

Investigation of the influence of two different thermal treatment processes on the change of various material properties of spruce resonance wood (*Picea abies* (L.) KARST.)

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Background

Due to various property changes such as low moisture sorption, reduced reaction to climatic variability or improved elastic properties different thermal treatment processes also offer its application in the field of instrument making for the treatment of tonewood. In recent years, these processes have become more important in the search for tropical wood alternatives, but are also recommended for use in restoration for artificial wood aging (Pfriem *et al.*, 2008, Krüger *et al.*, 2020). In previous studies investigations on property changes due to thermal treatment were presented, in which mostly changes in temperature or time were made but primarily using a single process. Therefore, in this study, the influence of two different processes but at the same treatment temperature, a thermo-vacuum process and a process that takes place in a reduced-oxygen atmosphere on various property changes of spruce resonance wood was investigated.

Keywords: thermal modification, resonance wood, CIELab, acoustic properties.

Experimental

The subject of the present study was spruce resonance wood (*Picea abies* (L.) KARST.) from the Swiss canton of Graubünden. Guitar soundboards (L 600 x R 230 x T 6 mm³), cut out of the same region from a single tree trunk, were thermally modified at a temperature of 160 °C. One part in a proprietary thermo-vacuum process (THV) and the second part in a low-oxygen process in a pilot plant at Eberswalde University (LOX). A third part remained untreated as reference. In total 137 test specimens for measurements in longitudinal (L) and 77 for radial (R) direction with the dimensions 190 x 28 x 4,5 mm³ (L, R x R, L x T) were cut and conditioned at 20 °C and 65% relative humidity (RH) until mass constancy. Resonance frequency and quality factor were determined by means of experimental modal analysis with free-free boundary conditions. The Young's modulus was calculated using the Euler–Bernoulli beam theory based on the frequency of the first bending mode. Furthermore, equilibrium moisture content, density and acoustic radiation were calculated and CIELab brightness values were measured with a spectrophotometer.

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Results and Discussion

The test results (Table 1) show that both treatment processes achieved similar property improvements of Young's modulus, acoustic radiation and quality factor in the longitudinal direction, whereas only the LOX process improved these properties in the radial direction. The density and especially the brightness values were significantly reduced due to the LOX process. Both processes lead to a reduction in the equilibrium moisture content, which is, however, reduced more strongly by the LOX process.

Table 1 mean test results (percentual standard deviation) of thermal treated (LOX, THV process) and untreated (reference) spruce test specimens (20 °C, 65% RH): Young's modulus (E), acoustic radiation (R) and quality factor (Q^{-1}) each in longitudinal (L) and radial (R) direction, density (ρ), equilibrium moisture content (EMC) and brightness value (L^*).

properties	reference	low oxygen process (LOX)	thermal – vacuum process (THV)
E_L (GPa)	11,1 (14)	11,8 (14)	12,0 (9)
E_R (GPa)	1,10 (18)	1,12 (18)	1,03 (13)
R_L ($m^4kg^{-1}s^{-1}$)	13,1 (6)	13,6 (7)	13,2 (10)
R_R ($m^4kg^{-1}s^{-1}$)	3,9 (3)	4,3 (4)	3,9 (5)
Q^{-1}_L (%)	0,31 (10)	0,27 (7)	0,28 (7)
Q^{-1}_R (%)	1,02 (6)	0,78 (5)	0,92 (9)
ρ (kgm^{-3})	408 (8)	397 (8)	409 (5)
EMC (%)	11,0 (5)	8,2 (5)	10,2 (5)
L^* (-)	82 (1)	63 (4)	79 (2)

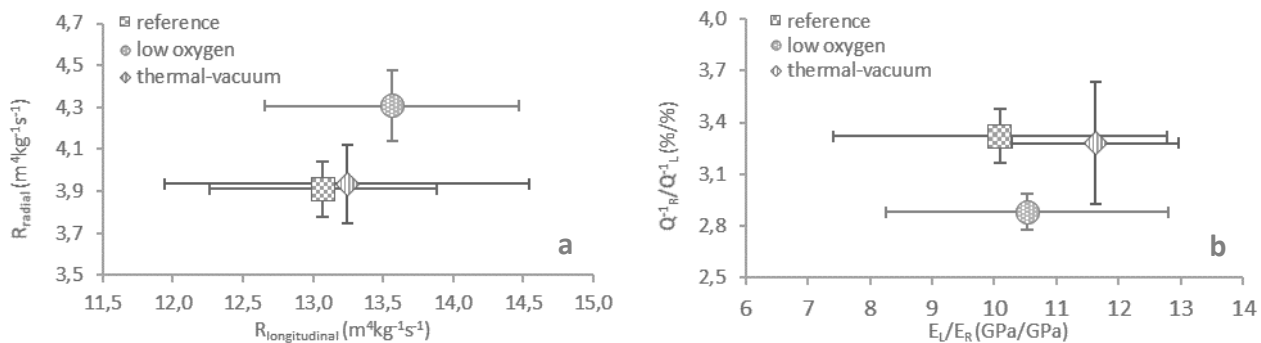


Figure 1 comparison of the acoustic radiation (R) in longitudinal and radial direction (a) and comparison of the ratio of the Young's modulus (E) longitudinal to radial to the ratio of the quality factors (Q^{-1}) radial to longitudinal (b).

The acoustic radiation values in the longitudinal and radial directions shown in Figure 1a can be described as a measure of the average amplitude or loudness of the radiation (Brémaud, 2012). The highest changes in acoustic radiation were obtained due to the LOX process, whereas slight changes were determined for the THV process. Figure 1b shows the ratios $E_{L/R}$ to $Q^{-1}_{R/L}$ which provides information on the anisotropy of these characteristic values. The LOX process achieved a reduction in the anisotropy of the quality factor by about 13%, mainly due to the reduced value in radial direction. Both processes lead to an increase in the anisotropy of the Young's modulus, with the THV method having a greater influence.

Conclusion

Due to the reduced density and moisture content as well as the significant reduction of the brightness value, it can be assumed that the LOX process represents a more intensive treatment variant compared to the THV process. Both processes achieved improvements in the elastic properties in longitudinal direction, however, the LOX process achieved higher improvements in radial direction.

References

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