Final REPORT

Durability of thermally modified Norway spruce (*Picea abies*) against wood-destroying basidiomycetes

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1 Test material

Thermally modified Norway spruce (*Picea abies*) sections (in the following: Norway spruce TMT) were provided by Swero GmbH & CO. KG (Wangen i. A., Germany) in September 2020. According to the supplier, the material had been treated in a steam-heat process in three batches, which had been labeled as SP2804, SP 0605, and SP 0906. The dimensions of the sections were approx. 115-145 (width) x 45 (thickness) x 600 (length) mm³.

2 Natural durability against basidiomycetes (CEN/TS 15083-1, 2005)

Material: The specimens were 25 × 15 × 50 (long.) mm³ and had an annual ring orientation of approx. 45°. The specimens were taken randomly from 30 sections per batch. Virulence control specimens for the brown rot fungi were made from Scots pine sapwood (*Pinus sylvestris*). In addition, wirulence control specimens were made from European beech (*Fagus sylvatica*).

Leaching: All test specimens were leached according to EN 84 (1997). The specimens were impregnated with distilled water. Subsequently, they were submerged in distilled water, which was changed every second day over a period of 14 days. Finally, the specimens were subsequently dried at 40, 60, 80 and 103°C for 24 h, weighed to the nearest 0.001 g, and conditioned at 20 °C and 65 % RH until constant weight.

Testing: After leaching and conditioning, the specimens were used to perform a durability test according to CEN/TS 15083-1 (2005) using the following test fungi:

Brown rot fungi:

- *Coniophora puteana* = (Schum.:Fr.) P. Karsten BAM Ebw. 15 (*C.p.*)
- *Rhodonia placenta = (Fr.) Niemelä, K.H. Larsson & Schigel (R.p.)*

The specimens were placed in culture vessels (i.e. Kolle flasks) which contained sterilized malt extract agar nutrient medium, which was inoculated with one of the fungal species. All culture vessels were placed in a culture room (22 °C/70 % RH) for a period of 16 weeks. After incubation, the specimens were removed from the culture vessels, cleaned and weighed to the nearest 0.001 g directly after harvesting and after drying at 103 °C for 24 h. The mass loss (ML) of each individual specimen due to fungal decay

was calculated based on its oven-dry mass before and after incubation, while the moisture content (MC) of the specimens was calculated based on the mass after harvesting and after oven-drying (see equations 1 and 2).

$$ML = \frac{m_{i,0} - m_{f,0}}{m_{i,0}} \cdot 100 \quad (1)$$

ML *mass loss [%]*

$m_{i,0}$ *oven-dry mass before incubation [g]*

$m_{f,0}$ *oven-dry mass after incubation [g]*

$$MC = \frac{m_f - m_{f,0}}{m_{f,0}} \cdot 100 \quad (2)$$

MC *wood moisture content [%]*

m_f *wet mass after incubation [g]*

$m_{f,0}$ *oven-dry mass after incubation [g]*

The durability of the tested wood was classified according to CEN/TS 15083-1 (2005) as summarized in Table 1.

Table 1: Durability classification according to CEN/TS 15083-1 (2005).

Durability class	**Description**	**Median mass loss [%]**
1	Very durable	≤ 5
2	Durable	> 5 to ≤ 10
3	Moderately durable	10 to ≥ 15
4	Slightly durable	15 to ≥ 30
5	Not durable	> 30

Results: Mass loss and MC after incubation are summarized in Table 2, Table 3, Figure 1, and Figure 2. Required minimum ML was achieved by all test fungi.

Thermally modified Norway spruce (Norway spruce TMT) was assigned to DC 1.

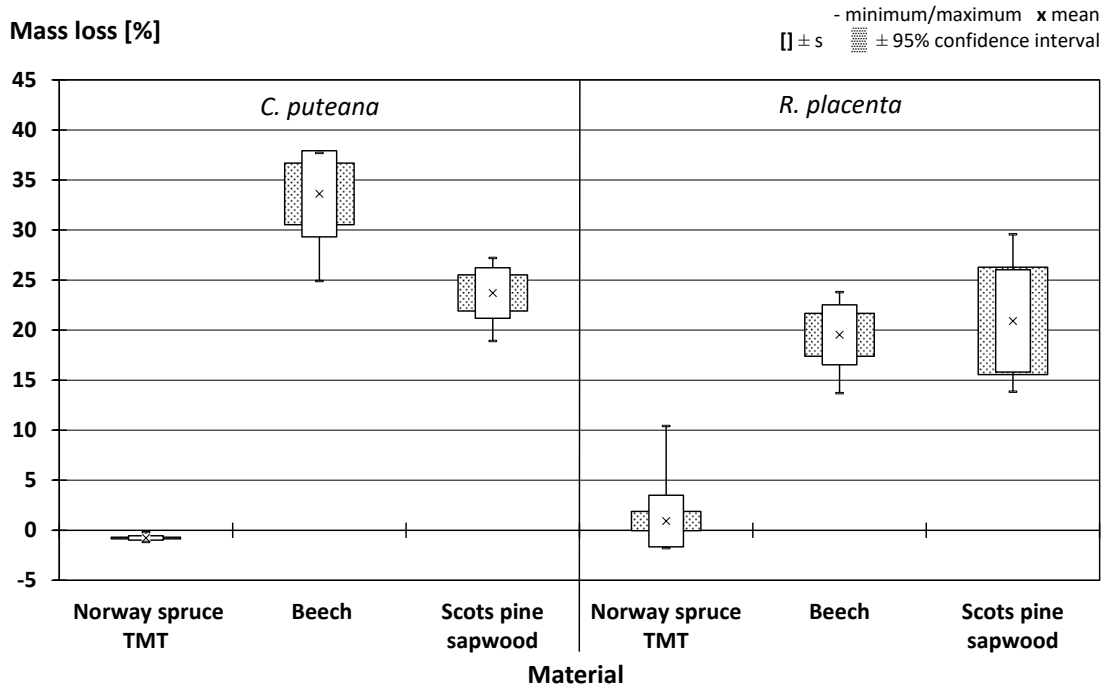

Figure 1: Mass loss of thermally modified Norway spruce (Norway spruce TMT) and virulence species after 16 weeks of incubation.

Table 2: Mass loss (ML) and wood moisture content (MC) of thermally modified Norway spruce (Norway spruce TMT) and virulence control specimens after incubation with the brown rot fungus *Coniophora puteana.*

Material	Number of replicates	Median ML [%]	Mean ML [%]	SD ML [%]	Mean final MC [%]	DC
Norway spruce TMT	30	-0.80	-0.77	0.21	66.01	1
Scots pine sap-wood	10	23.79	23.71	2.52	75.00	4
Beech	10	34.98	33.61	4.30	98.14	5

Table 3: Mass loss (ML) and wood moisture content (MC) of thermally modified Norway spruce (Norway spruce TMT) and virulence control specimens after incubation with the brown rot fungus *Rhodonia placenta.*

Material	Number of replicates	Median ML [%]	Mean ML [%]	SD ML [%]	Mean final MC [%]	DC
Norway spruce TMT	30	0.04	0.92	2.58	48.12	1
Scots pine sap-wood	6	20.00	20.92	5.11	62.38	4
Beech	10	19.95	19.53	3.00	84.19	4

Note: Four Scots pine sapwood virulence control specimens showed mass loss less than 3 % and a wood moisture content after incubation abiove 100 % and were therefore excluded.

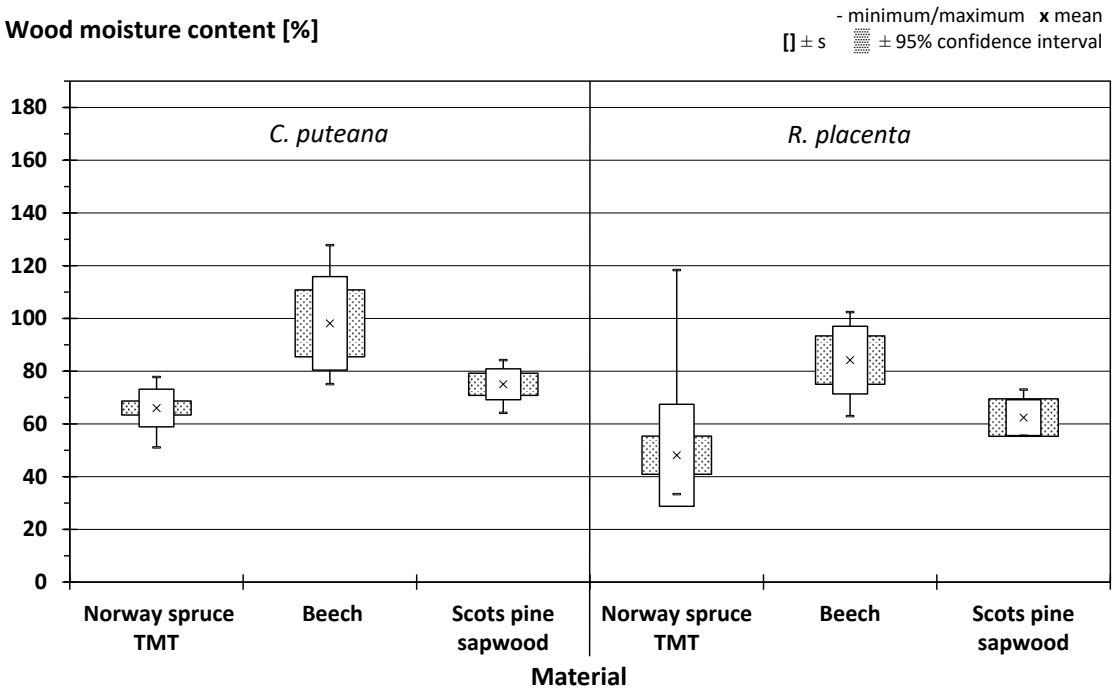

Figure 2: Wood moisture content (MC) of thermally modified Norway spruce (Norway spruce TMT) and virulence species after 16 weeks of incubation.

Literature

CEN/TS 15083-1 (2005) Durability of wood and wood-based products - Determination of the natural durability of solid wood against wood-destroying fungi, test methods - Part 1: Basidiomycetes. European Committee for Standardization (CEN), Brussels, Belgium.

EN 84 (1997) Wood preservatives - Accelerated ageing of treated wood prior to biological testing - Leaching procedure. European Committee for Standardization (CEN), Brussels, Belgium.

Appendix

Appendix A: Individual data for durability tests

Table A1: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Coniophora puteana* – Norway spruce TMT.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
NS 31	7.84	13.97	7.89	-0.62	77.03	1
NS 32	7.23	12.64	7.27	-0.53	73.96	1
NS 33	7.26	12.65	7.32	-0.87	72.89	1
NS 34	7.20	12.37	7.27	-0.94	70.21	1
NS 35	7.27	12.86	7.36	-1.17	74.76	1
NS 36	7.26	12.07	7.33	-0.98	64.67	1
NS 37	7.26	12.23	7.34	-1.02	66.75	1
NS 38	7.27	11.95	7.35	-1.06	62.65	1
NS 39	7.18	11.57	7.24	-0.91	59.83	1
NS 40	7.85	11.94	7.90	-0.69	51.09	1
NS 41	7.19	11.99	7.25	-0.93	65.28	1
NS 42	7.29	11.64	7.36	-0.91	58.15	1
NS 43	7.20	12.12	7.25	-0.60	67.20	1
NS 44	7.07	11.77	7.11	-0.48	65.59	1
NS 45	7.56	12.61	7.62	-0.69	65.53	1
NS 46	7.07	11.51	7.13	-0.85	61.31	1
NS 47	7.33	11.84	7.40	-0.90	59.97	1
NS 48	8.37	13.06	8.44	-0.85	54.81	1
NS 49	7.27	12.31	7.34	-0.88	67.81	1
NS 50	7.30	11.45	7.38	-1.04	55.09	1
NS 51	7.40	12.93	7.45	-0.68	73.66	1
NS 52	7.62	12.23	7.66	-0.59	59.67	1
NS 53	7.80	13.61	7.81	-0.19	74.26	1
NS 54	7.34	13.13	7.39	-0.63	77.75	1
NS 55	7.62	12.76	7.66	-0.58	66.60	1
NS 56	7.53	13.36	7.58	-0.69	76.24	1
NS 57	7.93	12.72	7.98	-0.61	59.45	1
NS 58	7.61	13.10	7.65	-0.51	71.25	1
NS 59	7.72	12.92	7.79	-0.92	65.76	1
NS 60	7.75	12.58	7.81	-0.75	61.13	1

Table A2: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Rhodonia placenta* – Norway spruce TMT.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
NS 1	7.39	10.77	7.36	0.39	46.25	1
NS 2	7.20	10.44	7.20	-0.06	44.99	1
NS 3	7.35	10.44	7.27	1.07	43.63	1
NS 4	7.20	10.10	7.17	0.44	40.83	1
NS 5	7.05	10.23	7.07	-0.27	44.64	1
NS 6	7.19	10.09	7.15	0.53	41.09	1
NS 7	7.28	10.55	7.28	-0.08	44.87	1
NS 8	7.20	10.40	7.22	-0.32	44.02	1
NS 9	7.17	10.25	7.15	0.31	43.32	1
NS 10	7.57	10.22	7.52	0.62	35.89	1
NS 11	7.56	10.80	7.56	0.11	42.93	1
NS 12	7.31	10.08	7.35	-0.45	37.24	1
NS 13	7.29	15.75	7.41	-1.72	112.41	1
NS 14	7.31	16.24	7.44	-1.78	118.33	1
NS 15	7.30	10.36	7.34	-0.55	41.15	1
NS 16	7.64	10.86	7.69	-0.62	41.33	1
NS 17	7.51	10.37	7.36	2.01	40.90	1
NS 18	7.17	9.74	6.99	2.48	39.28	1
NS 19	7.47	10.39	7.32	2.13	42.05	1
NS 20	7.36	10.39	7.37	-0.18	40.96	1
NS 21	7.56	11.58	7.43	1.79	55.94	1
NS 22	7.60	10.74	7.61	-0.24	41.06	1
NS 23	7.61	11.23	7.65	-0.50	46.87	1
NS 24	7.96	10.16	7.55	5.17	34.58	2
NS 25	7.55	11.03	7.59	-0.46	33.93	1
NS 26	7.42	9.21	6.87	7.37	60.49	2
NS 27	7.60	11.17	7.60	-0.03	46.90	1
NS 28	7.65	11.16	7.67	-0.27	45.52	1
NS 29	7.65	9.14	6.86	10.42	33.36	3
NS 30	7.52	11.91	7.50	0.21	58.78	1

Table A3: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Coniophora puteana* – Scots pine sapwood.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
SP 11	12.26	16.86	9.37	23.59	79.96	4
SP 12	10.98	14.94	8.43	23.27	77.33	4
SP 13	10.55	14.04	8.55	18.92	64.21	4
SP 14	10.88	14.33	8.08	25.75	77.29	4
SP 15	11.12	14.50	8.09	27.21	79.10	4
SP 16	10.66	13.70	8.10	23.98	69.13	4
SP 17	9.73	13.38	7.27	25.35	84.19	4
SP 18	11.25	14.80	8.60	23.57	72.09	4
SP 19	12.43	16.99	9.92	20.18	71.27	4
SP 20	11.27	14.77	8.42	25.30	75.47	4

Table A4: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Rhodonia placenta* – Scots pine sapwood.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
SP 1	12.08	25.05	11.78	2.50	112.65	n.a.*
SP 2	11.24	24.86	11.05	1.68	125.05	n.a.*
SP 3	11.12	14.10	8.92	19.80	58.07	4
SP 4	12.16	16.33	9.44	22.39	73.04	4
SP 5	10.22	23.89	10.00	2.19	138.86	n.a.*
SP 6	9.75	23.90	9.58	1.77	149.59	n.a.*
SP 7	12.31	16.52	9.83	20.18	68.16	4
SP 8	10.56	14.64	9.10	13.85	60.91	4
SP 9	10.15	11.11	7.15	29.58	55.49	4
SP 10	12.11	15.42	9.73	19.69	58.59	4

*Excluded from calculations and durability classification

Table A5: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Coniophora puteana* – Beech.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
B 11	11.59	15.84	7.54	34.94	110.08	5
B 12	12.85	16.38	9.36	27.21	75.08	4
B 13	11.65	16.92	7.43	36.26	127.79	5
B 14	12.29	15.98	8.32	32.31	92.08	5
B 15	13.20	17.72	9.92	24.90	78.70	4
B 16	12.11	15.25	7.54	37.70	102.20	5
B 17	11.98	15.01	7.83	34.62	91.62	5
B 18	12.27	15.68	7.97	35.02	96.70	5
B 19	11.63	16.64	7.47	35.74	122.73	5
B 20	11.48	13.24	7.18	37.45	84.40	5

Table A6: Individual data for mass loss (ML), moisture content (MC) and durability class (DC) in durability tests against *Rhodonia placenta* – Beech.

ID	Oven-dry mass before incubation [g]	Wet mass after incubation [g]	Oven-dry mass after incubation [g]	ML [%]	MC [%]	DC
B 1	12.29	20.29	10.14	17.48	100.01	4
B 2	11.60	16.50	9.34	19.44	76.59	4
B 3	11.12	13.80	8.47	23.79	62.92	4
B 4	11.64	15.61	8.98	22.91	73.92	4
B 5	11.60	17.62	9.25	20.28	90.49	4
B 6	13.39	21.32	11.55	13.70	84.56	3
B 7	12.39	16.69	9.75	21.26	71.15	4
B 8	12.21	20.63	10.19	16.54	102.43	4
B 9	11.80	17.88	9.48	19.66	88.73	4
B 10	11.55	17.61	9.22	20.23	91.08	4