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11TH HARDWOOD CONFERENCE PROCEEDINGS

Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Editors: Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Session III
Surface coating and bonding characteristics of hardwoods

Influence of pretreatments with essential oils on the colour and light resistance of maple (*Acer pseudoplatanus*) wood surfaces coated with shellac and beeswax

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ABSTRACT

Clove (*Eugenia carryophyllata*) and thyme (*Satureja hortensis*) essential oils (C-EO, T-EO) have demonstrated their antifungal properties and might be useful in the field of wood conservation for remedial or preventive treatments. The present research aimed at studying the effect of pre-treatments of maple (*Acer pseudoplatanus*) wood surfaces with alcoholic solutions (10%) of C-EO and T-EO on their colour, subsequent coating with shellac or beeswax and the colour stability of the finished surfaces when exposed to artificial light simulating natural light filtered by window glass.

Pre-treatments with essential oils of maple wood caused only small colour changes ($\Delta E < 3$) under the experimental conditions. Coating with shellac changed totally the colour of all wood samples ($\Delta E > 30$), slightly lower values for those pre-treated with T-EO and higher values for those pre-treated with C-EO. The corresponding values for beeswax finishing were much lower, varying in the range 4.00-7.5, with the same trend. The light induced colour changes after 96 h exposure were almost similar for the uncoated wood samples, regardless the pre-treatment with essential oils. The colour changes of the samples pre-treated with T-EO and coated with shellac or beeswax were almost similar or slightly lower compared to those measured for the controls without pre-treatment. Contrarily, pre-treatments with C-EO resulted in increased light induced colour changes of the coated surfaces, with about 3 units for shellac and 14 units for beeswax. This might be explained by the photo-induced oxidation of eugenol, the main component of C-EO, resulting in formation of new chromophores with quinoid structures, as supported by FTIR. These changes are more visible through the thinned, nearly colourless beeswax film.

INTRODUCTION

Essential oils (EOs) are environmentally friendly products, recognised for centuries as beneficial to human health, when adequately used. Their biological properties include antimicrobial, antifungal and antioxidant effects, being related to their complex organic chemical composition. A number of studies have demonstrated their potential for wood preservation (Panek et al. 2014, Bahmani and Schmidt 2018, Reiprecht et al. 2019, Simunkova et al. 2022,) by their activity against wood decay fungi and moulds. Employment of EOs as alternative to classic biocides in the field of wood / furniture conservation for remedial or preventive treatments (Pop et al. 2021, Pop et al. 2022, Tran-Ly et al. 2022) is a promising option. Conservation materials and treatments need to satisfy specific requirements. For instance, they should not change the colour of the treated materials, should be compatible with the traditional finishing material and they should not affect negatively the ageing behaviour of the artefacts. To meet these requirements, studies in the field come to demonstrate the advantages of utilisation of essential oils for wood treatments: Panek (2014) highlighted that essential oils had no negative effect on the colour stability on beech wood and Simunkova (2022) concluded that the colour of spruce wood treated with essential oils was preserved and wetting properties and adhesion of wood surfaces were improved.

The ageing of wooden artefacts is always associated with changes in colour (Kranitz 2014). Light-induced ageing of different wood species and coated surfaces is a widely studied phenomenon, but mostly for outdoor applications. Although maple wood is a common hardwood species, often employed in conservation-restoration works, quite limited research focussed on its colour investigation and behaviour when exposed to light in indoor conditions (de Moura and Hernandez 2005, Dzurenda et al. 2022, Timar et al. 2016). Considering these aspects, previous research of the authors investigated clove

(*Eugenia carryophyllata*) and thyme (*Satureja hortensis*) essential oils as modifying agents for Shellac solutions. A good compatibility with alcoholic shellac solutions was found, alongside a slight influence of modification on the colour of finished maple surfaces and their colour changes by UV-VIS light simulating indoor conditions. (Timar and Beldean 2022).
The present research aimed at studying the effect of pre-treatments of maple (*Acer pseudoplatanus*) wood surfaces with alcoholic solutions (10%) of clove and thyme essential oils on their colour, compatibility with shellac and beeswax in traditional finishing technologies and the colour stability of the coated surfaces when exposed to light in indoor conditions. An accelerated laboratory test to artificial UV-VIS radiation, simulating natural light filtered by window glass, in conjunction with colour measurements in the CIELab system and FTIR investigations, were employed for this purpose.

MATERIALS AND METHODS

Materials

Clove (*Eugenia caryophyllata)* essential oil (coded C-EO) and Thyme (*Satureja hortensis*) essential oil (coded T-EO), as a commercial products (100 %) available on Romanian market (https://www.steauadivina.ro) were employed. Solutions of EO in ethyl alcohol at volumetric ratios of 1:10 (v:v) were prepared for this purpose.
A shellac solution (coded SL) with an addition of 10% rosin was prepared by dissolving in ethyl alcohol (98%) under stirring on a warm water bath (40–50 °C). The solids content was 13.2%.
Natural beeswax sheets (coded BW) were dissolved on a warm water bath (40–50 °C) in white spirit D40-Denatured from CTS Company (https://ctsconservation.com), resulting a paste-like polish with concentration of 18-20 %.
Wood samples from European maple (*Acer pseudoplatanus*) with dimensions of (120x80x5) mm, with radial faces, were employed. The surfaces were sanded with H120, H150 grit paper and cleaned from dust. All samples were conditioned (20±2°C, 55±5% RH) before and after finishing and prior to any investigation.

Treating and finishing of wood samples

The experimental schedule for wood samples preparation (schematically presented in Figure 1) included:(*i*) pre-treatments with essential oils (C-EO, T-EO); (*ii*) coating with shellac or beeswax (SL, BW) and (*iii*) the combined pre-treatments with essential oils and subsequent coating with shellac or beeswax (C-EO-SL, T-EO-SL and C-EO-BW, T-EO-BW).

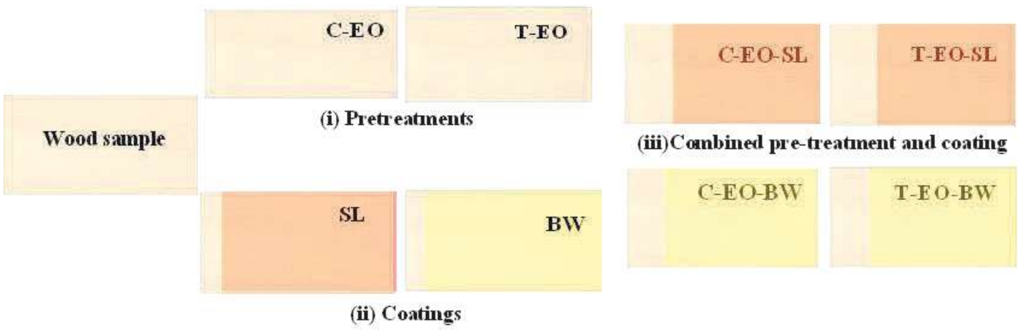

Figure 1: Experimental treating schedule and codification of the samples

The essential oils were applied by brushing until fibre saturation in two successive layers (30 min apart) at total application rates of about 160-170 g/m^2. This step was followed by 24h conditioning at room temperature. Control untreated samples and pre-treated samples were then finished by hand with SL and BW, following the specific traditional techniques.
Shellac base coat was applied by brushing in three layers of about 110 g/m^2 at intervals of 30-60 minutes drying time. Afterwards, the samples were sanded with 320 grit size paper and finishing was continued by employing a polishing rubber to apply the shellac solution in thin coats until pores filling and glossy surface were obtained.
Beeswax polish, pre-heated on water bath, was applied by brushing in three layers at a total specific consumption of 135-150 g/m^2. After 72 h conditioning at room temperature, the

surfaces were lustred with a polishing pad until a matt gloss was attained. Four replicates for each treating variant were prepared. Two of them were kept as control, while the other two were exposed to light

It has to be remarked that the pre-treated samples could be satisfactory finished, with no obvious incompatibility issues between pre-treatments with C-EO and T-EO and SL or BW. However, slightly longer intervals between the application of the successive layers of coatings were necessary in the case of C-EO pre-treatment.

Accelerated UV-VIS aging exposure

A Feutron 400 FKS environmental climatic chamber (Germany) equipped with a UVA Spot 400T lamp, fitted with a glass H2 filter, was employed to expose the wood samples to light in the range of 295 to 600 nm, simulating natural light filtered by window glass. Each cycle of 24 h UV exposure consisted in four steps of 6 h UV irradiation at 40°C alternated with dark periods of 0.5 h. This procedure was repeated four times, resulting 24, 48, 72 and 96 hours of exposure. More details related to procedure were previously published by the authors (Timar and Beldean 2022). Two replicates from each treating and finishing variant, alongside corresponding two uncoated controls, were tested simultaneously.

Colour measurements

An AvaSpec-USB2 spectrometer (Netherlands) equipped with an integrating AVA sphere, with a circular measuring aperture of 8 mm, were employed for colour measurements, under standard illuminant D65 and 2° standard observer. Data were processed with AVASOFT—version 7.7

The samples were measured initially, prior any treatment or finishing and after treatments, before light exposure and after each period of exposure. A special device was employed to carry out the repeated colour measurements in the same 5 points/sample. The CIELab colour coordinates L*, a*, b* were registered and averages were calculated for each sample and each treatment variant. Colour differences ΔE were calculated with Eq. 1:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \qquad (1)$$

Where: ΔL^*, Δa^* and Δb^* are the differences of initial and final values (before and after treatments or ageing for different periods of time) of L^*, a^* and b^* parameters.

FTIR Investigations

An Alpha Bruker equipment endowed with attenuated total reflection module (ATR) was used for FTIR investigation of wood surfaces prior and after pre-treatments and coating, before and after light induced ageing. All spectra were registered in the range 4000-400 cm^{-1}, at a resolution of 4 cm^{-1} and 24 scans per spectrum and were further processed for baseline correction and smoothing, employing OPUS software. Average spectra of minimum 3 recordings (on three random areas) of the investigated samples were computed for each treatment variant and exposure situation (0, 24, 48, 72, 96 hours of light exposure). The min-max normalised average spectra were compared to highlight detectable chemical changes associated with the different preparation phases and light exposure of the maple wood samples.

Statistical Data Processing

The measurements performed in duplicates were presented as mean value ±SD and were statistically analysed by One-way Anova and Post-hoc analysis in Excel. The difference between groups was considered significant at a confidence level of 95% (α=0.05) when $p<0.05$.

RESULTS AND DISSCUSION

General aspects

Pre-treatments of maple wood samples did not impede their subsequent coating with shellac and beeswax solutions by the traditional techniques. Filled grain finishes, with glossy (SL) or silky matt effect (BW), which enhanced or highlighted the natural beauty of wood were obtained. An image of the general aspect of the various samples prepared and investigated in this research is presented in Figure

2. This includes, comparatively, scanned images of the samples prior (Figure 2a) and after exposure to light induced colour ageing for 96h (Figure 2b).

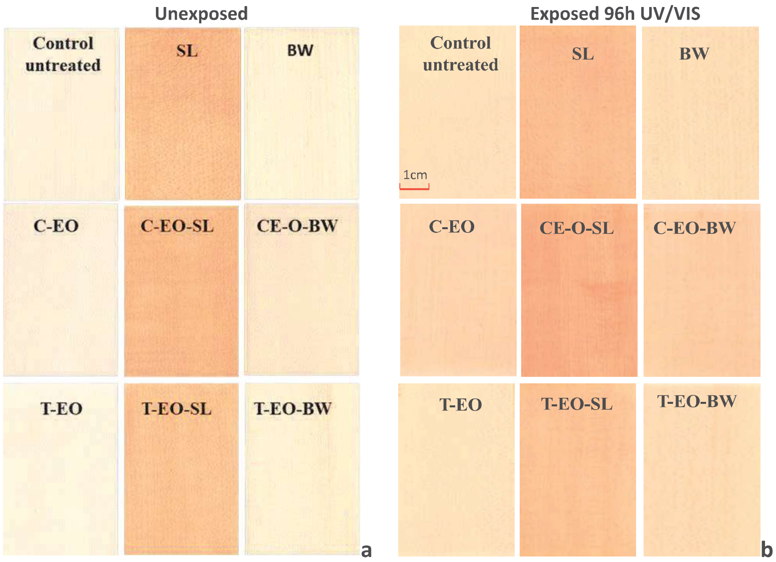

Figure: 2 General aspect of maple wood samples uncoated and coated with shellac (SL) and beeswax (BW) before (a) and after exposure to UV/VIS light, in an accelerated test, for 96 h (b). Untreated controls and samples pre-treated with clove (C-EO) and thyme (T-EO) essential oils are included in both groups

It is visible that all the samples, regardless pre-treatment or coating, suffered slight colour changes as result of exposure to light under the experimental conditions employed in this research. These colour changes were perceived as darkening and shade modifications, different samples turning more reddish or yellowing. The in-time evolution of the global colour changes (ΔE) is presented by the plots in Figure 3.

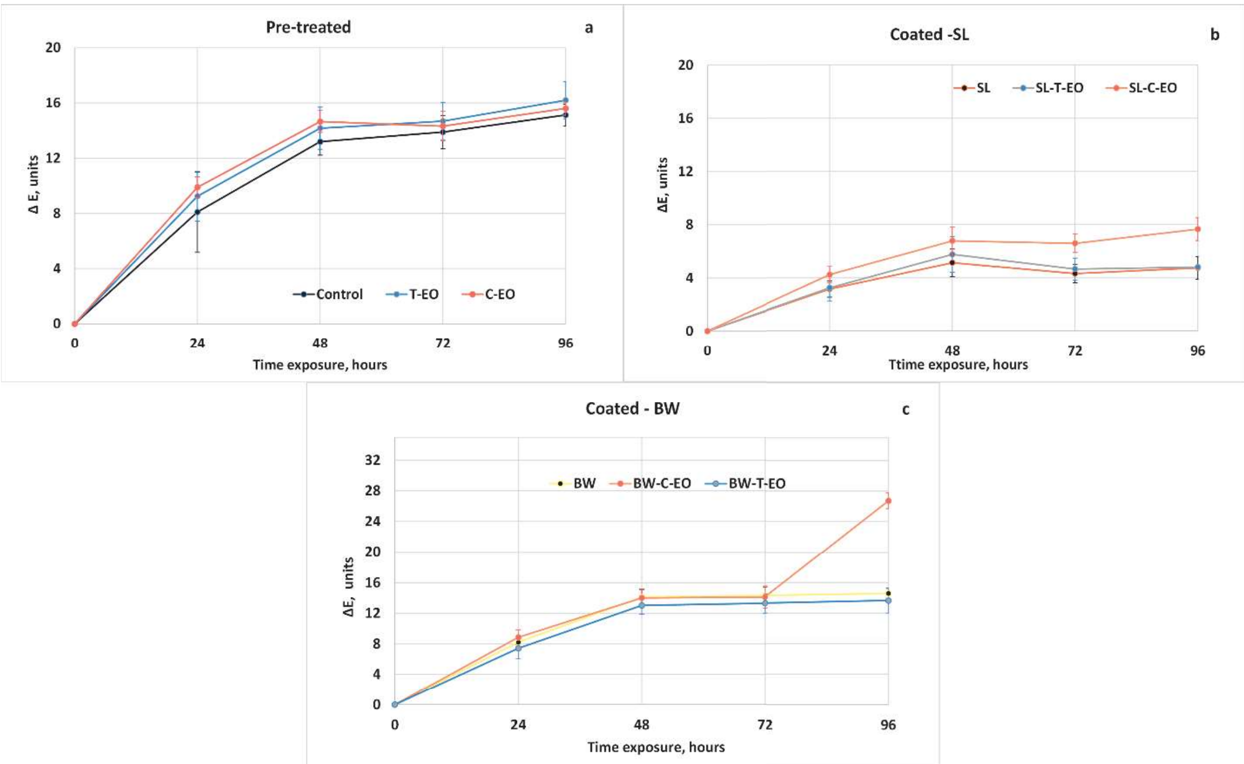

Figure 3: Evolution of colour differences (ΔE) after 24,48,72 and 96 hours of exposure to UV-VIS accelerating ageing; samples pre-treated with C-EO and T-EO(a)-, samples coated with SL(b) and BW(c)

The evolution of colour difference values ΔE indicated a rapid change at the beginning of the ageing process, and then, depending to the type of treatment, this evolution was more or less abrupt. For instance, uncoated: control and pre-treated samples (C-EO and T-EO) registered a similar increasing trend (Figure 3a). The coating with SL (Figure 3b) indicated a protective effect of shellac, reflected in smaller ΔE values (<8 units) compared with uncoated samples. Wood coated with BW recorded similar values of ΔE with uncoated samples up to 72h exposure (13-14 units) followed by a sharp increase of ΔE for C-EO-BW samples at 96h, due to increasing of redness a* and yellowness b* parameters and decreasing of lightness L*. More research and extended exposure times are necessary to explain this particular evolution.

Influence of pre-treatments on the colour of maple wood surfaces

The colour parameters (L*, a*, b*) calculated as average values and the corresponding standard deviations (*italics*) for uncoated and coated samples, without pre-treatment or pre-treated with essential oils are presented in Table 1. The colour differences ΔE resulting from pre-treatments with C-EO and T-EO and caused by coating with SL and BW are also presented.

Pre-treatments with essential oils caused only small colour changes (ΔE values of 2.46 for C-EO and 1.67 for T-EO). These values account for small colour differences (ΔE =0.2-2.0) or colour differences visible only with high quality screen (ΔE=2.0-3.0), according to Allegretti et al 2009. Statistical analysis of data indicated that pre-treatment with C-EO resulted in significant differences of parameters L* and a*(samples became more reddish and darker compared to controls) and no significant difference in yellowness b*. None of the colour parameters were found statistically different for pre-treatment with T-EO. It concludes that T-EO did not cause statistically significant colour changes of the maple wood substrate, which agreed with visual perception.

Table 1: Colour parameters for uncoated and coated samples, without pre-treatment or pre-treated with clove (C-EO) or thyme (T-EO) essential oils, before ageing test

Pre-treatment Coating		**No (Control)**			**C-EO**			**T-EO**			**CE-O**	**T-EO**
		L*	**a***	**b***	**L***	**a***	**b***	**L***	**a***	**b***	**PTE index**	**PTE index**
Uncoated	Av	86.69	3.33	13.52	83.62	5.04	14.13	86.05	3.48	12.95	-	-
	Stdev	*0.92*	*0.49*	*1.58*	*0.29*	*0.14*	*0.39*	*0.95*	*0.39*	*0.99*		
	ΔE	-	-	-	**2.46** *(0.57)*			**1.67** *(1.58)*				
Coated-SL	Av	69.33	10.25	41.02	69.33	11.20	44.06	71.48	9.63	40.89	1.16	0.92
	Stdev	*1.35*	*0.68*	*1,34*	*1,63*	*1,30*	*0,92*	*0,88*	*0.38*	*1.15*		
	ΔE	**33.02** *(1.57)*			**38.54** *(1.33)*			**30.54** *(1.92)*				
Coated - BW	Av	85.52	3.51	16.55	81.52	5.44	19.76	83.91	4.08	17.98	1.87	1.25
	Stdev	*0.68*	*0.43*	*0.57*	*1.01*	*0.48*	*0.79*	*1.05*	*0.22*	*1.56*		
	ΔE	**4.00** *(0.38)*			**7.50** *(0.70)*			**5.00** *(1.09)*				
Notes	**ΔE** values represent colour changes due to the pre-treatments (grey), respectively coating with SL (pink) or BW (yellow) **PTE index** is calculated in Eq.2											

Coating with shellac changed totally the colour of all wood samples (ΔE 30.54-38.54) the values of ΔE above 12.0 corresponding to different colours in visual perception (Allegretti et al. 2009). This colour change is due to the reddish-brown colour of this natural resin, well reflected by the significant increase of the redness (Δa* values of about 6-7 units) and yellowness (Δb* values of about 27-30 units) of all the SL coated samples compared to their corresponding uncoated controls. Accordingly, a global colour difference value (ΔE) of 33.02 was obtained for the coated controls, while the values for the pre-treated substrates were slightly (by 2.5 units) lower (ΔE=30.54) for T-EO (no significant statistic) and with about 5 units higher (ΔE= 38.54) in the case of C-EO (statistically significant difference).

Coating with beeswax resulted in much lower colour changes (ΔE: 4.00-7.5 units), with the minimum change for the untreated controls and maximum value (ΔE =7.50 units) for those pre-treated with C-EO. The corresponding value for the samples pre-treated with T-EO was 5.0 units, both of them being statistically different compared to the untreated control.

In order to better highlight the influence of pre-treatments on the colour of the coated maple wood samples, a pre-treatment effect index (PTE) was calculated as the ratio between the ΔE values determined for the pre- treated samples and the control samples, according to Eq. 2

$$PTE = \frac{\Delta E\ pretretated}{\Delta E control} \quad (2)$$

The PTE indexes presented in Table 1 clearly show that influence of pre-treatment of maple wood substrates with C-EO or T-EO is dependent on both the type of essential oil and the type of finish. Clove essential oil is a slightly yellow-orange product and its influence on the colour of the uncoated substrates and final finished surfaces is higher (PTE=1.16-1.87) compared to thyme essential oil (PTE= 0.92-1.25). Also, its influence is higher for the surfaces coated with beeswax, with light beige colour (PTE=1.87), than in the case of surfaces coated with the darker, reddish-brown SL solution (PTE=1.16).

Influence of pretreatment with essential oils on the light-induced colour changes

In Table 2 are presented the final colour changes after 96 hours of exposure to accelerating UV-VIS aging, calculated as average values and their SD (*italics*) for each type of pre-treatment and coating.
The light induced colour changes after 96 h light exposure under the experimental conditions employed in this research were pretty similar for all the uncoated wood samples, regardless the pre-treatment with essential oils (ΔE: 15.13-16.20), values which were found not statistically different. Lower colour changes, varying in the range ΔE: 4.74-7.66, were registered for the shellac coated samples, with minimum values for control and T-EO pre-treated samples (4.74 vs 4.80). In all cases the protective effect of SL film on the effect of light exposure was maintained. The corresponding values for beeswax varied in a larger range ΔE: 13.64-26.74 units. Compared to the ΔE of 14.56 determined for BW coated controls without pre-treatment, the values for the T-EO pre-treated samples were slightly lower (ΔE = 13.64 – statistically not different), while that for the C-EO pre-treated samples was considerably higher (ΔE = 26.74), overpassing the value for the corresponding uncoated samples (ΔE =15.13).

Table 2: Colour changes for uncoated and coated samples, without pre-treatment or pre-treated with clove (C-EO) or thyme (T-EO) essential oils, after ageing test (96h UV/VIS)

Pre-treatment Coating		Colour changes after 96 h light exposure												Influence index	
		No (Control)				C-EO				T-EO				C-EO	T-EO
		ΔL*	**Δa***	**Δb***	**ΔE***	**ΔL***	**Δa***	**Δb***	**ΔE***	**ΔL***	**Δa***	**Δb***	**ΔE***	**PTE**	**PTE**
Uncoated	Av	-7.38	3.70	12.68	**15.13**	-9.86	3.33	11.60	**15.60**	-6.54	2.74	14.53	**16.20**	1.03	1.07
	stdev	*0.35*	*0.30*	*0.75*	*0.80*	*0.34*	*0.39*	*0.74*	*0.48*	*1.25*	*0.66*	*1.07*	*1.34*		
Coated-SL	Av	-1.90	3.99	0.71	**4.74**	-5.16	4.76	-2.29	**7.66**	-2.33	3.87	1.11	**4.80**	1.61	1.01
	stdev	*1.03*	*0.73*	*1.39*	0.86	*0.89*	*0.71*	*2.15*	*1.18*	*0.71*	*0,53*	*1.30*	0.94		
Coated-BW	Av	-7.09	4.56	11.84	**14.56**	-12.37	8.06	22.24	**26.74**	-6.84	4.23	10.96	**13.64**	1.83	0.94
	stdev	*0.40*	*0.61*	*0.83*	0.67	*1.25*	*0.76*	*1.14*	1.04	*0.94*	*0.38*	*1.74*	1.64		

The calculated PTE indexes were close to 1.0 (0.94-1.07) for the T-EO pre-treated samples, showing no or very little influence on the colour changes caused by light exposure regardless the uncoated or coated state and type finish. On the contrary, in the case of C-EO, the pre-treatment had no influence on the light induced colour changes of the uncoated samples (PTE=1.03), but resulted in considerably higher colour changes for the coated samples: PTE=1.61 (SL) and PTE=1.83 (BW). This may indicate chemical changes determined by the presence of C-EO:

FTIR investigations

Both wood and the employed essential oils are organic materials with complex chemical composition, with more constituents with various chemical structures, so that complex FTIR spectra reflect these features. As infrared spectra are vibrational spectra of the different chemical bonds, functional groups and other structural moieties, it is easy to understand overlapping of most absorption bands in the spectra of wood substrates and essential oils (Figure 4a) or in the spectra of uncoated and SL coated samples (Figure 4b).

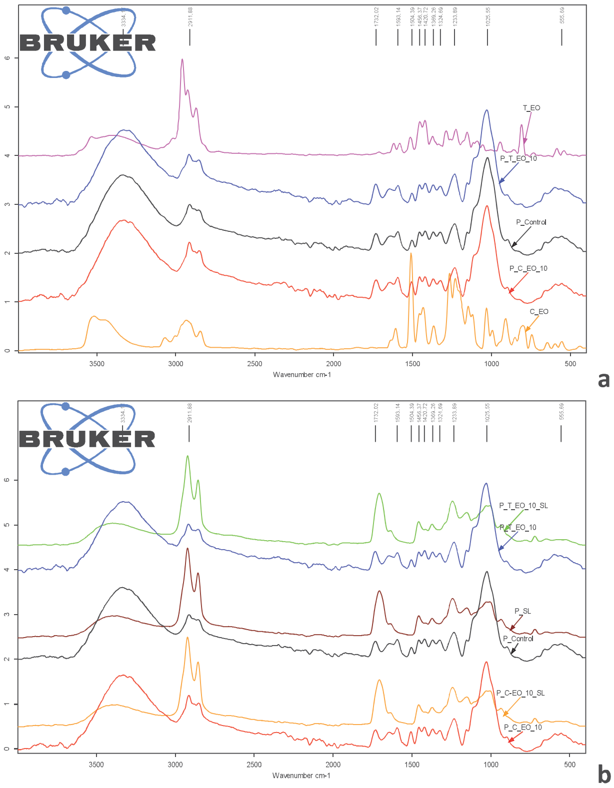

Figure 4: FTIR spectra for clove and thyme essential oils (C-EO, T-EO), control and pretreated maple wood surface (a); comparative spectra of uncoated and shellac (SL) coated maple wood surfaces with different pre-treatments, before ageing

It is worth noting that a distinct peak of C-EO at about 1514 cm^{-1}, assigned to eugenol, its main chemical component, is overlapping the absorption band at 1504 cm^{-1}, assigned to the skeletal vibration of aromatic ring in lignin, due to their common phenyl-propane skeleton. However, the increase of this peak is visible for the uncoated C-EO pre-treated samples. Coating with shellac hinders this particularity due to the fact that actually only the surface coating layer is analysed by the FTIR-ATR technique. More details on the spectra of C-EO, T-EO and shellac were previously reported (Timar and Beldean 2022).

The comparative FTIR spectra for the uncoated and coated maple samples, with or without pre-treatment, before and after 96 h light exposure are depicted in Figure 5. Only the fingerprint region was chosen for the uncoated and SL coated samples (Figure 5a, b), while the spectra on the whole registered IR range are presented for the samples coated with beeswax (Figure 5c).

The spectra of control sample (M) after 96 h light exposure (Figure 5a) clearly show the specific pattern of wood photodegradation by UV radiation: decrease of the lignin absorption at 1504 cm^{-1}, which nearly disappears due to lignin degradation, occurring in parallel with photo-oxidative processes highlighted by the increased absorptions at 1732 cm^{-1} (unconjugated carbonyl) and 1640 cm^{-1} (aromatic ketones, conjugated carbonyl bonds), while the absorption at around 1600 cm^{-1} (aromatic ring) is receded and included in the broader band at 1640 cm^{-1}.These are good accordance with previous research and literature data and explain the associated colour changes (Evans et al. 2005, Kataoka et al. 2007, Tolvaj et al. 2013, Timar et al. 2016, Timar and Beldean 2022).

For the samples pre-treated with C-EO and T-EO, similar changes occur, especially for T-EO, but the decrease of the peak at 1504 cm^{-1} is less pronounced (especially for C-EO), while the increase of the unconjugated carbonyl bond seems more important. At the same time the increase of the absorption at 1640 cm^{-1} seems smaller and the absorption at 1600 cm^{-1} remains distinct, especially in the case of C-EO pre-treatment.

These changes might suggest a possible protective effect of the two essential oils, even if the small differences in light induced colour changes were not statistically significant. C-EO and T-EO were found to absorb UV (Sharma et al. 2020) radiation and undergo photo-oxidative reaction, by a radicalic mechanism (Elgendy et al. 2008).

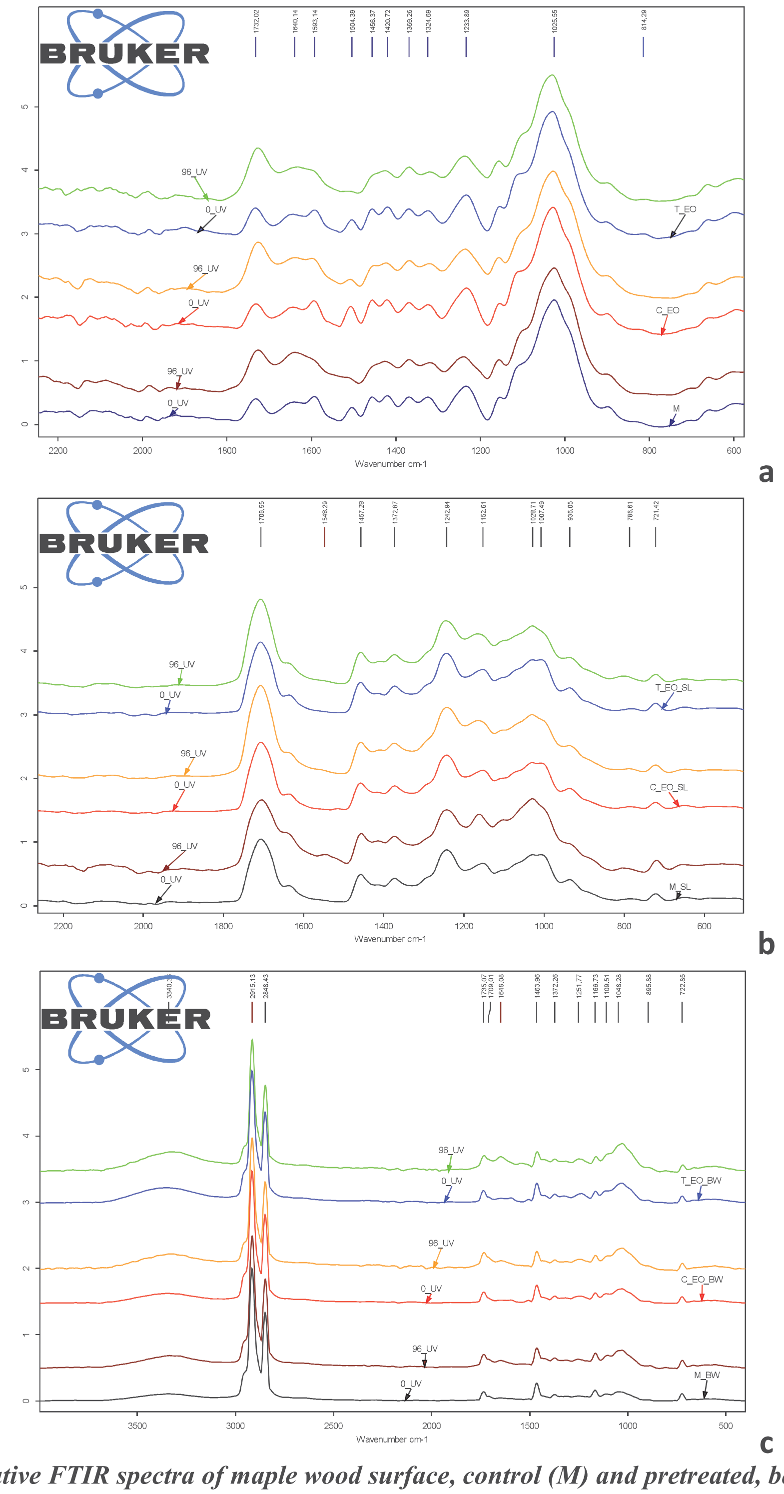

Figure 5: Comparative FTIR spectra of maple wood surface, control (M) and pretreated, before (0-UV) and after 96 h light induced accelerated ageing (96-UV) for: uncoated samples (a); shellacs (SL) coated samples (b); beeswax (BW) coated samples (c)

Essential oils with phenolic main components have been recognised as active antioxidants by their radical scavenging activity (Gulcin 2011, Fadel et al. 2020), but this may result in their own oxidation to chromophores containing products. C-EO was recognised as a very active antioxidant essential oil and its oxidation by different pathways to products containing quinoid structures (Elgendy et al. 2008, Yildiz et al. 2017), known as chromophores (Alfieri et al. 2021), was demonstrated.
The spectra of SL coated samples before and after 96h light exposure (Figure 5b) show only little differences, demonstrating a fairly good resistance. For the M_SL samples a slight increase of the small shoulder at around 1637 cm^{-1}, slight trend of broadening of absorption at 1706 $cm^{-1}$and a trend of a new

absorption at about 1550 cm^{-1} are observed, denoting some oxidative phenomena. For the C-EO and T-EO pre-treated samples the only detectable change is an increase of the unconjugated carbonyls absorption at 1706 cm^{-1}. An increase of this absorption band was assigned to C-EO and T-EO oxidation following sun light exposure, while their embodying in polymers matrix inhibited the degradation process of the polymers themselves (Masek et al. 2021).
The spectra of BW coated samples before and after 96h light exposure (Figure 5c) show only little differences, demonstrating a very good ageing resistance of beeswax. A slight trend of increased absorptions at around 3400 cm^{-1} (-OH groups) and around 1040 cm^{-1} (C-O, C-O-C vibrations), both of high intensity in the wood FTIR spectra, may indicate an increased transparency to FTIR of the substrate due to wax layers thinning by absorption into the wood structure, considering its thermoplastic character and the fact that light irradiation was achieved at 40°C. These results are supported by previously published research (Liu et al. 2019, Liu et al. 2022), which also concluded on the high transparency to UV light of beeswax in favour of light induced colour changes of the underneath wood substrate.
Accordingly, the higher light induced colour changes determined for the maple wood surfaces pre-treated with C-EO and T-EO and coated with beeswax should be attributed to the increased transparency of the nearly colourless and thinned coating film, making visible the colour changes of the wood substrate. These light induced colour changes were maximum for the substrate pre-treated with C-EO due to its capability of absorbing UV light and oxidation to coloured products. A similar result was reported for spruce-wood pre-treated with C-EO, which demonstrated an increased colour change under the action of UV light in a natural and an artificial weathering test (by Oberhofnerová et al. 2018).

CONCLUSIONS

Influence of pre-treatment with clove (*Eugenia carryophyllata*) and thyme (*Satureja hortensis*) essential oils on maple wood substrates is dependent on both the type of essential oil and the type of finish.
No application problems or compatibility issue were observed during the treating with clove (C-EO) and thyme (T-EO), though slightly longer intervals between the application of the successive layers of coatings were necessary in the case of C-EO pre-treatment.
Pre-treatment with T-EO had no significant influence on the colour of the uncoated or coated surfaces, neither on their resistance to light, in a simulated indoor conditions test.
Pre-treatment with C-EO resulted only in small colour changes of maple surfaces, without significant influence on the light induced colour changes of the uncoated surfaces. However, the light induced colour changes of the C-EO pre-treated coated samples were significantly higher than those of coated controls.
UV absorption and subsequent photo oxidation of C-EO, resulting in new chromophores, alongside the differences in colour and transparency to ultraviolet and visible between of shellac and beeswax, might explain these results. This hypothesis is partly sustained by FTIR, but more research is needed.
Based on the colour changes results, among the two essential oils tested, T-EO could be considered for potential application in the field of conservation, as pre-treatment in finishing technologies.
The potential recurrent benefits in terms of behaviour of the coated surfaces in conditions of biological attack risk will be investigated in future research.

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