

Superior wood for violins – wood decay fungi as a substitute for cold climate

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Summary

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- Violins produced by Antonio Stradivari during the late 17th and early 18th centuries are reputed to have superior tonal qualities. Dendrochronological studies show that Stradivari used Norway spruce that had grown mostly during the Maunder Minimum, a period of reduced solar activity when relatively low temperatures caused trees to lay down wood with narrow annual rings, resulting in a high modulus of elasticity and low density.
- The main objective was to determine whether wood can be processed using selected decay fungi so that it becomes acoustically similar to the wood of trees that have grown in a cold climate (i.e. reduced density and unchanged modulus of elasticity).
- This was investigated by incubating resonance wood specimens of Norway spruce (*Picea abies*) and sycamore (*Acer pseudoplatanus*) with fungal species that can reduce wood density, but lack the ability to degrade the compound middle lamellae, at least in the earlier stages of decay.
- Microscopic assessment of the incubated specimens and measurement of five physical properties (density, modulus of elasticity, speed of sound, radiation ratio, and the damping factor) using resonance frequency revealed that in the wood of both species there was a reduction in density, accompanied by relatively little change in the speed of sound. Thus, radiation ratio was increased from 'poor' to 'good', on a par with 'superior' resonance wood grown in a cold climate.

Key words: compound middle lamella, radiation ratio, resonance wood, resonance frequency, violins, wood decay fungi.

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Introduction

Instruments produced by Antonio Stradivari during the late 17th and early 18th centuries are reputed to have superior tonal qualities than more recent instruments. Dendrochronological studies show that, during his later decades, Stradivari used Norway spruce wood that had grown mostly during the Maunder Minimum (Burckle & Grissino-Mayer, 2003; Topham & McCormick, 2000), a period of reduced solar activity when relatively low temperatures caused trees to lay down wood with narrow annual rings, a high modulus of elasticity and low density (Esper *et al.*, 2002).

Traditionally, wood used in the manufacture of musical instruments is treated with primers, varnishes or minerals to stiffen it. Such treatment can strengthen the adhesion between cell layers, but increases the density and vibrating mass because the cell lumina become occluded by the substance (Barlow *et al.*, 1988; Schleske, 1998, 2002a), which ultimately reduces the speed of sound.

The increase in density has an adverse affect on the radiation ratio ($R = \text{speed of sound } (c) / \text{density } (\rho)$), reducing the speed of sound and its resonance frequencies (Barlow *et al.*, 1988; Schleske, 2002b). Tests of other chemical treatments have shown that they increase the dynamic modulus of elasticity

Table 1 Principal acoustic properties used for the assessment of tonal wood quality of axial (L) and radial (R) samples

Property	Assessment
Density, ρ (kg m ⁻³)	ρ for the specimens in L and R directions
Young's modulus of elasticity, E (MPa)	E for L and R directions
Speed of sound, c (m s ⁻¹)	$c = \sqrt{\frac{E}{\rho}}$ for L and R directions
Radiation ratio, R (m ⁴ kg ⁻¹ s ⁻¹)	$R = \frac{c}{\rho} = \sqrt{\frac{E}{\rho^3}}$ for L and R directions
Damping factor, δ_L for L direction and δ_R for R direction	$\delta = K \frac{\Delta f}{f_r}$ where f_r is the resonance frequency, Δf the associated damping and K is a coefficient which varies between $\frac{1}{\pi}$ and $\frac{\pi}{\sqrt{3}}$

(E_L and E_R) and decrease the damping factor (δ_L and δ_R) (Yano *et al.*, 1994; Ono & Norimoto, 1984; Meyer, 1995). Such treatments do not alter wood density, but increase the crystallinity of the cell wall, which is considered disadvantageous for wood processing (Yano *et al.*, 1994). Other authors suggest that the wood of violins made by Guarneri and Stradivari was chemically treated to kill woodworm and fungi (Nagyvary *et al.*, 2006).

An alternative approach to improving the acoustic properties of wood is to reduce its density by fungal or bacterial degradation. Some degradation probably resulted from the practice during the 17th and 18th centuries of floating tree trunks in water (Gug, 1991), but there is no evidence that this caused any noticeable reduction in wood density. According to Nagyvary (1988), the microbial degradation of pit membranes that occurred during this treatment would have resulted in an increase in wood permeability, so that subsequent penetration of varnish was enhanced. Recently, a new thermal treatment has been used to improve the acoustic properties of resonance wood. Treatment at high temperatures results in a reduction in density, because of decomposition of hemicellulose and cellulose, but the modulus of elasticity is reduced (Wagenführ *et al.*, 2005a,b). A negative side-effect of the treatment is that the material becomes brittle, causing problems during the manufacture of instruments.

Most of the described treatments alter the woody cell wall and adversely affect the properties of the compound middle lamellae, both of which have a pivotal role in determining the overall stiffness of wood.

In a homogeneous bulk material, ignoring surface effects, the speed of sound, c , is governed by two mechanical properties: the modulus of elasticity and the density. In wood, which is strongly anisotropic, c varies directionally and is increased by any discontinuities in the compound middle lamella, such as those resulting from microbial degradation. Using the formulae shown in Table 1, it can be deduced that such degradation, even if very slight, results in an abrupt reduction in the E modulus and speed of sound (Schwarze *et al.*, 1995) and has

a negative impact on the acoustic properties of the wood.

The compound middle lamella is penetrated or otherwise altered by most species of wood-decay fungi, except for members of the Xylariaceae (e.g. *Kretzschmaria deusta* and *Xylaria longipes*), which have little ability to degrade guaiacyl (Nilsson *et al.*, 1989; Schwarze *et al.*, 1995), which the compound middle lamella contains in very high concentrations. As a result, this layer remains as an intact skeleton, even at quite an advanced stage of decay (Nilsson *et al.*, 1989; Schwarze *et al.*, 1995; Schwarze, 2007), which explains why the speed of sound through the wood is little affected until that stage (Schwarze *et al.*, 1995, Schwarze, 2007) and is the reason why decay caused by *K. deusta* is hard to detect in trees by means of acoustic devices (Schwarze *et al.*, 1995, 2004; Schwarze, 2007).

The objective of this study was to investigate whether wood-decay fungi, such as the soft-rot fungus *X. longipes*, which lacks the ligninolytic ability to degrade the compound middle lamella, or the white-rot fungus *Physisporinus vitreus*, which does so only at an advanced stage of wood decay, can be used to improve the acoustic properties of resonance wood. For this purpose, wood specimens of Norway spruce and sycamore before and after incubation were assessed microscopically, mechanically and physically (Spycher *et al.*, 2008).

Materials and Methods

We selected 80 specimens of the heartwood from Norway spruce (*Picea abies* L.) and 40 specimens from sycamore (*Acer pseudoplatanus* L.), free from visible defects or knots and with narrow annual rings according to the criteria for resonance wood. The density of the Norway spruce and sycamore wood specimens ranged from 360 to 490 kg m⁻³ and from 530 to 630 kg m⁻³, respectively.

To determine acoustic properties in the axial as well as the radial direction, 20 specimens in each sample were cut with their longest sides axially orientated ('axial specimens') and another 20 were cut with their longest sides radially orientated ('radial specimens'). The dimensions of the axial specimens

were 3 mm (tangential) \times 25 mm (radial) \times 150 mm (longitudinal), and those of the radial specimens were 3 mm (tangential) \times 25 mm (longitudinal) \times 100 mm (radial). Before every measurement, wood specimens were preconditioned at 23°C and 50% RH until a constant weight was reached (i.e. the moisture content (MC) of the specimens was $10.5 \pm 0.5\%$). The mass losses with their corresponding standard deviations (SD) were also measured before and after incubation at 23°C and 50% RH. Additionally, 40 specimens of Norway spruce wood were impregnated with 1% malt solution, so that the MC above the fibre saturation point was reached (approx. 28%) before incubation with *Physisporinus vitreus* (Pers.: Fr.) P. Karst. (a basidiomycete) and *Xylaria longipes* Nitschke (an ascomycete). The incubation process was initiated according to European Standard EN 113 (European Committee for Standardization, 1997) with the aim of exposing the wood to a high inoculum of each fungus to facilitate colonization of the wood. The samples were incubated in the dark at 22°C and 70% RH.

Five physical properties were assessed before and after 6, 12 and 20 wk incubation with the fungi, using resonance frequency (Görlacher, 1984) measurements according to Spycher *et al.* (2008) (Table 1). Differences between values in percentage before and after incubation were estimated for each specimen, and the average of these variations and the corresponding SD were calculated from 10 or five specimens for Norway spruce and sycamore, respectively.

Bending strength (σ_b) was determined by three-point bending tests, whereby a central load was applied to specimens with a span (L) of 100 mm (German Standard DIN 52186; Deutsches Institut für Normung EV, 1978). The tests were carried out with a universal 100 kN bending test machine with a load rate of 2.5 mm min^{-1} . The load was measured using a 1000 N force sensing device with a maximum error of 2% and a midspan deflection (w) with a maximal error of 1%. Two values were recorded: the maximum stress (σ_{max} MPa) reached and the bending strength for each specimen (σ_b MPa), where the maximal deflection was w_{max} . Mean values and SD were calculated from 20 and 12 wood specimens of Norway spruce and sycamore, respectively. One-way analysis of variance (ANOVA) of the recorded values was performed, with respect to acoustic properties and bending strength, for all wood samples using SPSS software (Chicago, IL, USA) with the significance level set at $P < 0.05$.

For light microscopy, the incubated wood was cut into smaller blocks (10 \times 5 \times 5 mm), which were embedded, sectioned and stained according to the procedures of Schwarze & Fink (1998). The specimens, with transverse, radial and tangential faces exposed for examination, were fixed in 2% glutaraldehyde buffered at pH 7.2–7.4, dehydrated with acetone, embedded in a methacrylate medium and subsequently polymerized at 50°C. The embedded specimens were sectioned at approx. 2 and 3 μm using a rotary microtome (Leica® 2040 Supercut) fitted with a diamond knife. For general observa-

tion of wood anatomy, sections were stained for 12 h in safranin and then counterstained for 3 min in methylene blue and 30 min in auramine. To detect early stages of selective delignification, duplicate sections were also stained with safranin and astra blue (Srebotnik & Messner, 1994). Safranin stains lignin regardless of whether cellulose is present, whereas astra blue stains cellulose only in the absence of lignin.

Colour micrographs (Kodak EPY 64T) were taken with a Leitz Orthoplan microscope fitted with a Leitz-Vario-Orthomat camera system.

Results

Anatomy of Norway spruce wood

The wood of Norway spruce is very homogeneous in structure and consists primarily of longitudinal tracheids (95%; Fig. 1a, b), generally with uniseriate bordered pits. Resin canals are surrounded by a sheath of eight to 12 or more thick-walled epithelial cells. Xylem rays are heterocellular (i.e. possess ray parenchyma and ray tracheids), with smooth walls. The transition from early wood to late wood is gradual.

Anatomy of sycamore wood

Sycamore wood, which is diffusely porous, contains groups of fibres that appear to be of high and low density when viewed in transverse section (Fig. 2a). The less dense groups lie between vessels and have abundant intercellular spaces. The denser groups are associated with the vessels, and each group forms a complete paratracheal sheath without intercellular spaces. Living wood fibres are also concentrated at the borders of the annual increments, where they are associated with apotracheal terminal parenchyma.

Wood colonization and cell wall degradation

In the wood of Norway spruce incubated with *P. vitreus*, the main avenues of hyphal growth in the xylem were along the xylem rays and tracheids. After 6 wk incubation, the only detectable effect on the tracheids was selective degradation of pit membranes (Fig. 1c).

After 12 wk, degradation of the uniseriate xylem rays and selective delignification of the tracheid cell walls were apparent within the early wood. Initially, selective delignification was more pronounced in the xylem rays and the early wood, but at a more advanced stage of decay the late-wood tracheids were also affected. Delignification of the secondary walls of tracheids commenced from within the lumen towards the middle lamella and occurred in the immediate vicinity of the hyphae growing on the surface of the cell lumen (Fig. 1c). Cell wall delignification was more pronounced in the tangential direction and after staining with safranin, methylene and auramine staining resulted in a distinct colour change of the

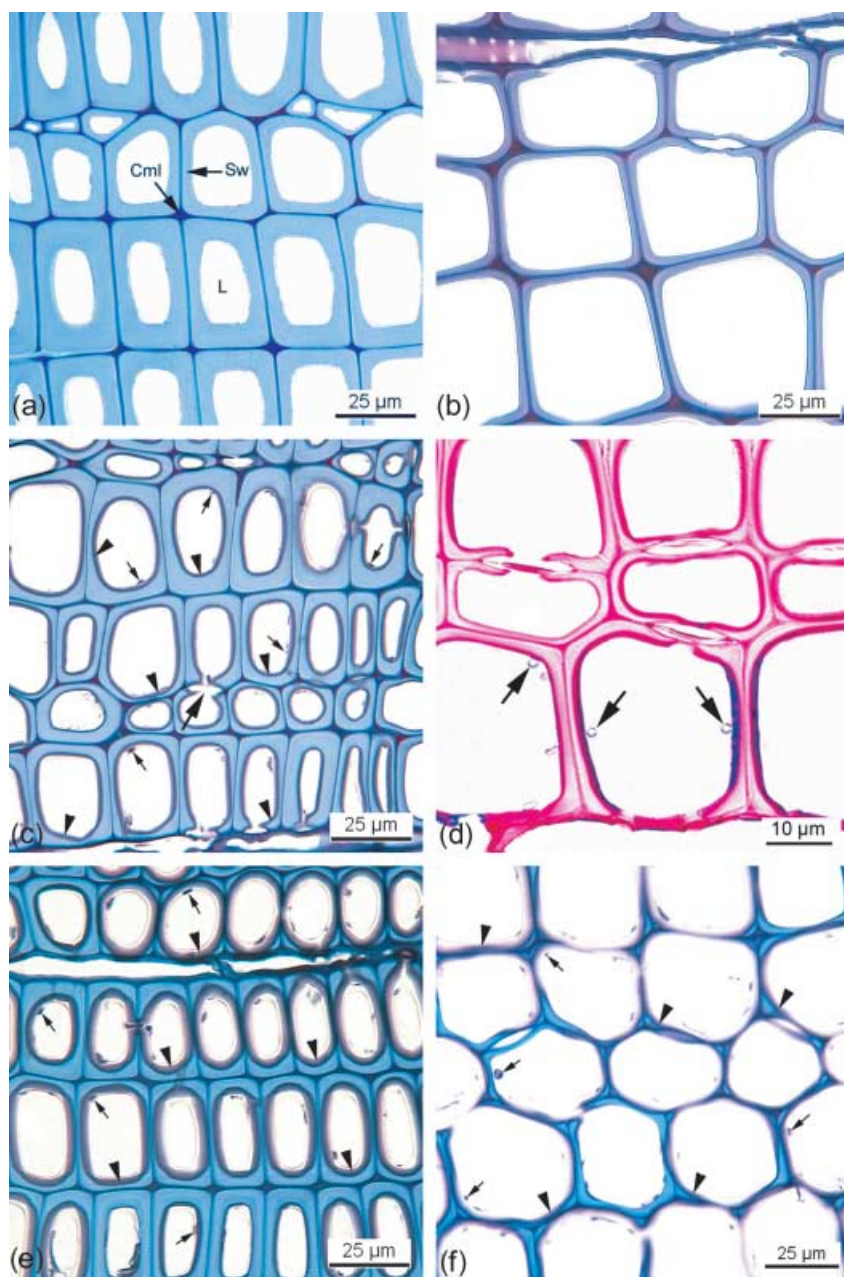


Fig. 1 Transverse sections (TS) of untreated controls and Norway spruce (*Picea abies*) wood incubated with *Physisporinus vitreus*. Late- (a) and early-wood (b) tracheids of control specimens. L, cell lumen; Sw, secondary wall; Cml, compound middle lamella. (c) After 12 wk incubation, preferential degradation of bordered pits (large arrow) and delignification of secondary walls (arrowheads) commence from hyphae (small arrows) growing within the cell lumen of the late- and early-wood tracheids. Note the hyphae (arrows) in the cell lumina growing on the S3 layer. Section stained with safranin, methylene blue and auramin. (d) Panel (c) stained with safranin and astra blue. Note that delignified regions of cell wall appear blue in close proximity to hyphae (arrows). (e) After 20 wk incubation, secondary walls are strongly delignified (arrowheads) and cell wall thinning is apparent in the late- and early-wood tracheids (f).

inner secondary wall from light to dark blue, indicating selective delignification and the exposure of cellulose. Confirmation was also obtained by staining sections with safranin and astra blue, which showed that the discoloured inner secondary wall was delignified and, in the absence of lignin, cellulose was subsequently stained blue (Fig. 1d).

In comparison with control sections (Fig. 1a,b), delignification was apparent in the late-wood tracheids after 12 wk incubation (Fig. 1c,d), followed by cell wall thinning that developed around hyphae in the cell lumina and progressed throughout the inner secondary wall. The compound middle lamella was not visibly altered, however, and remained intact

even after 12 wk (Fig. 1c,d). After 20 wk incubation, attack of the compound middle lamella, which is the critical phase of degradation in the present context, commenced in the early wood (Fig. 1f), despite being absent in the late wood (Fig. 1e).

In the wood of sycamore incubated with *X. longipes*, hyphae (1–2 µm in diameter) were apparent within the cell lumina of fibres, vessels and parenchymal cells of the xylem rays. Hyphal growth was most abundant in the cell lumina of fibres with intercellular spaces (Fig. 2b–f). When viewed at low magnification, the preferential degradation of low-density regions produced a distinctive pattern (Fig. 2b), initially in the immediate vicinity of individual hyphae (Fig. 2c–e). In the early stages of decay,

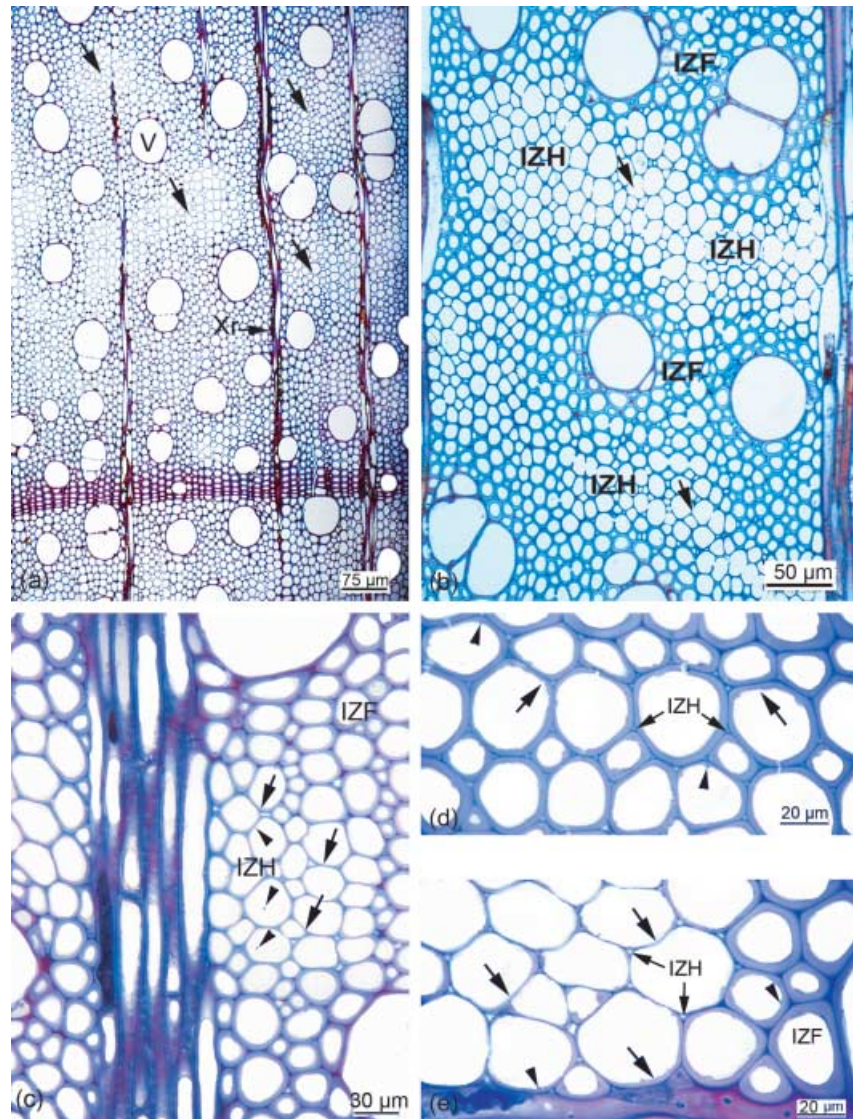


Fig. 2 (a) Transverse sections (TS) of untreated sycamore (*Acer pseudoplatanus*) wood showing the diffuse porous distribution of vessels (v). Note the groups of fibres that appear to be of high and low density (arrows). V, vessels; Xr, xylem rays. (b) TS of sycamore wood incubated with *Xylaria longipes*. After 18 wk, fibre regions in between vessels (arrows) containing intercellular spaces (IZH) are preferentially degraded, whereas fibre regions without intercellular spaces (IZF) surrounding vessels are resistant to decay. (c–e) TS showing progressive cell wall thinning of wood fibre regions containing intercellular spaces (IZH) by *Xylaria longipes* after 6 (c), 12 (d) and 20 wk (e).

there was general dissolution of the cell walls, typical of a simultaneous rot, so that hyphae in the cell lumina induced a general thinning of the walls. At this time, there was no evidence of wall thinning within fibre regions without intercellular spaces, even though hyphae were present within their cell lumina (Fig. 2c–e). Even after 20 wk incubation, when the decay of the low-density fibre regions was more advanced, the compound middle lamellae and the walls of xylem rays and vessels were resistant to degradation (Fig. 2e). At this time, cell wall thinning commenced within fibre regions without intercellular spaces (Fig. 2e).

Alteration of the acoustic properties of degraded wood

Degradation of Norway spruce wood by *P. vitreus* was accompanied by changes in its acoustic properties (Fig. 3a,b). A significant increase ($P < 0.05$) in R was recorded after 12

and 20 wk incubation (Table 2) and can be attributed to a reduction in density (–14.8% after 20 wk), coupled with little change in the speed of sound (–2.7% after 20 wk). After 20 wk incubation, there was a significant increase ($P < 0.05$) in the damping factor (340% in the radial direction) (Fig. 3a,b), which correlated with the selective degradation of pit membranes.

In sycamore wood that was incubated by *X. longipes*, throughout all incubation periods the speed of sound in the axial direction remained more or less the same as in the controls (Fig. 4a,b). By contrast, density was reduced by approx. 10% within 6 wk (Fig. 4a,b) and the R values increased significantly ($P < 0.05$; Table 2) after 6, 12 and 20 wk (Fig. 4a,b). No major alterations of the damping factor were recorded in the axial direction, which indicates that the damping capacity of the incubated sycamore wood resembled that of untreated wood.

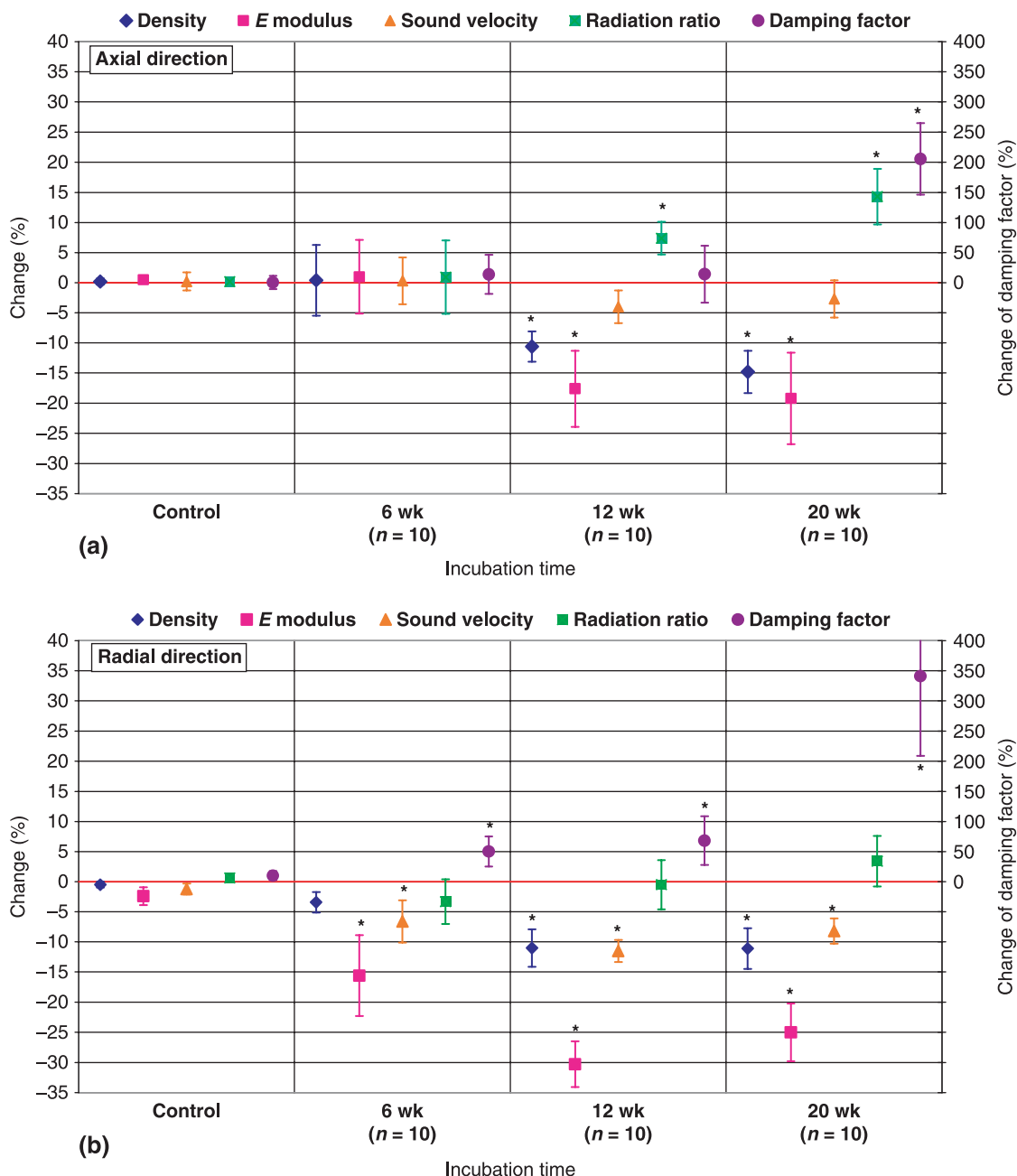


Fig. 3 Alterations in density and the acoustic properties of *E* modulus, speed of sound, radiation ratio (left axis) and damping factor (right axis) in Norway spruce (*Picea abies*) wood after incubation with *Physisporinus vitreus*. (a) Axial direction, (b) radial direction. Error bars \pm SD. Significant differences between untreated controls and incubated samples: *, $P < 0.05$.

Table 2 Radiation ratio (\pm SD) in the axial direction in sycamore (*Acer pseudoplatanus*) and Norway spruce (*Picea abies*) wood specimens after 6, 12 and 20 wk incubation with *Physisporinus vitreus* and *Xylaria longipes*, respectively

Incubation period	Sycamore		Norway spruce	
	Before incubation	After incubation with <i>X. longipes</i>	Before incubation	After incubation with <i>P. vitreus</i>
6 wk	6.0 \pm 0.5	6.4 \pm 0.6	12.3 \pm 1.3	12.3 \pm 1.3
12 wk	6.3 \pm 0.7	7.0 \pm 0.7	12.8 \pm 0.8	13.7 \pm 0.9
20 wk	5.9 \pm 0.4	6.8 \pm 0.5	12.0 \pm 0.3	13.7 \pm 0.8

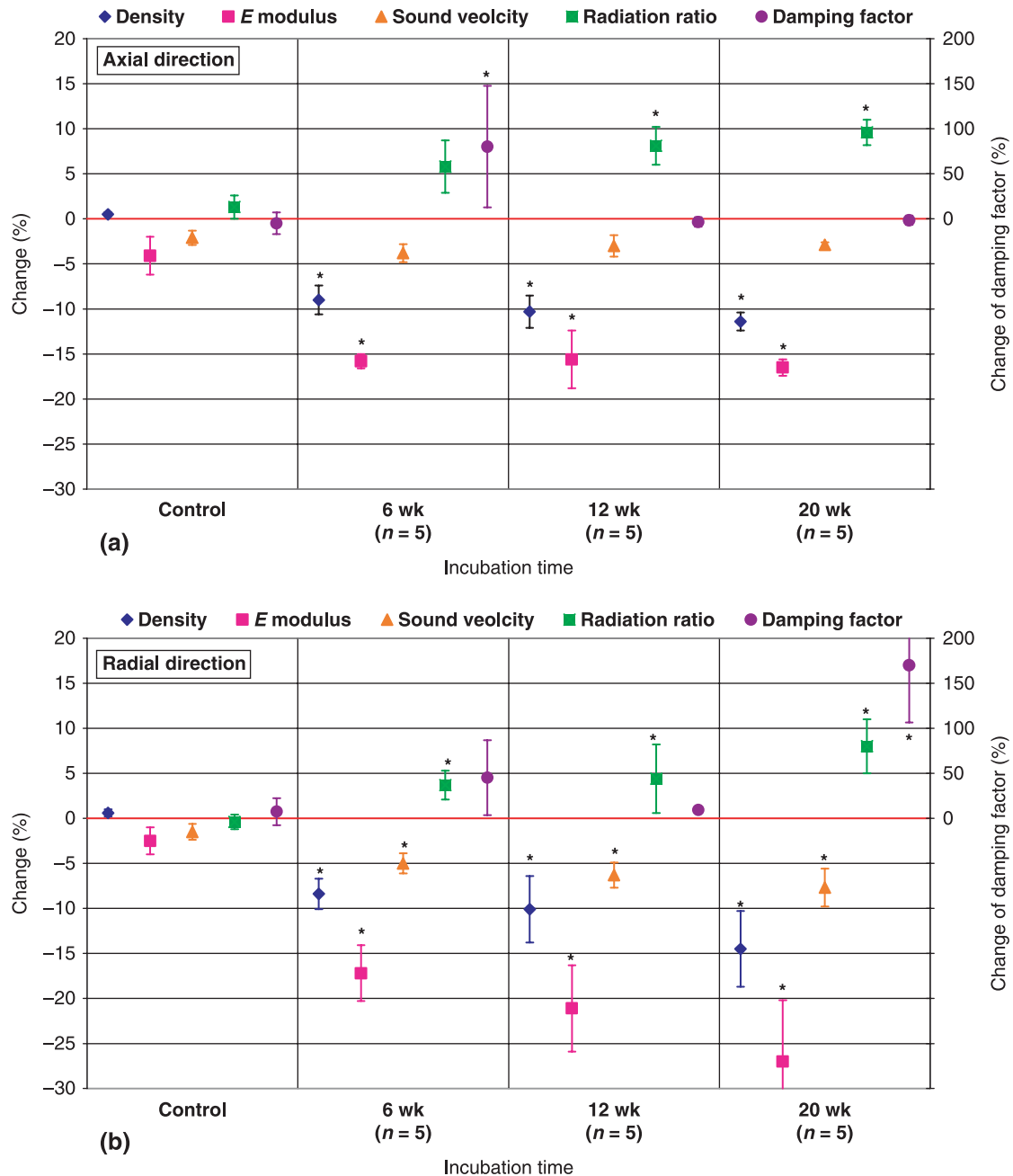


Fig. 4 Alterations in density and the acoustic properties of *E* modulus, speed of sound, radiation ratio (left axis) and damping factor (right axis) in sycamore (*Acer pseudoplatanus*) wood after incubation with *Xylaria longipes*. (a) Axial direction, (b) radial direction. Error bars \pm SD. Significant differences between untreated controls and incubated samples: *, $P < 0.05$.

Alteration of the strength of degraded wood

The axial bending strength of control specimens of Norway spruce was 75.8 ± 7 MPa, whereas specimens incubated for 20 wk showed values of 63.6 ± 10 MPa (Fig. 5). The radial bending strength of control specimens was 6.4 ± 0.5 MPa, whereas specimens incubated for 20 wk showed values of 4.7 ± 1 MPa (Fig. 5). The mean axial bending strength of the sycamore wood specimens incubated for 20 wk was

47.4 ± 6.6 MPa, compared with 68.8 ± 11.8 MPa in the controls (Fig. 5). The corresponding values for radial bending strength were 10.4 ± 2.2 MPa and 16.6 ± 1.2 MPa.

Discussion

Incubation of wood with two species of decay fungi caused marked density losses and cell wall thinning; that is, the partly degraded wood resembled superior resonance wood grown

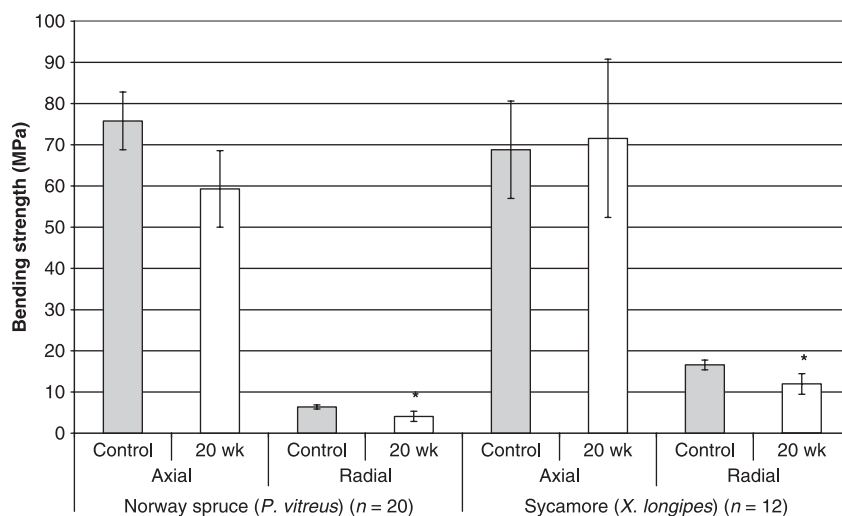


Fig. 5 Bending strength (in MPa) of Norway spruce (*Picea abies*) and sycamore (*Acer pseudoplatanus*) wood incubated for 20 wk with *Physisporinus vitreus* and *Xylaria longipes*, respectively. Error bars \pm SD. Significant differences between untreated controls and incubated samples: *, $P < 0.05$.

under cold climate conditions. This finding is in good agreement with other research that shows that the gradual decomposition and loss of hemicellulose with time lowers wood density without affecting its Young's modulus, subsequently increasing the radiation ratio (Bucur, 2006).

The observed pattern of degradation by *P. vitreus* seems to be unique with regard to the selective delignification of the secondary wall without degradation of the middle lamellae, even at advanced stages of decay. The significant increase ($P < 0.05$) in the damping factor (340% in the radial direction) that was recorded after incubation of 20 wk can be attributed partly to selective degradation of pit membranes (Schwarze & Landmesser, 2000; Schwarze *et al.*, 2006; Schwarze, 2007). The degradation of pit membranes by *P. vitreus* is an important aspect that could have significant benefits in wood protection processes, namely for improving the permeability of waterborne wood preservatives (Schwarze *et al.*, 2006). Similarly, an increase in wood permeability facilitates penetration of varnish, which is traditionally used to increase the stiffness (i.e. Young's modulus of elasticity) of the wood used for making violins (Nagyvary, 1988). Thus, it is conceivable that the significant reduction in Young's modulus of elasticity recorded in Norway spruce wood incubated by *P. vitreus* could be mitigated by additional treatment with wood-stiffening varnishes (e.g. copaiba balsam), which can result in an increase in the speed of sound by 18.8% in treated compared with untreated wood (Schleske, 1998). Such treatment would ultimately further enhance the radiation ratio. Incubation with *P. vitreus* for > 20 wk will adversely affect the properties of resonance wood, rendering it unsuitable for violin manufacturing.

In sycamore wood incubated with *X. longipes*, degradation began preferentially within groups of libriform wood fibres containing intercellular spaces, leaving fibre regions without such spaces, vessels and xylem ray parenchyma undegraded and largely intact, even when decay had become advanced elsewhere. These differences in cellular decay resistance have been

previously reported for *Armillaria mellea* on sycamore wood and correspond to the degree of lignification within the two types of fibre (Campbell, 1931, 1932; Nilsson *et al.*, 1989; Schwarze *et al.*, 2000; Schwarze, 2007). Even after 20 wk incubation, the compound middle lamella in sycamore wood showed little signs of degradation, which indicates that even longer incubation periods could be used without reducing the speed of sound.

Particularly in the case of the top plates for violins, a large R (Table 1) of the material is desirable to produce a big sound (Holz, 1966; Wegst, 2006; Spycher *et al.*, 2008). A high radiation ratio in the axial direction is of utmost significance for first-quality resonance wood (Ono & Norimoto, 1983; Müller, 1986). For the manufacture of an excellent concert violin for use by a soloist, the violin maker requires at least 'very good' material quality for the two quarter cuts (top plate: Norway spruce wood; bottom plate: sycamore wood). In the present study, degradation of Norway spruce and sycamore wood by *P. vitreus* and *X. longipes*, respectively, was accompanied by significant increases ($P < 0.05$) in R after 6, 12 and 20 wk incubation (Table 2). In the wood of both species, improvement in the radiation ratio was achieved by a reduction in density of approx. 12%, coupled with relatively little alteration in the speed of sound (Table 2). In Norway spruce wood, R values of 10 and 16 have been measured in acoustically 'poor' and 'excellent' specimens, respectively, with corresponding values of 5.5 and 8 in sycamore wood (M. Schleske, unpublished). Thus, in our study, the acoustic quality of Norway spruce and sycamore wood was increased from 'poor' to 'good'.

The axial bending strength of incubated Norway spruce and sycamore wood specimens was not significantly reduced, in comparison with the controls, after 20 wk incubation, whereas a significant reduction ($P < 0.05$; Fig. 5) in the radial bending strength of both wood species was recorded. These results are in good agreement with those of previous studies that showed that, in comparison with controls, the impact-bending

strength of Norway spruce wood was not significantly reduced after 12 wk incubation with *P. vitreus* (Schwarze *et al.*, 2006).

The reduction in radial bending strength is important for Norway spruce, but may not be relevant for the use of sycamore wood in violin-making (M. Schleske, unpublished); that is, the mechanical impact on the sycamore bottom plate is mostly a dynamic effect, while the static forces exerted in compression are compensated by the geometry of the violin (Bond, 1976; Spycher, 2008). Furthermore, the top plate made of Norway spruce wood is responsible for the global sound emission of the violin, but not for its strength and stability. The potentially disadvantageous radial strength losses in Norway spruce and sycamore wood after incubation could be mitigated simply by using thicker top and bottom plates (Wegst, 2006; Spycher, 2008).

The quality of the resonance wood is very important for the acoustic quality of the violin. The procedure described here for modifying wood is intended primarily to enable the manufacture of better solo instruments. A solo violinist prefers an instrument that can play 'against' the orchestra. Its tonal properties include high projection, high volume and dynamic range, together with a sensitive modulation of tonal colours, and these depend directly on the material quality of the resonance plates of the violin, which in turn is correlated positively with the velocity of the longitudinal sound waves (both across and along the grain) and negatively with wood density. A material with a high ratio of the speed of sound to density increases the sound emission of the instrument, which means that the plate amplitudes are high in relation to the force that excites the strings. This enhancement of resonance makes the difference between a violin of average quality and one that is suitable for a top soloist. Because of the enormous size of modern concert halls, acoustic instruments made from wood modified by fungi will be desirable for meeting the needs of soloists in the future.

In further studies, we will be attempting to optimize the uniformity of colonization and decay processes, particularly identifying the critical incubation time above which the radiation ratio is adversely affected. The exact influence of the bending strength on the violin will also be determined, using a prototype violin made from fungal-treated wood plates. Additionally, the influence of the damping factor on the acoustic quality of resonance wood and the effects of its modification on the final properties of the violin will be investigated.

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