WOOD RESEARCH doi.org/10.37763/wr.1336-4561/70.3.527541
e-ISSN 2729-8906
70(3): 2025 527-541 pp.

THE IMPACT OF ACRYLIC RESIN ON THE PERFORMANCE OF SPRUCE AND FIR WOOD: THE STUDY OF HARDNESS, WATER ABSORPTION, AND NATURAL WEATHERING

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(RECEIVEDJULY2025)

ABSTRACT

This study investigated the effects of acrylic resin stabilization on the properties of Norway spruce (*Picea abies,* (L.) H. Karst) and European silverfir (*Abies alba,* Mill) wood. The primary focus was on enhancing durability by improving hardness, water resistance, and UV resistance. Results demonstrated a significant increase in hardness (D-Shore) for both species, with spruce exhibiting a 72.3% improvement and fir showing a 16.5% enhancement. Water absorption tests revealed a substantial decrease in water uptake for stabilized samples compared to untreated controls. However, colorimetric analysis indicated a slight decrease in UV resistance for stabilized samples, likely attributed to the lack of UV stabilizers within the acrylic resin.

KEYWORDS:Wood modification, construction, natural weathering, hardness, colourimetry.

INTRODUCTION

Wood, a natural and renewable material, has been utilized across diverse applications due to its favourable mechanical properties and aesthetic appeal (Ramage et al. 2016). However, its susceptibility to moisture and UV radiation limits long-term performance outdoors (Williams 2005), causing dimensional instability, decay, cracking, and discoloration, highlighting the need for effective modification (Hill 2007). Growing demand for sustainable, durable wood products drives research into modification techniques to mitigate degradation, extend service life, and reduce replacement frequency. Flame retardants (Lowden & Hull 2013; Lili et al. 2025) and UV effects on composite wood materials (Fabiyi& McDonald 2010) are also important considerations for wood protection.

Resin stabilization, particularly using acrylic resins, is a promising technique to improve wood's resistance to environmental stress. Acrylic resins penetrate wood cell walls, enhancing mechanical strength, reducing water absorption, and improving dimensional stability (Ding et al. 2011, Keleş & Durmaz 2023). This creates the protective barrier against moisture uptake, crucial for extending service life in fluctuating humidity (Özgenç 2020, Wu et al. 2020, Huo et al. 2025). The process involves impregnating liquid monomers that polymerize within the wood structure, filling voids and reinforcing cell walls, resulting in a more hydrophobic and dimensionally stable material by reducing hygroscopicity, swelling, and shrinkage (Rowell 2012, Li 2011). Acrylic resin treatments also enhance wood hardness, improving resistance to abrasion, impact, and wear (Jiao et al. 2021). The formation of a robust polymer matrix within the wood contributes to these improved mechanical characteristics and durability (Deka & Saikia 2000). Specific resins like polymethyl methacrylate (PMMA) have shown significant improvements in hardness and dimensional stability (Li et al. 2010), and can enhance resistance to decay and fungal attacks, increasing longevity (Rosu et al. 2020). The choice of resin, viscosity, and impregnation parameters like pressure and temperature significantly influence penetration and the resulting property enhancements (Gecer et al. 2015).

This study specifically investigates the effects of acrylic resin stabilization on two commercially important softwood species: Norway spruce (*Picea abies*(L.) H. Karst) and European silver fir (*Abies alba*Mill). These species are widely used in construction, furniture manufacturing, and outdoor applications due to their availability and favourable mechanical properties, making their durability a critical concern. Understanding the impact of acrylic resin treatment on these species is essential for optimizing their use and extending their service life in various applications. The primary objective is to evaluate the impact of acrylic resin treatment on hardness, water absorption, and UV resistance, providing the comprehensive assessment of its effectiveness. By quantifying the changes in these critical properties, this study contributes to the deeper understanding of benefits and drawbacks of acrylic resin stabilization. The findings will provide valuable information for industries seeking to improve the durability of wood products, particularly for outdoor applications, where exposure to harsh environmental conditions is a significant concern. Furthermore, this research highlights the importance of developing optimized acrylic resin formulations that incorporate UV stabilizers to ensure long-term protection against environmental degradation (Rawat et al. 2019).

Despite the potential of acrylic resins for enhancing wood properties, concerns remain regarding their long-term performance under UV exposure. Some studies indicate that acrylic resins, without UV stabilizers, may not provide adequate protection against photodegradation, leading to colour changes and surface deterioration (Bisht et al. 2021). Therefore, this research also aims to assess the UV resistance of acrylic resin-treated spruce and fir wood, providing valuable insights into the limitations and potential improvements of this modification technique. This investigation will contribute to the development of more effective and durable wood treatment strategies, supporting the sustainable use of wood in various applications.

MATERIAL AND METHODS

Materials and chemicals

Local hardware shop supplied the wood of Norwayspruce (*Picea abies* (L.) H. Karst) and European silver fir (*Abies alba* Mill). The samples were sourced from construction-grade lumber and precisely (±0.2 mm) cut to dimensions of 100×100×10 mm (tangential × radial × longitudinal). In accordance with ISO 13061-1:2014, the initially air-dried wood samples were subsequently oven-dried at 103±2°C until a constant weight was achieved. Chemicals, (2-hydroxyethyl)-methacrylate (97%), (hexane-1,6-diyl)-diacrylate (80%) and 2,2-azobis(2-methylpropionitrile) were purchased from Sigma-Aldrich and dodecyl-methacrylate (97%) was purchased from Avantor, Inc.

Stabilization process

The stabilization process utilized a mixture of acrylic resins formulated by combining (2-hydroxyethyl) methacrylate (HEMA) at a concentration of 60% by mass, dodecyl methacrylate (DDMA) at 30% by mass, and 1,6-hexanediol diacrylate (HDDA) at 10% by mass(Tab. 1). To initiate polymerization, 2,2'-azobis(2-methylpropionitrile) (AIBN) was added as an activator. The components were thoroughly mixed and allowed to stand for approximately 2 h to ensure complete dissolution and homogeneity.

The prepared wood samples were then submerged in the resin solution, with weights used to ensure they remained fully immersed. To facilitate resin penetration by removing entrapped air from the wood structure, the container holding the samples and resin was placed in a vacuum chamber. A vacuum corresponding to 90 kPa below atmospheric pressure was applied for 30 min to remove the gases from the wood samples.Following the vacuum treatment, the chamber was returned to atmospheric pressure, allowing the resin to penetrate and saturate the wood. This saturation process was continued for several days, during which the resin level in the container was monitored and replenished as necessary to maintain full submersion. After 72 h, saturation was considered complete when no further resin absorption by the samples was observed.To cure the resin within the wood, the saturated samples were individually wrapped in aluminium foil to prevent resin evaporation. They were then placed in an oven and cured at a temperature of 90°C for 2 h. After the curing period, the samples were unwrapped and allowed to cool to room temperature (approximately 25°C). Finally, any excess hardened resin on the surfaces of the samples was removed using a belt sander to ensure dimensional accuracy for subsequent testing and characterization.

Tab. 1:Properties of acrylic resin solution.

Properties of the uncured system (acrylic resin)	
Viscosity at 25 °C	5-30 mPa.s
Density at 23 °C	0.92-0.96 $g.cm^{-3}$
Appearance	clear liquid
Properties of the cured system (acrylic resin)	
Colour	clear/water-clear
Hardness	Shore D 80-85

The stabilization process involved the preparation and treatment of spruce and fir wood samples. From the total of 24 samples per species, 12 samples of each were selected for the stabilization.Before the stabilization, the dimensional parameters of the prepared wood sample were measured. These were used to compare and monitor the dimensional and mass changes of the samples before and after modification process.

Characterization

For the measurement of the hardness Digital Shore D Hardness Tester—Sauter HD (Sauter GmbH, Balingen, Germany) was used.

The colourimetry of the samples was performed using by a Colorimeter NR200 Precision (Threenh Technology Co., Ltd.; Shenzhen, China) with the following characterizations: Measuring aperture Φ8 mm, Colour space CIE L*a*b* and Light Source D65. The colour change caused by UV radiation was monitored using the CIE L*a*b* colour space coordinates. The colour data (L∗a∗b∗) were directly obtained from the apparatus using the CSCQ3 software, which performed colour difference analysis. In this way, the colour of the measured surface is expressed using three coordinates:L*—coordinate on the axis indicating lightness, a*—coordinate on the axis between red and green, b*—coordinate on the axis between yellow and blue.To describe the total shift in this colour space, the total colour difference is used, which can be expressed by Eq. 1, as follows:

$$\Delta E_t = \sqrt{(L_t^* - L_0^*)^2 + (a_t^* - a_0^*)^2 + (b_t^* - b_0^*)^2} \qquad (1)$$

where:ΔEt is the total colour difference at time t, L^*_t is the value of L^* at time t, L^*_0 is the value of L^*before exposure to UV radiation, a^*_t is the value of a^* at time t, a^*_0 is the value a^* before exposure to UV radiation, b^*_t is the value of b^*at time t, b^*_0 is the value of b^* before exposure to UV radiation.

The weight percent gain (WPG) was calculated using Eq. 2. This represents the mass change between the oven-dried state (M_1) and the specimen after curing (M_3), indicating the amount of chemical retained in the specimen.

$$WPG\% = \frac{M_3 - M_1}{M_1} \times 100 \qquad (2)$$

Thermogravimetric analysis (TGA) was performed using a Netsch STA 449 F5 Jupiter. The measurements were done under air (20% O_2 + 80% N_2) with a gas flow of 100 mL.min^{-1}.

The heating of the samples proceeded uniformly at a rate of 10°C.min^{-1}. The temperature range of the measurement was set from 35°C to 800°C, and the sample weight was10±0.5 mg.

The effectiveness of the chemical treatment was evaluated by assessing the water uptake capacity of the wood samples. Together 12 wood samples were used, divided into two groups: 6 stabilized and 6 unstabilizedcontrol samples. Water uptake was determined gravimetrically throughout a 109-day monitoring period. Measurement frequency varied over time; initial measurements (days 2–3) were recorded at varying hourly intervals, followed by daily measurements, and finally less frequent measurements in the later stages until the end of the observation period.

The exposure of natural weathering of wood samples in the exterior was carried out according to the standard EN 927–3 (2006) in frames facing south at an angle of 45° and placed approximately 1 m above the ground. The most well-known effect of exposing unprotected wood to outdoor weathering, including periods of sun and rain, is a change in colour of its surface. The measurements took place during the winter months (December 2023 to April 2024), a period when wood is subjected to the most significant abiotic stressors, including freezing temperatures, wind, increased precipitation, and humidity.Colour changes were monitored by assessing L^*, a^*, and b^* parameters using a colorimeter. The colour change (ΔE) was calculated by comparing the L^*, a^*, and b^* values measured at the start of the test with those taken after three months, following the drying of the samples. For this test, a wooden structure was built and placed on the roof of the Institute of Integrated Safety (Trnava, Slovakia, elevation above sea level 144 m). Tab. 2 shows an overview of the climatic conditions during 5 months of weathering.

Tab. 2: An overview of the air climatic conditions during natural outdoor weathering (Time and Date 2025, online).

Average climatic parameter	Months of exposure				
	December	January	February	March	April
Temperature (°C)	2	1	8	9	12
Humidity (%)	90	77	79	72	70

RESULTS AND DISCUSSION

Physical properties

The results of the stabilization process with acrylic resin for 12spruce samples and 12 fir samples are presented as follows. For each parameter, the first value corresponds to spruce samples, and the second value corresponds to fir samples. The values represent the average measurements obtained for each set of samples: weight of dried wood [g], weight after stabilization [g], dimension *a* [mm], dimension *b* [mm], overall average thickness [mm], volume [cm³], density before stabilization [$g.cm^{-3}$] and density after stabilization [$g.cm^{-3}$].

The sample thickness was measured at three locations and the average thickness value was considered for further calculations. The total volume and subsequently the average wood density value were calculated from the measured parameters (Tab. 3).

Tab. 3: Properties of wood samples.

Sample	Spruce	Spruce after stabilization	Fir	Fir after stabilization
Weight of dried wood [g]	41.24	43.38*	48.92	48.81*
Weight after stabilization [g]	-	99.28	-	82.57
WPG [%]	-	128.86	-	69.16
Dimension a [mm]	98.93	100.25	99.58	100.00
Dimension b [mm]	95.83	94.75	96.24	95.42
Average thickness	10.53	10.60	10.38	10.58
Volume [cm^3]	99.80	100.71	99.42	100.95
Density [$g.cm^{-3}$]	0.41	0.99	0.49	0.82

*Weight of dried, unstabilized wood.

Hardness

Hardness measurements (Shore D) were performed on unstabilized and stabilized samples of fir and spruce wood (Fig. 1). For each sample group (unstabilizedfir, unstabilizedspruce, stabilized fir, stabilized spruce), five measurements were taken at different points, and the arithmetic mean hardness was calculated. The average hardness of unstabilized wood samples was measured as follows: for fir samples, the average hardness was 49.68 while for spruce it was 42.73. After stabilization, the average hardness increased significantly: for firsamples, the average hardness was 57.87, and for spruce samples, the average hardness was 73.65. Following stabilization with acrylic resin, a notable increase in the average hardness was observed for both wood species. Spruce samples exhibited a substantial increase of approximately 72.3%, while fir samples showed an increase of approximately 16.5%.The results clearly indicate that the stabilization with acrylic resin enhances the hardness of both fir and spruce wood under the conditions of this test. The observed increase in hardness suggests that the acrylic resin has effectively reinforced the wood structure, improving its resistance to indentation.

The obtained results of hardness are within the interval (35.30 to 77.20) reported by other authors, e.g. by Esteves et al. (2021).

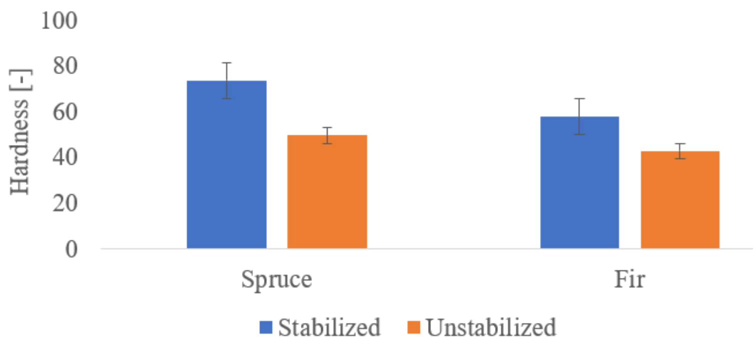

Fig. 1:Hardness of stabilized and unstabilizedwood samples according to Shore D.

Colorimetry

The colour of the surface of the samples was measured in the CIEL*a*b* colour space with a 3nh colorimeter NR200. The obtained results are presented in Tab.4. The colour change can be expressed as the total colour difference ($_{\Delta}E$). This is the value that indicates the total shift in the colour space. Its value can be calculated as Eq. 1.

*Tab. 4: Colour parameters of the samples in CIEL*a*b* colour space.*

Colour coordinate	Stabilized fir	Unstabilizedfir	Stabilized spruce	Unstabilizedspruce
L_0*	78.71	77.86	78.30	77.66
L_t*	69.00	70.97	71.83	70.59
a_0*	8.08	9.13	6.07	8.04
a_t*	12.87	13.26	11.30	14.53
b_0*	20.56	22.54	17.13	21.51
b_t*	32.87	33.54	32.86	36.73

The laboratory measurements revealed distinct colour differences ($_{\Delta}E$) between the tested samples. The overall colour difference varied depending on the wood species and stabilization treatment. For spruce samples, the unstabilized wood exhibited a higher colour difference ($_{\Delta}E$ = 17.99) compared to the stabilized spruce ($_{\Delta}E$ = 17.62). Conversely, stabilized fir samples showed a greater colour difference ($_{\Delta}E$ = 16.40) than the unstabilized($_{\Delta}E$ = 13.63) (Fig. 2). For the comparison, Barcik et al. (2015) reported overall colour differences (ΔE) within the interval from 1.01 to 26.05 (for wood exposed to temperature 160 to 240°C). Thus, colour changes caused by natural weathering are comparable to the changes induced by temperatures between 210 to 240°C.

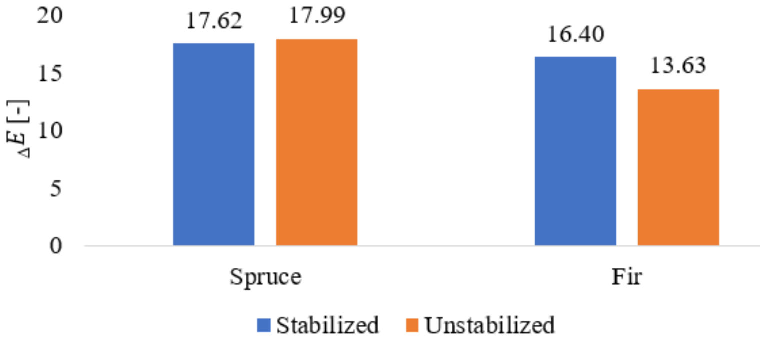

Fig. 2:Colour differences ($_{\Delta}E$) between stabilized and unstabilized wood samples.

Water uptake

Water absorption revealed significant differences between stabilized and unstabilized samples. Unstabilized samples exhibited a much higher percentage weight gain (WPG), with spruce samples reaching 154% and fir samples 108%, compared to 34% for stabilized spruce and 49% for stabilized fir (Fig.3).Additionally, unstabilized samples showed visible mould growth and a noticeable odour in the water, indicative of biotic degradation, which became apparent midway through the 109-day measurement monitoring period. In contrast, stabilized samples remained visually unchanged throughout the experiment, highlighting the protective effect of resin stabilization against water absorption and biotic factors.

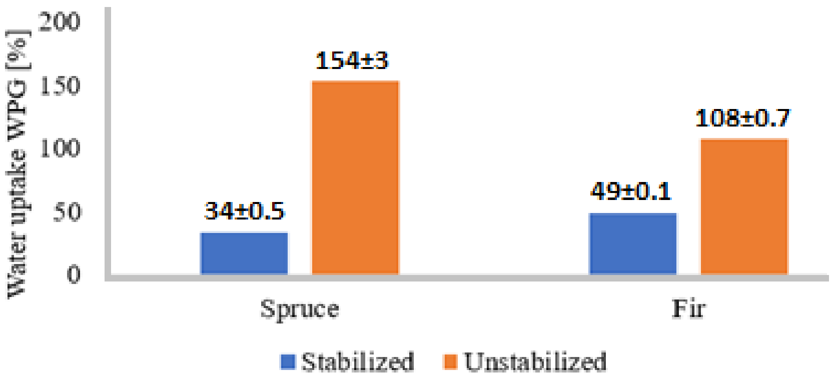

Fig.3:Water uptake WPG(%) after 109 days.

The Fig. 4 displays the water uptake behaviour of different wood samples over time, measured as the increase in weight.All samples exhibit a characteristic water uptake pattern, characterized by a rapid initial increase in weight within the first few hundred hours, followed by a gradual slowing down of the uptake rate over longer periods, indicating towards to equilibrium.Stabilized samples generally start at higher initial weights and reach higher final weights compared tounstabilized samples. Stabilized Spruce shows the highest overall water uptake in terms of absolute weight gained and reaches the highest final weight among all samples.Unstabilized samples start at lower initial weights. While unstabilizedfir starts slightly heavier than unstabilizedspruce. The difference in the total water uptake between stabilized and unstabilized samples appears more pronounced for spruce than for fir. Fig. 4 shows the typical dynamics of water absorption in wood and wood-based product. The detail analysis of the water absorption dynamics in wood is described e.g. by Khazaei (2008).

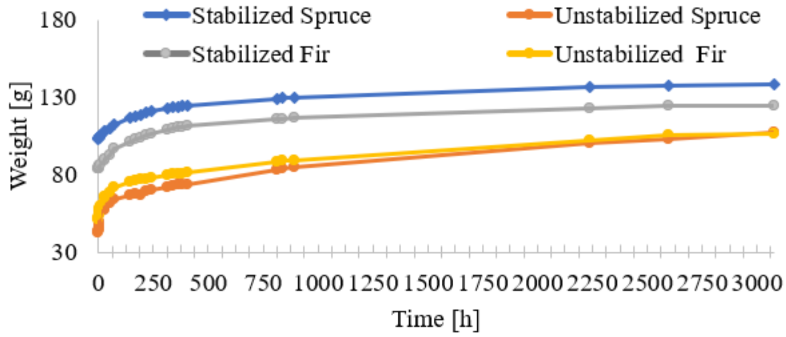

Fig.4: Temporal dynamics of water absorption of stabilized and unstabilizedwood samples over109-day period.

Natural outdoor weathering of wood samples

To quantitatively evaluate the colour stability of the wood samples under outdoor exposure, colorimetric measurements were conducted using the CIELabcolour space for 1652 h. The parameters L∗, a∗, and b* were recorded periodically over the exposure period. The temporal evolution of these colour parameters for unstabilizedsamples of fir, stabilized samples of fir, unstabilizedsamples of spruce, and stabilized samples of spruce are presented in Fig.5.

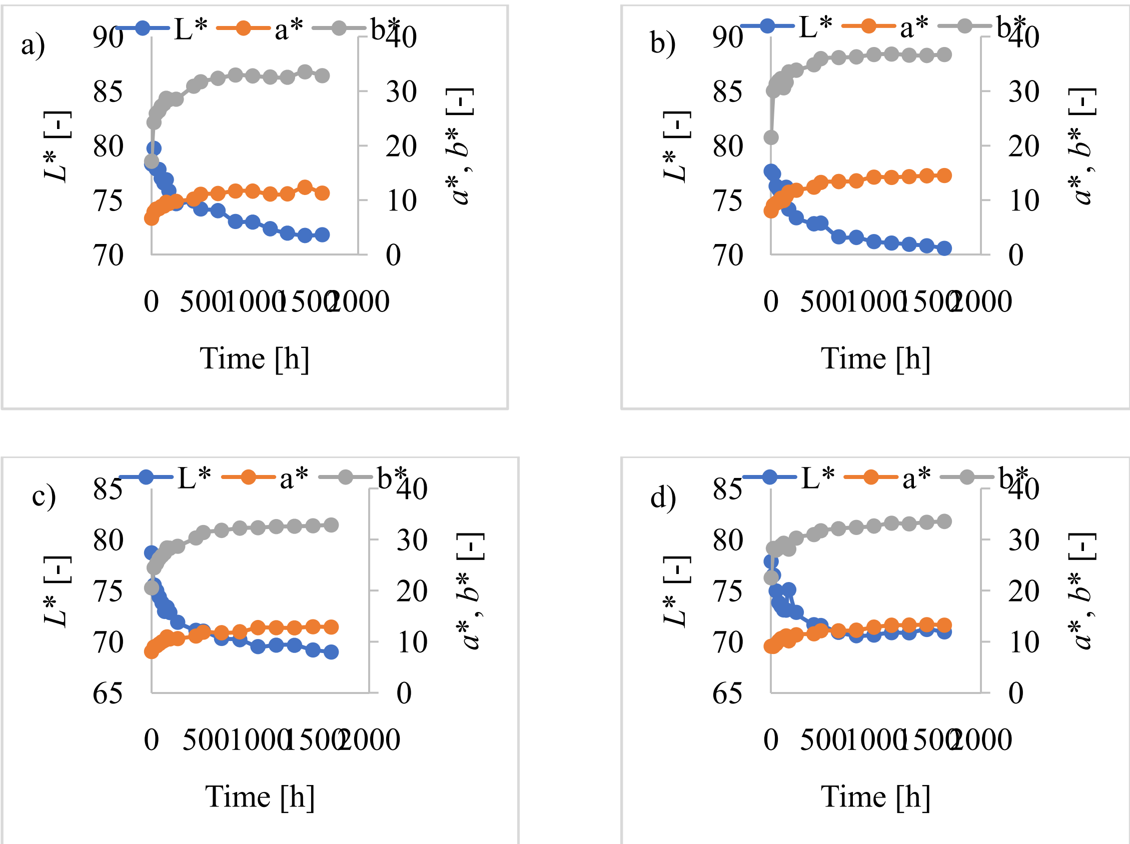

Fig. 5:Changes in CIELab colour coordinates over the exposure period for: a) stabilized spruce, b) unstabilizedspruce, c) stabilized fir, d) unstabilizedfir.

These results suggest that the colour stability response to UV exposure differs between spruce and fir wood, and is influenced by the stabilization process. In stabilized samples, the yellowing of the acrylic resin under UV radiation, potentially due to the absence of effective UV stabilizers, likely contributes significantly to the overall colour change. Concurrently, in both stabilized and unstabilized samples, the natural photodegradation of wood components, particularly lignin, also plays a crucial role in colour alteration upon prolonged UV exposure. The interplay and relative dominance of these mechanisms – resin degradation/yellowing and wood photodegradation – likely explain the distinct $_\Delta E$ values observed for each species and treatment type (Fig. 6).

Similar dynamics of wood colour changes due to UV irradiance exposition was reported by Kannar et al. (2018). The typical colour changes of wood induced by elevated temperature and UV irradiation are characterised by an initial rapid alteration, followed by a slower, gradual evolution over time.

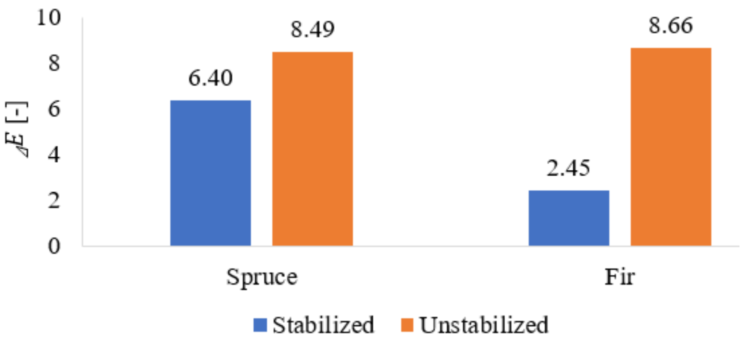

Fig. 6: Colour differences ($_\Delta E$) between stabilized and unstabilized wood samples after natural outdoor weathering.

To potentially reduce the yellowing of wood samples treated with acrylic resins, the addition of a UV absorber could be considered, as Bisht et al. (2021) demonstrated a significant reduction in discolouration and photodegradation of transparent wood composites by using an epoxy resin doped with 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol. Applying a similar principle, i.e., incorporating a suitable UV absorber into the acrylic resin, could lead to improved colour stability in our case as well.

After one month of exposure, measurements revealed that the stabilized samples demonstrated better resistance, as no colour changes were observed, nor were there any visible alterations caused by biotic factors. The unstabilizedsamples, while showing no changes due to biotic degradation factors, were darker in comparison to the stabilized samples. After three months of exposure, visible signs of fungal growth were observed on the untreated samples. Visual comparison after four months showed greater colour stability in the stabilized samples, with the stabilized Spruce and Fir samples appearing lighter. The results indicate that acrylic resin stabilization significantly enhanced the wood's outdoor durability. Unstabilizedspruce samples exhibited deeper and longer cracks compared to the stabilized ones. Biotic degradation was observed after 6-months period, primarily on the unstabilizedsamples.

Thermogravimetric analysis (TGA)

Based on the thermogravimetric measurements (Tab. 5, Figs.7 and 8), it can be concluded that the mass loss of the samples occurred in three distinct stages. The first stage was very slight, occurring at temperatures up to 150°C. This stage is frequently described in the literature in both inert and oxidative atmospheres and is commonly associated with the removal of moisture from the samples (Chao et al. 2019, Aydemir et al. 2011, Zhang et al. 2022). The mass loss in this stage ranged from 1.2% to 3.9%, indicating significant initial drying.

The second stage of degradation took place at temperatures approximately between 250°C and 400°C. In the case of wood, this stage is caused by the decomposition of its main components, primarily hemicelluloses and cellulose. Cellulose is highly crystalline, whereas hemicellulose is amorphous and degrades before cellulose (Jambreković et al. 2022).

The final stage of mass loss was observed at temperatures around 450°C. This stage does not occur during thermogravimetric analysis in a nitrogen atmosphere and can therefore be attributed to the oxidation of the carbonaceous residue by atmospheric oxygen (Korošec et al. 2023).At temperatures above 500°C, the thermal decomposition of the wood samples was practically complete, which is consistent with the results of other authors, e.g.Shapchenkova et al. (2021)orJeske et al. (2012).From the results, it is evident that Fir wood forms approximately 5% more carbonaceous residue in the second degradation stage compared to spruce wood. Since the residue at 800°C was comparable for both wood species, the mass loss of Fir wood is consequently higher in the third stage.

A significant difference was observed in the thermogravimetric curves between samples containing acrylates and pure wood. For pure wood, the second degradation stage was less pronounced, suggesting that the main decomposition of the acrylates occurs at similar temperatures as the decomposition of hemicelluloses and cellulose. Furthermore, the end of the third mass loss stage was shifted by approximately 20°C in the acrylate-containing samples. This indicates that the carbonaceous residue remaining after the decomposition of acrylates is slightly more stable in an oxidative atmosphere. These findings are also supported by the results of other authors. For instance, thermogravimetric analysis of poly-2-hydroxyethyl methacrylate (poly-HEMA) in nitrogen indicates a single breakdown stage between 195°C and 400°C, with approximately 5-6% of the original weight remaining as carbonaceous residue at 400°C (Demirelli et al. 2001). Decomposition of dodecyl methacrylate homopolymer in air started at 150°C with 12.5% weight loss and 75% weight was lost at 400°C (Ghosh et al. 2017). There is a single step weight loss during degradation process for poly-1,6-hexanediol diacrylate. It occurred at temperatures from 300 to 500°C. It degrades through random chain scission and chain end scission mechanism and results in carbon residue (Goswami et al. 2010).

Aged and unaged samples did not show significant differences in their TGA profiles, suggesting that the aging process primarily affected only a thin layer on their surface, while their bulk material remained practically unchanged. Similar conclusions were reported by Zachar et al. (2017) concerning the impact of wood ageing on its ignition temperature.

Thermogravimetric analysis (TGA; Tab. 5, Figs. 7 and 8) revealed three distinct mass loss stages for the samples. The first, slight stage (up to 150°C), attributed to moisture removal (Chao et al. 2019; Aydemir et al. 2011; Zhang et al. 2022), accounted for 1.2% to 3.9% mass loss, indicating initial drying.

Tab. 5: The results of thermogravimetric analysis.

Sample	1st stage		2nd stage		3th stage		Residue at 800 °C [%]
	t_{pDTG} [°C]	Δm [%]	t_{pDTG} [°C]	Δm [%]	t_{pDTG} [°C]	Δm [%]	
Spruce	75.5	3.2	328.0	68.0	440.5	26.4	1.9
Weathered spruce	65.5	3.8	327.5	68.2	436.8	26.9	1.6
Stabilized spruce	118.6	3.9	331.7	86.0	463.9	8.8	1.3
Weathered, stabilized spruce	57.4	1.2	332.5	85.0	461.7	10.9	1.4
Fir	59.3	2.7	320.0	63.5	442.7	31.6	1.9
Weathered fir	69.0	3.3	324.6	63.9	447.5	30.3	2.0
Stabilized fir	60.4	2.9	331.0	79.8	458.2	15.3	1.5
Weathered, stabilized fir	60.0	1.8	330.6	79.9	458.9	15.6	1.6

The second degradation stage (approx. 250-400°C) in wood involved decomposition of hemicelluloses (amorphous, degrading first) and crystalline cellulose (Jambreković et al. 2022). The final stage (around 450°C), absent in a nitrogen atmosphere, was due to the oxidation of the carbonaceous residue by atmospheric oxygen (Korošec et al. 2023). Above 500°C, thermal decomposition was virtually complete, consistent with previous findings (Shapchenkova et al. 2021, Jeske et al. 2012).Fir formed ~5% more carbonaceous residue in the second stage than Spruce; however, with comparable residue at 800°C for both species, fir exhibited greater mass loss in the third stage.

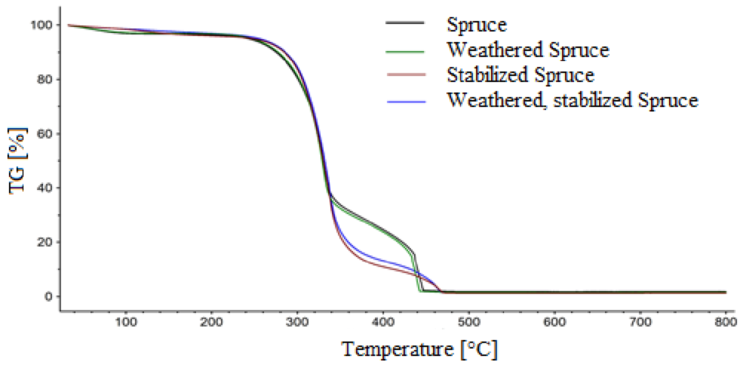

Fig. 7: Thermogravimetric curves of spruce samples.

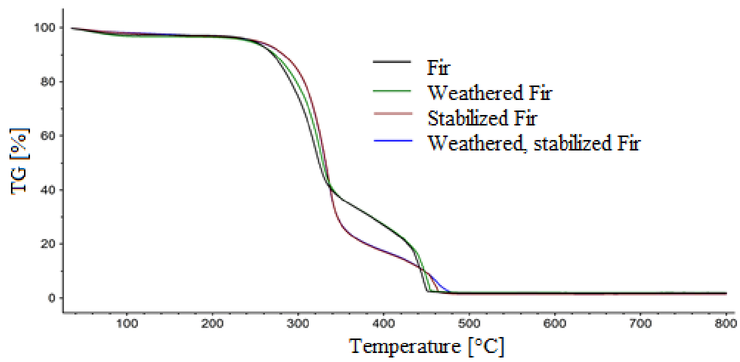

Fig. 8: Thermogravimetric curves of fir samples.

Significant TGA differences were observed between acrylate-containing samples and pure wood. The main decomposition of acrylates occurred at similar temperatures to that of hemicelluloses and cellulose, altering the profile of the second degradation stage. Furthermore, the end of the third mass loss stage shifted ~20°C higher for acrylate samples, indicating slightly greater oxidative stability of their carbonaceous residue. These observations align with literature: poly-2-hydroxyethyl methacrylate in N_2 shows a single degradation stage (195-400°C) leaving ~5-6% residue at 400°C (Demirelli et al. 2001); dodecyl methacrylate homopolymer in air begins decomposing at 150°C (12.5% mass loss), with 75% lost by 400°C (Ghosh et al. 2017); and poly-1,6-hexanediol diacrylate degrades in a single step (300-500°C) via chain scission, yielding carbon residue (Goswami et al. 2010).TGA profiles of aged and unaged samples were similar, suggesting aging effects were superficial, leaving the bulk material largely unchanged.

CONCLUSIONS

This study demonstrated that stabilizing Norway spruce (*Picea abies*(L.) H. Karst) and European silver fir (*Abies alba,*Mill) wood with acrylic resin significantly enhanced critical properties. Treated wood exhibited substantially improved hardness, markedly reduced water absorption, and superior performance during four months of exterior weathering, including better colour stability and resistance to physical degradation and fungal growth. However, accelerated UV chamber testing revealed a complex picture regarding discolouration ($_{\Delta}E$). The laboratory parameter measurements showed distinct colour differences depending on the wood species and stabilization treatment. For spruce samples, the unstabilized wood exhibited a higher colour difference ($_{\Delta}E$=17.99) compared to the stabilized spruce ($_{\Delta}E$=17.62). Conversely, stabilized fir samples showed a greater colour difference ($_{\Delta}E$=16.40) than the unstabilizedfir ($_{\Delta}E$ = 13.63). This mixed response under UV, particularly the increased discolouration observed in Fir, was attributed to the acrylic resin's inherent susceptibility to UV degradation due to the absence of UV stabilizersprimarily under the UVC radiation.Therefore, while this acrylic stabilization method offers considerable improvements for wood durability, particularly for exterior applications, the incorporation of UV protective additives into the resin formulation is crucial for optimizing its performance against photodegradation and ensuring long-term aesthetic stability, especially for species like fir.

ACKNOWLEDGMENTS

Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00459

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