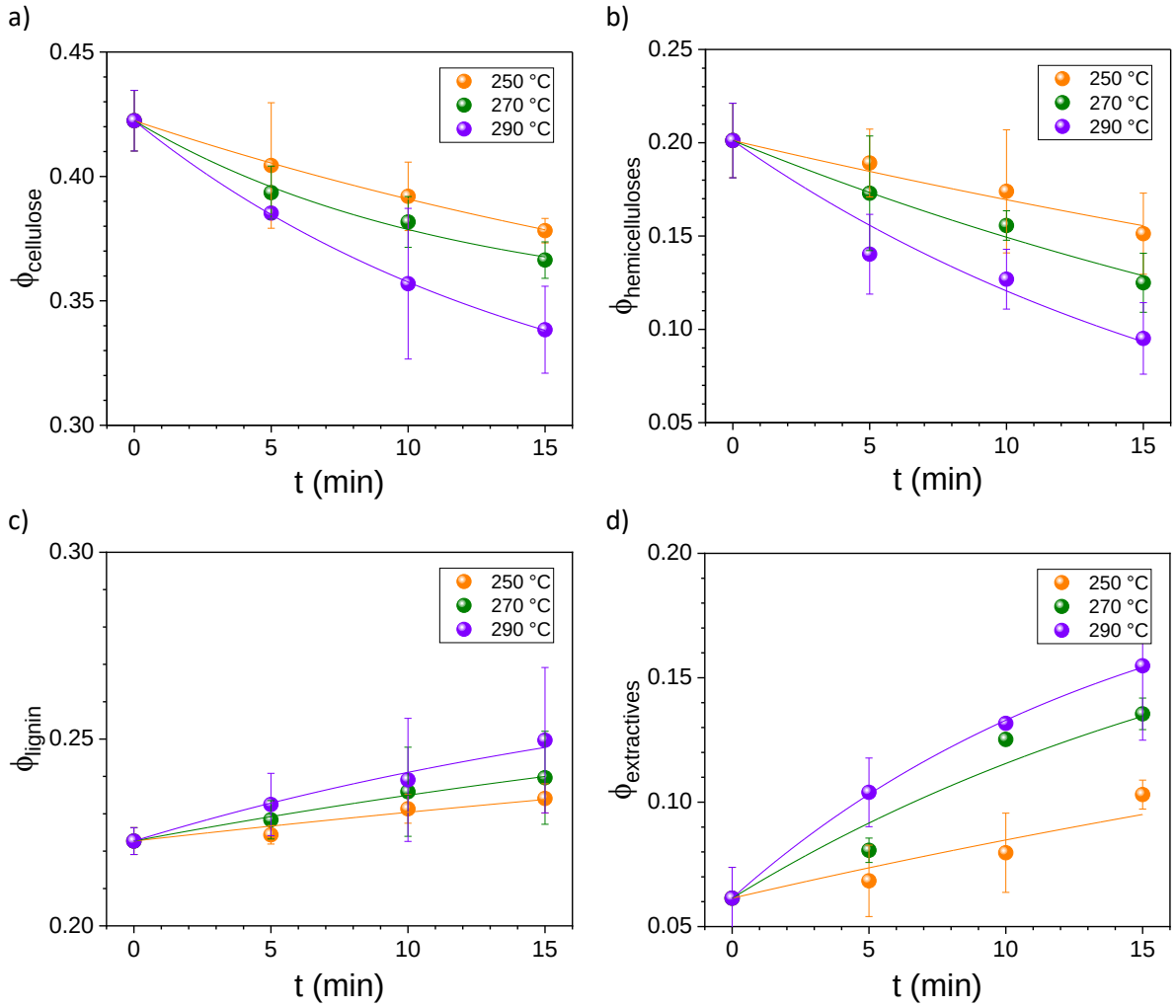

Fig. SI-3. Kinetics curves for the degradation process of (d) cellulose and (e) hemicelluloses, and kinetic curves for the increase in (c) lignin and (d) extractives content.

Table SI-2. Mass fraction (ϕ), relative ($\Delta\phi_{rel}$) and absolute ($\Delta\phi_{abs}$) mass percentage change of cellulose, hemicelluloses, lignin and extractives from the chemical analysis of the rubberwood samples at different temperatures and heating times.

		Cellulose			Hemicelluloses			Lignin			Extractives		
sample	t (min)	ϕ	$\Delta\phi_{rel}$ (%)	$\Delta\phi_{abs}$ (%)	ϕ	$\Delta\phi_{rel}$ (%)	$\Delta\phi_{abs}$ (%)	ϕ	$\Delta\phi_{rel}$ (%)	$\Delta\phi_{abs}$ (%)	ϕ	$\Delta\phi_{rel}$ (%)	$\Delta\phi_{abs}$ (%)
control		0.42			0.20			0.22			0.06		
250 °C	5	0.40	-4	-2	0.19	-6	-1	0.22	1	0	0.07	11	1
	10	0.39	-7	-3	0.17	-14	-3	0.23	4	1	0.08	30	2
	15	0.38	-10	-4	0.15	-25	-5	0.23	5	1	0.10	68	4
270 °C	5	0.39	-7	-3	0.17	-14	-3	0.23	3	1	0.08	31	2
	10	0.38	-10	-4	0.16	-23	-5	0.24	6	1	0.13	104	6
	15	0.37	-13	-6	0.12	-38	-8	0.24	8	2	0.14	121	7
290 °C	5	0.39	-9	-4	0.14	-30	-6	0.23	4	1	0.10	69	4
	10	0.36	-16	-7	0.13	-37	-7	0.24	7	2	0.13	114	7
	15	0.34	-20	-8	0.10	-53	-11	0.25	12	3	0.15	152	9

Table SI-3. Tangential, radial and volumetric drying shrinkage rate (β_w) values of the rubberwood samples from waterlogged wood to air-dried wood, with the corresponding relative decrease percentage ($\Delta\beta_w$) of the rubberwood samples at different temperatures and heating times. Note: sd is the standard deviation.

		Tangential			Radial			Volumetric		
Sample	t (min)	β_w (%)	sd	$\Delta\beta_w$ (%)	β_w (%)	sd	$\Delta\beta_w$ (%)	β_w (%)	sd	$\Delta\beta_w$ (%)
control		3.42	0.13		1.64	0.37		5.18	0.42	
250 °C	5	3.17	0.34	7	1.57	0.07	4	4.42	0.54	15
	10	3.19	0.29	7	1.54	0.27	6	4.74	0.31	8
	15	3.19	0.36	7	1.78	0.32	9	4.66	0.14	10
270 °C	5	3.19	0.50	7	1.54	0.45	6	4.31	0.48	17
	10	3.00	0.25	12	1.52	0.21	7	4.39	0.44	15
	15	2.69	0.29	21	1.61	0.42	2	4.30	0.24	17
290 °C	5	2.52	0.12	26	1.49	0.43	9	4.29	0.20	17
	10	2.30	0.23	33	1.32	0.11	20	3.66	0.14	29
	15	2.20	0.41	36	1.16	0.22	29	3.29	0.57	36

Table SI-4. Tangential, radial and volumetric drying shrinkage rate (β_{max}) values of the rubberwood samples from air-dried wood to absolute-dried wood, with the corresponding relative decrease percentage ($\Delta\beta_{max}$) of the rubberwood samples at different temperatures and heating times. Note: sd is the standard deviation.

		Tangential			Radial			Volumetric		
Sample	t (min)	β_{max} (%)	sd	$\Delta\beta_{max}$ (%)	β_{max} (%)	sd	$\Delta\beta_{max}$ (%)	β_{max} (%)	sd	$\Delta\beta_{max}$ (%)
control		5.32	0.21		2.90	0.14		8.60	0.18	
250 °C	5	5.69	0.46	7	2.85	0.27	2	8.67	0.90	1
	10	5.62	0.28	6	2.73	0.42	6	8.34	0.40	3
	15	5.23	0.48	2	3.10	0.38	7	8.32	0.59	3
270 °C	5	5.62	0.45	6	2.89	0.48	0	8.63	0.63	0
	10	5.46	0.64	3	2.58	0.47	11	8.12	0.46	6
	15	5.03	0.67	5	2.86	0.11	1	8.23	0.40	4
290 °C	5	4.86	0.28	9	2.61	0.29	10	8.57	0.54	0
	10	4.68	0.38	12	2.49	0.46	14	7.24	0.66	16
	15	3.46	0.32	35	2.08	0.34	28	5.76	0.47	33

Table SI-5. Tangential, radial and volumetric thickness swelling rate (α_w) values of the rubberwood samples from air-dried wood to waterlogged wood, with the corresponding relative decrease percentage ($\Delta\alpha_w$) of the rubberwood samples at different temperatures and heating times. Note: sd is the standard deviation.

		Tangential			Radial			Volumetric		
Sample	t (min)	α_w (%)	sd	$\Delta\alpha_w$ (%)	α_w (%)	sd	$\Delta\alpha_w$ (%)	α_w (%)	sd	$\Delta\alpha_w$ (%)
control		5.49	0.31		3.13	0.28		9.37	0.37	
250 °C	5	5.57	0.33	1	3.20	0.31	2	8.93	0.57	5
	10	5.57	0.18	1	3.15	0.29	1	8.84	0.65	6
	15	5.48	0.48	0	3.02	0.26	4	8.40	0.94	10
270 °C	5	5.54	0.37	1	3.14	0.21	0	8.86	1.00	5
	10	5.35	0.41	3	3.02	0.19	4	8.57	0.48	9
	15	5.25	0.27	4	2.83	0.14	10	8.20	0.81	12
290 °C	5	5.48	0.21	0	2.87	0.14	8	8.43	1.11	10
	10	4.66	0.22	15	2.85	0.22	9	7.83	0.91	16
	15	4.04	0.17	26	1.90	0.09	39	6.13	0.78	35

Table SI-6. Tangential, radial and volumetric thickness swelling rate (α_{max}) values of the rubberwood samples from absolute-dried wood to air-dried wood, with the corresponding relative decrease percentage ($\Delta\alpha_{max}$) of the rubberwood samples at different temperatures and heating times. Note: sd is the standard deviation.

		Tangential			Radial			Volumetric		
Sample	t (min)	α_{max} (%)	sd	$\Delta\alpha_{max}$ (%)	α_{max} (%)	sd	$\Delta\alpha_{max}$ (%)	α_{max} (%)	sd	$\Delta\alpha_{max}$ (%)
control		2.08	0.12		1.20	0.24		3.65	0.43	
250 °C	5	1.53	0.12	26	0.97	0.07	19	2.51	0.17	31
	10	1.46	0.16	30	0.97	0.10	19	2.51	0.37	31
	15	1.22	0.30	41	0.89	0.18	26	2.18	0.51	40
270 °C	5	1.43	0.30	31	0.92	0.45	23	2.43	0.45	33
	10	1.41	0.17	32	0.92	0.16	23	2.48	0.35	32
	15	1.16	0.27	44	0.84	0.15	30	2.03	0.45	44
290 °C	5	1.41	0.03	32	0.91	0.43	24	2.35	0.53	36
	10	1.26	0.16	39	0.89	0.05	26	2.14	0.16	41
	15	0.89	0.10	57	0.59	0.09	51	1.52	0.20	58

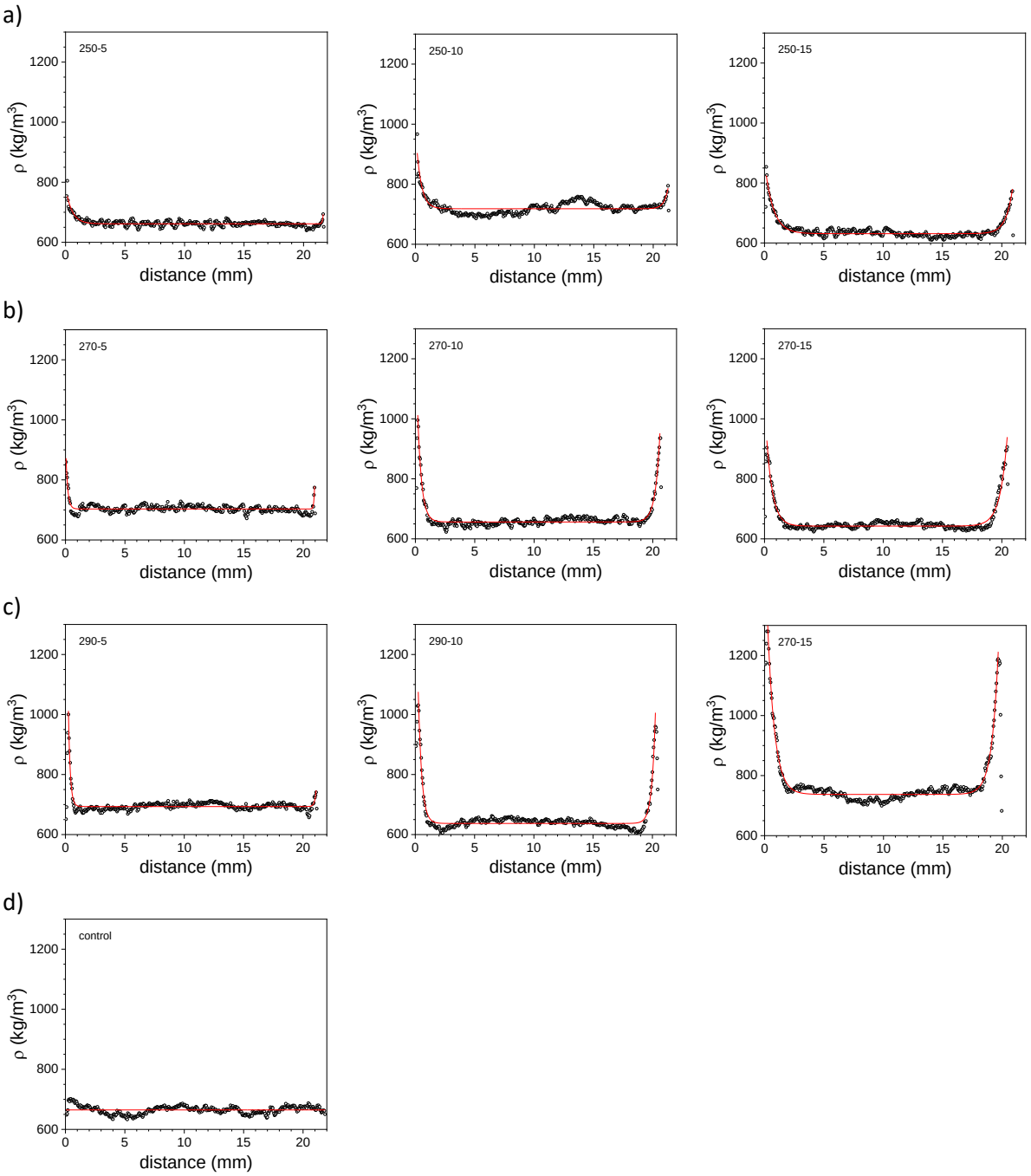

Fig. SI-4: Density profiles with the corresponding fitting curve (red) for the rubberwood samples at a) 250 °C, b) 270 °C, and c) 290 °C, from 5 to 15 min heat treatment. The control sample is shown in d) for comparison.

Table SI-7. Core density (ρ_0), density increase ($\Delta\rho$), total distance in the tangential direction (d), and deformation depth (D) from the evaluation of the density profile of the rubberwood samples at different temperatures and heating times.

sample	t (min)	ρ_0 (Kg/m^3)	$\Delta\rho$ (Kg/m^3)	d (mm)	D (mm)
control		665 ± 1		21.87 ± 0.05	
250 °C	5	662 ± 1	62 ± 6	21.50 ± 0.05	0.29 ± 0.04
	10	718 ± 1	127 ± 10	21.10 ± 0.05	0.38 ± 0.06
	15	631 ± 1	172 ± 5	20.75 ± 0.05	0.64 ± 0.03
270 °C	5	703 ± 1	122 ± 9	20.90 ± 0.05	0.11 ± 0.01
	10	656 ± 1	326 ± 7	20.40 ± 0.05	0.36 ± 0.05
	15	643 ± 1	291 ± 6	20.25 ± 0.05	0.56 ± 0.02
290 °C	5	693 ± 1	186 ± 9	20.85 ± 0.05	0.14 ± 0.02
	10	637 ± 1	404 ± 10	20.00 ± 0.05	0.29 ± 0.01
	15	737 ± 1	524 ± 9	19.40 ± 0.05	0.57 ± 0.01

Table SI-8. Modulus of elasticity (MOE), modulus of rupture (MOR), surface hardness in the tangential direction (SH-T), surface hardness in the radial direction (SH-R), screw holding power (SHP), and compressive strength (CS) parallel to grain direction of the rubberwood samples at different temperatures and heating times.

sample	t (min)	MOE (GPa)	MOR (MPa)	SH-T (kN)	SH-R (kN)	SHP (kN)	CS (MPa)
control		9242 ± 763	92 ± 4	4777 ± 236	2991 ± 227	2218 ± 139	50 ± 4
250 °C	5	8970 ± 461	83 ± 8	4041 ± 513	3165 ± 348	2163 ± 199	46 ± 4
	10	9251 ± 511	80 ± 10	4291 ± 517	3401 ± 337	2396 ± 306	49 ± 4
	15	9043 ± 384	65 ± 8	3737 ± 368	3175 ± 259	2172 ± 313	48 ± 2
270 °C	5	9283 ± 657	82 ± 7	4095 ± 446	3281 ± 329	2264 ± 83	48 ± 4
	10	9129 ± 451	72 ± 6	3967 ± 454	3131 ± 367	1922 ± 274	47 ± 4
	15	9071 ± 414	63 ± 9	3926 ± 491	3029 ± 247	1864 ± 251	45 ± 3
290 °C	5	9270 ± 256	64 ± 8	4072 ± 391	3198 ± 200	2063 ± 349	45 ± 4
	10	8517 ± 450	55 ± 7	3891 ± 479	3178 ± 283	1840 ± 144	43 ± 6
	15	8219 ± 518	48 ± 7	3708 ± 512	3048 ± 370	1533 ± 148	40 ± 6

Table SI-9. The color characteristics (L*, a*, b* and ΔE*) of the rubberwood samples at different temperatures and heating times.

sample	t (min)	L*	a*	b*	ΔE*
control		73 ± 3	9 ± 1	21 ± 1	
250 °C	5	62 ± 2	11 ± 1	20 ± 1	9 ± 3
	10	59 ± 3	11 ± 1	19 ± 1	15 ± 3
	15	46 ± 8	11 ± 1	16 ± 3	28 ± 9
270 °C	5	58 ± 4	11 ± 1	20 ± 2	13 ± 3
	10	56 ± 3	12 ± 1	20 ± 3	17 ± 2
	15	41 ± 5	12 ± 2	14 ± 3	33 ± 5
290 °C	5	59 ± 4	11 ± 1	20 ± 1	15 ± 2
	10	49 ± 6	12 ± 1	18 ± 2	24 ± 2
	15	37 ± 3	15 ± 2	12 ± 1	54 ± 5

Table SI-10. Changes in crystallinity (χ), maximum volumetric drying shrinkage rate (β_{maxV}), maximum volumetric thickness swelling rate ($\alpha_{w\ maxV}$), modulus of elasticity (MOE), modulus of rupture (MOR), surface hardness (SH-T and SH-R), screw holding power (SHP), compressive strength (CS), mass loss rate of white-rot fungi (MLW), and mass loss rate of brown-rot fungi (MLB) of the rubberwood samples at different temperatures and heating times compared with the control sample.

T (ºC)	t (min)	χ (%)	β_{maxV} (%)	α_{maxV} (%)	MOE (%)	MOR (%)	SH-T (%)	SH-R (%)	SHP (%)	CS (%)	MLW (%)	MLB (%)
250	5	30	1	-31	-3	-9	-15	6	-2	-7	-25	-32
	10	24	-3	-31	0	-13	-10	14	8	-2	-35	-34
	15	56	-3	-40	-2	-29	-22	6	-2	-3	-39	-35
270	5	40	0	-33	0	-10	-14	10	2	-4	-30	-33
	10	30	-6	-32	-1	-21	-17	5	-13	-5	-39	-36
	15	44	-4	-44	-2	-31	-18	1	-16	-10	-26	-33
290	5	40	0	-36	0	-30	-15	7	-7	-9	-35	-37
	10	46	-16	-41	-8	-40	-19	6	-17	-13	-29	-34
	15	60	-33	-58	-11	-47	-22	2	-31	-20	-22	-30