ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 265-275

ECOLOGICAL MATERIALS USED IN PRESERVATION AND RESTORATION ON NEW WOOD

Silvea PRUTEANU
Phd. Student - "Alexandru Ioan Cuza" University Iasi - Faculty of Geography; Nature Science
Address: ARHEOINVEST Platform, Blvd. Carol I 11, 700506, Iasi, Romania
Laboratory of Scientific Investigation and Conservation of Cultural Heritage
E-mail: silvia.lazar.pruteanu@gmail.com

Lăcrămioara Gabriela GHERMAN
Phd. Student - "Alexandru Ioan Cuza" University Iasi - Faculty of Geography; Nature Science
Address: ARHEOINVEST Platform, Blvd. Carol I 11, 700506, Iasi, Romania
Laboratory of Scientific Investigation and Conservation of Cultural Heritage
E-mail: gabrielascutarita@yahoo.com

Ion SANDU
Prof.univ.dr.- Alexandru Ioan Cuza" University Iasi
Address: ARHEOINVEST Platform, Blvd. Carol I 11, 700506, Iasi, Romania
Laboratory of Scientific Investigation and Conservation of Cultural Heritage
E-mail: Ion.sandu@uaic.ro

Mikiko HAYASHI
National Research Institute for Cultural Propeties, Center for Conservation Science and Restauration Techniques, Tokio, Japan
E-mail: hayashimikiko@gmail.com

Dănuţ-Gabriel COZMA
"Alexandru Ioan Cuza" University from Iasi, Faculty of Chemistry
Address: 11 Carol I Blvd., Iasi, 700506, Romania
E-mail: dcozma@uaic.ro

Viorica VASILACHE
CS III. - Alexandru Ioan Cuza" University Iasi
Address: ARHEOINVEST Platform, Blvd. Carol I 11, 700506, Iasi, Romania
Laboratory of Scientific Investigation and Conservation of Cultural Heritage
E-mail: viorica_18v@yahoo.com

Irina Crina Anca SANDU
CSIII. dr. - Requimte e Núcleo do Departamento de Conservação e Restauro, Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Campus da Caparica
Address: 2829-516 Caparica, Portugal
E-mail: lilly75flower@yahoo.com

Abstract:
The paper presents the effects of ecological treatments on different wood species. Tests are made on lime tree and oak, which are immersed in red oil and propolis in alcohol solution disepersed in red oil.. The subject of analysis is observing these substances effect on dimensional stability and hydric modification on new wood. Also, is highlighted the behavior of the wood species after the immersion in the two solutions, compared with untreated wood of the same species, hydric stabilised. Is presented a new preservation procedure safer for the curator.

Key words: *old wood; lime tree; oak; hydric modification; dimensional stability.*

INTRODUCTION

Old wood from artefacts, used either as panel (base), or as an ornament, suffers in time a series of degradations and deteriotations under the infuence of the environemental factors, which can be lead to precolaps depending on their aggression. Beeing an organic material with heterogenic porous structure, the effects of the deterioration and degradation processes act quickly in the absence of some adequate measures of passive (air conditioning) and active preservation (the treatment which stops the degradation and deterioration in their evolution). Some of the worst effects, very common in wood art work are: wood fragilisation and decay due to viruses, bacteria, yeasts, fungi, lichens etc., cracking and erosion due to the wood boring insects, all of them amplified by the aggression of the moisture and high temperature, and last but not the least carbonization due to combustion. Along with these, the fading effect of the wood is met and is seen on the panel paintings or at items with spatial configuration: the bending, twisting, cracking, fracturing and others (Hayashi 2008, 2009, 2010a, b, Sandu 2002, 2008, Unger *et al*. 2001, Vasilache *et al*. 2008, Walker 2006).

From this point of view, wood is the subject of some meticulous research regarding the implication of the optimal processes of hydric and dimensional stabilization, of protection against microbiological agents and boring insects, fireproofing, waterproofing, and everything that imply climatic and mechanical protection. The ideal situation would be that this treatments, with very good retention, are applied immediately after the artistic work is done, so that no later intervention would harm it (Ciocan *et al*. 2009, Hayashi *et al*. 2008, 2009, Hunter 1995, Sandu *et al*. 2007, 2008a, b, c and d, 2009a, b, 2010, Siau 1995).

The treatments needed for the occurrence of deterioration or degradation processes, in most cases with a complex mechanism induced by multiple factors from the time of the exhibition or utilization, are necessary to be applied on as few steps as possible, using materials with minimal influence over the wood (Sandu 2002, 2008, Unger *et al*. 2001, Walker 2006).

There are known a series of modern procedures for old wood protection through the use of synergistic organic systems (Sandu *et al*. 2009c, d, 2010b, 2011b), with various functions for blocking the cumulative effects of deterioration and degradation, with high permeability in the volume faze by forming an uniform nanolayer, compatible with the persistent retention. Lately attention turns to natural organinc products or of semisynthesis, ecological as: liquid paraffin and petroleum derivatives, wax products, tannins, lignin sulphonates, alkaloids, terpenes, flavones and others (Sandu 2002, 2008, 2011a, Unger *et al*. 2001, Walker 2006).

It was developed a method of determination of the normal range of variation for the moisture content in new wood (Sandu *et al*. 2009e, 2010a, 2011c, Siau 1995, Vasilache *et al*. 2009), located between the limits in which the wood gives microstructural destructions on fiber and cell level: minimum moisture content (0,5…1,5%) and the saturation point of the moisture content in fibre (32…36%), depending on the specie, tree age, state of conservation etc. (Hayashi *et al*. 2010a, b). This method has wide applications in archaeometry, (for establishing some temporal occurrence characteristics) and in the impact studies of some active preservation treatments.

This work analyses the variation in longitudinal, radial and tangential shrinkage together with the variation in density and porosity for two wood species (lime and oak), when treated with red oil and alcoholic propolis solution in red oil compared with untreated samples, at different relative humidities (100%, 85%, 65% and 25%). The two natural treatments allow the hydric and dimensional stabilization, as well as protection against microbiological agents and boring insects. For waterproofing and everything that implies climatic and mechanical protection, it was necessary to study the effect of the large variations in the relative air humidity on the treated wood.

OBJECTIVE

The purpose of this paper is to present a study regarding the influence of two natural, organic products (propolis and red oil) used in a synergistic system, compatible with two species of new wood (lime tree and oak), over some physical and structural charateristics.

EXPERIMENTAL PART

Two species of new wood were taken for this study, the most common in Romanina’s art work: lime tree (*Tilia sp.*) and oak (Quercus petraes L.). For each type, as a reference it was used new wood hydric stabilized and untreated against treated new wood and hydric stabilized. The samples were made within the dimensions: longitudinal L (40mm), Tangential T (20mm) and Radial (10mm).

The hydric stabilization was made by holding the sample in the oven at 103±5°C, until it a constant weight. A set of three samples from each specie was used as a reference and other sets of three samples were treated with red oil and alcoholic propolis solution 20% dispersed in red oil, by immersion for 60minutes, according to a new method (Sandu *et al*. 2009b, c, 2010b, 2011b). After the immersion, filter paper was used to absorb the excess solution and then the samples were weighed to a constant weight, for

ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 265-275

6 days in normal atmospheric conditions (22°C and 55%RH) and afterwards measured over the three dimensions: radial, tangential and longitudinal. Afterwards the samples underwent a process of hydration in a climate controlled chamber type Aer concept (FIRLABO), with constant temperature of 20°C and a maximum of 100% humidity, until reaching a constant weight when the measures were taken again. Then, the samples underwent a gradual process of dehydration in the same climate controlled chamber at different humidity values (100%, 85%, 65% and 25%). At each dehydration step, the shrinkage of the samples was measured. Based on the wood shrinkage at each step of dehydration (100%→85%, 85%→65%, 65%→25% and 25%→0%) the volume change was measured, the specific mass and porosity. Porosity (P) was calculater with following formula:

$P = (1-\rho_0/1530) \times 100$ (%) (1)

Where: ρ_0 represents the oven dry density calculated with the formula:

$\rho_0 = W_0/ V_0$ (kg/m^3) (2)

For studying the variation in porosity, two levels of relative humidity were considered, “before treatment” and “after treatment”, respectively at 85% before treatment and 25% after the treatment.

RESULTS AND DISCUSSIONS

LIME TREE: variations recorded

In **Fig. 1** it is presented the longitudinal shrinkage variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

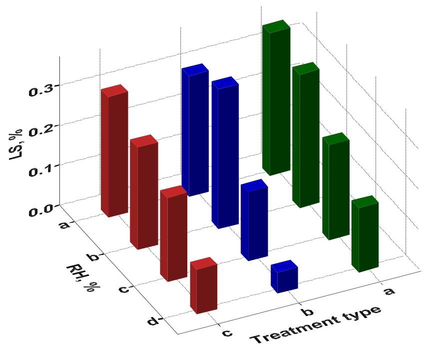

Fig. 1
Variation of longitudinal shrinkage for lime tree:
Relative humidity (RH), with specifications: a - 100%, b - 85%, c - 65%, d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig. 2** it is presented the radial shrinkage variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

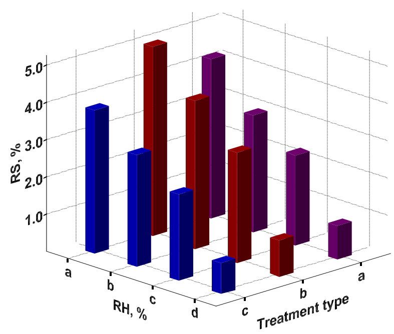

Fig. 2
Variation of the radial shrinkage for lime tree:
Relative humidity (RH), with specifications: a - 100%, b - 85%, c - 65%, d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig. 3** it is presented the tangential shrinkage variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

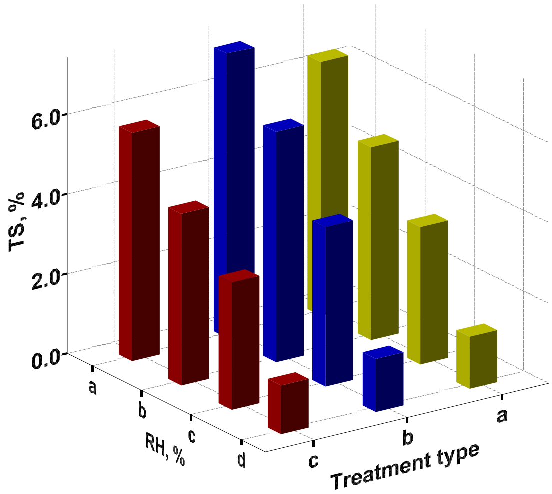

Fig. 3
Variation of the tangential shrinkage for lime tree:
Relative humidity (RH), with specifications: a - 100%, b - 85%, c - 65%, d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig. 4** it is presented the volume shrinkage variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

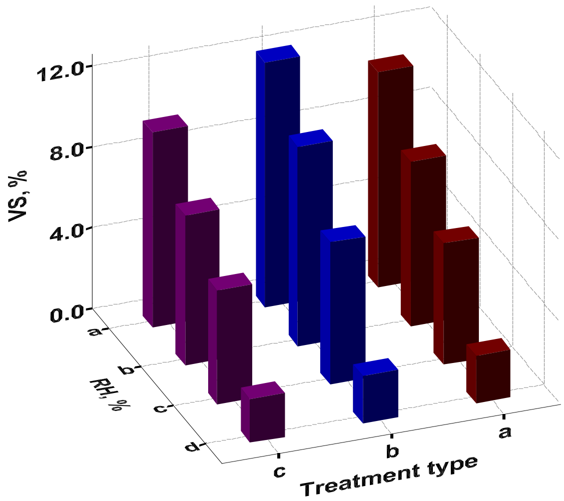

Fig. 4
Variation of the volume shrinkage for lime tree:
Relative humidity (RH), with specifications: a - 100%, b - 85%, c - 65%, d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.5** it is presented the density variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

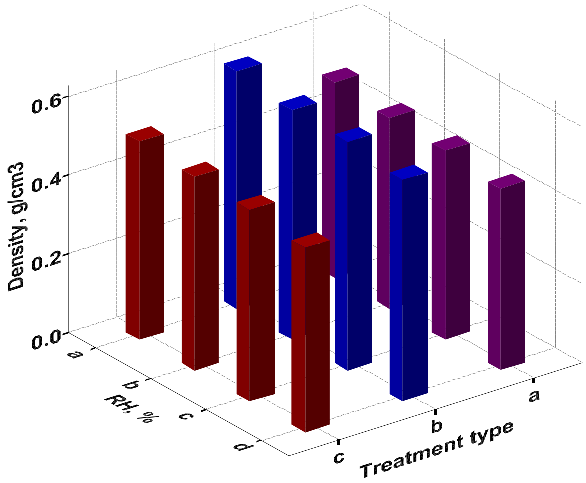

Fig. 5
Variation of the density for lime tree:
Relative humidity (RH), with specifications: a - 100%, b - 85%, c - 65%, d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.6** it is presented the porosity variation for the lime tree, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

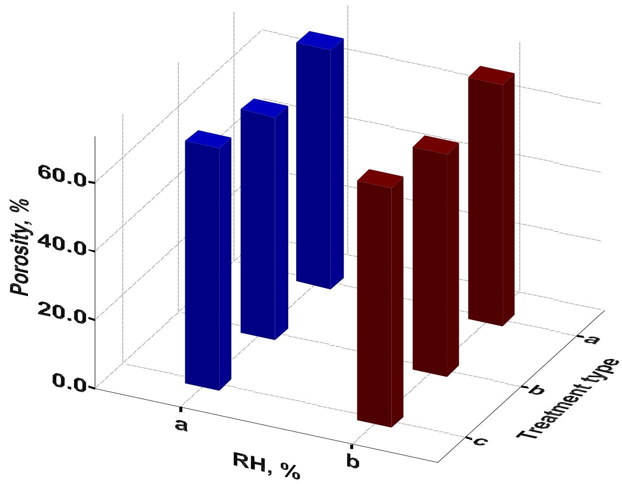

Fig. 6
Variation of the porosity for lime tree:
Relative humidity (RH), with specifications: a - before treatment 85%; b – after treatment 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 265-275

OAK: variations recorded

In **Fig.7** it is presented the longitudinal shrinkage variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

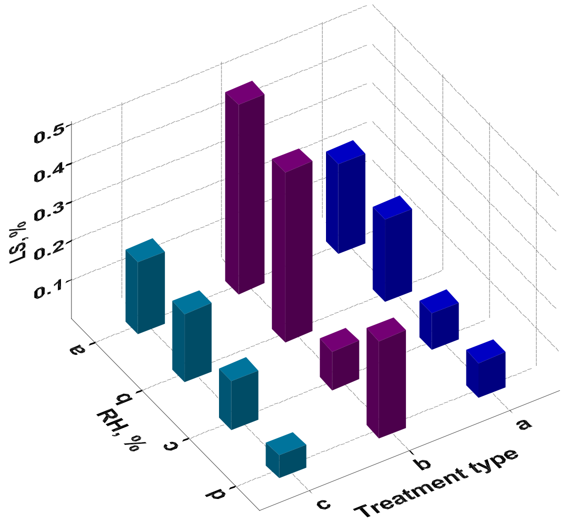

Fig. 7
Variation of the longitudinal shrinkage for oak:
Relative humidity (RH), with specifications: a - 100%; b - 85%; c - 65%; d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.8** it is presented the radial shrinkage variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

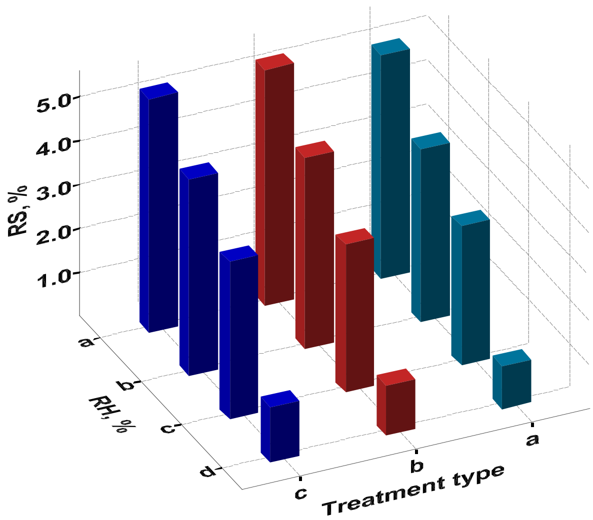

Fig. 8
Variation of the radial shrinkage for oak:
Relative humidity (RH), with specifications: a - 100%; b - 85%; c - 65%; d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.9** it is presented the Tangential shrinkage variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

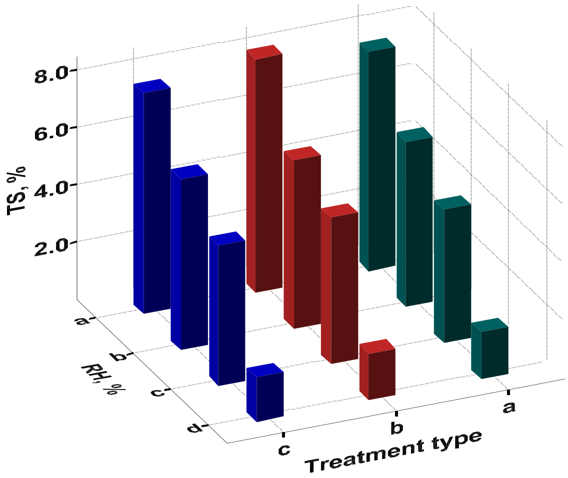

Fig. 9
Variation of the Tangential shrinkage for oak:
Relative humidity (RH), with specifications: a - 100%; b - 85%; c - 65%; d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.10** it is presented the Volume variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

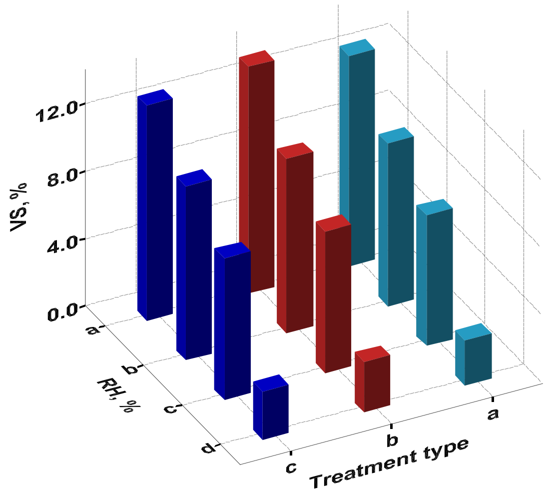

Fig. 10
Variation of the Volume for oak:
Relative humidity (RH), with specifications: a - 100%; b - 85%; c - 65%; d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.11** it is presented the density variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil

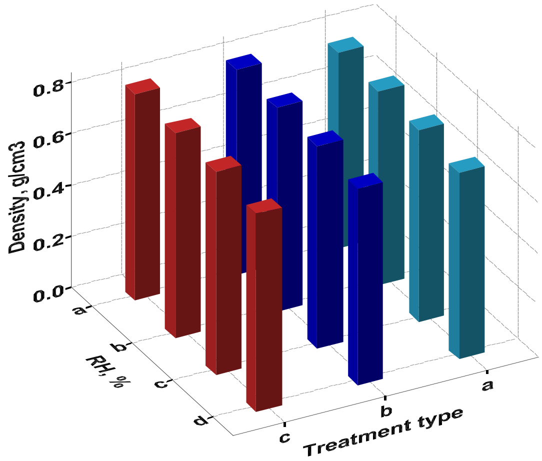

Fig. 11
Variation of the Density for oak:
Relative humidity (RH), with specifications: a - 100%; b - 85%; c - 65%; d - 25%
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

In **Fig.12** it is presented the porosity variation for the oak, treated with propolis in red oil solution, under the influence of atmospheric moisture, by comparison with new, untreated wood (*absent*) and the one treated with red oil.

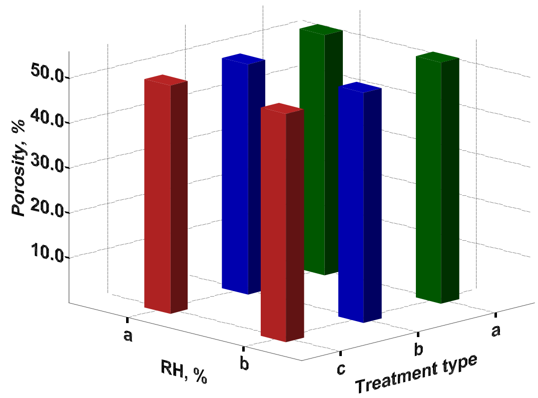

Fig. 12
Variation of the Porosity for oak:
Relative humidity (RH), with specifications: a - before treatment 85%; b – after treatment 25%;
Treatment type with the specifications: i - reference (absent); ii - treated with red oil;
iii - treated with alcoholic propolis solution 30% dispersed in red oil.

Although lime wood is a hardwood, it should interact strongly with the propolis treatment, but the data obtained demonstrate the opposite. The oak samples which have high density, have interacted better with the organic solutions used in the experiment, their dimensional characteristics varying in much higher limits.

The shrinkage values on the three axes of both wood species, as expected, varied so: T > R > L.
The lime wood sample, untreated: T (5.5%) > R (3.5%) > L (0.26%), treated with red oil: T (6.7%) > R (4.8%) > L (0.27%), and treated with propolis in alcohol solution dispersed in red oil: T (6.0%) > R (4.0%) > L (0.32%).The oak wood sample, untreated: T (7.0%) > R (4.8%) > L (0.12%), treated with red oil: T (7.5%) > R (4.8%) > L (0.42) and treated with propolis in alcohol solution dispersed in red oil: T (6.8%) > R (4.6%) > L (0.17%).

In the same order the volume and density, vary as follows: for lime, according to the treatment type (i, ii, iii), ii > iii > i, while for oak, ii > i ≥ iii. However, the porosity, as function of the treatment, varies for lime i > iii > ii, while for oak i > ii ≥ iii.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 9 N° 4 2013
pp. 265-275

In order to assess the influence of the treatment and of the relative humidity on the specimens dimensional shrinkage for both species investigated, are given in Fig. 13. This compares the variation of ratios T/R, T/L, R/L. Three cases are considered: i –untreated wood, ii – wood treated with red oil and iii – wood treated with alcoholic solution of propolis dispersed in red oil.

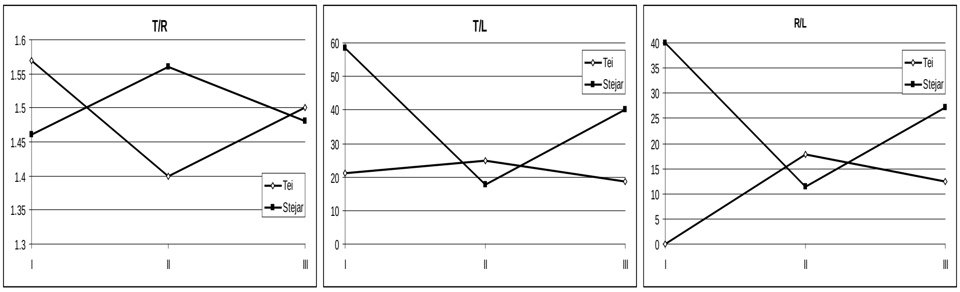

Fig. 13
The variations of ratios T/R, T/L, R/L when treating wood with red oil (ii), with alcoholic solution of propolis in red oil (iii) compared with untreated wood (i).

The three shrinkage ratios vary differently for the two species, which was to be expected because lime is lower in density than the oak, for which the process of organic solutions penetration takes place at a different speed. There is a good correlation between the penetration speed of the solution and species density.

According to the graphs, the differences in the ratio T/R between lime and oak is greater for treatment with red oil than for untreated wood and decreases very much when treating wood with propolis dispersion solution in red oil. For the other ratios, the differences seem to increase for untreated and wood treated with propolis dispersion in red oil, but decrease for treatment with red oil. This behaviour can be explained by the fact that following the treatment, a great part of the red oil components with hydrophobic activity, leave the wood, while propolis makes a membrane system at the wood cell surface, which is permeable for reversible water. The deep penetration in the volume faze in the lime tree sample, of the propolis organic solution, led to the partial obstruction of the vessels and ducts, which are more reachable than the ones in oak. Instead at the oak samples the solution makes only a superficial layer, the anatomic elements quickly reacting to the atmospheric moisture.

In Fig. 14 it is illustrated the comparative variation of volume, density and porosity for the two wood species in all three situations considered: i – untreated wood, ii – wood treated with red oil and iii – wood treated with alcoholic solution of propolis dispersed in red oil.

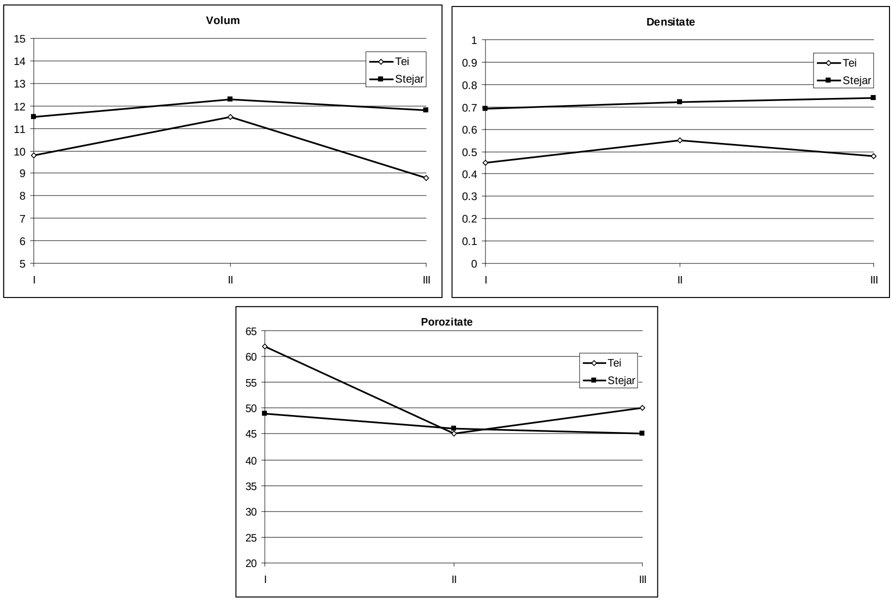

Fig. 14.
Comparative variation of volume, density and porosity for the two wood species (lime and oak) when treating with red oil (ii), with alcoholic solution of propolis dispersed in red oil (iii) compared with untreated wood (i).

Compared with variation in ratios T/R, T/L si R/L, the variations in volume, density, porosity differ very much in the three situations i, ii and iii. The variations in volume seem to have similar trends, but the situation is not the same for density and porosity. Oak has an ascendant trend for the variation in density and descendent for porosity. This may be because of the retention of some volatile components of red oil and of the propolis solution, compared to lime, which permits the elimination with a higher rate of the same volatile components of the two treatments.

Fig. 13 and 14 illustrate the way in which the two organic solutions influence the wood shrinkage for the two species, whose values fall within the normal range of variation till the limit situation is reached (precollaps), when fissures and bows begin to occur.

This study enables the optimization of various organic solutions used for preservation and prevents the wood from fungal or borer insects attack, and waterproofing.

Species	Type of treatment	Dimensional ratios		
		T/R	T/L	R/L
Lime	i	1.57	21,15	13,46
	ii	1.40	24.81	17.78
	iii	1.50	18.75	12.50
Oak	i	1.46	58.33	40.00
	ii	1.56	17.86	11.43
	iii	1.48	40.00	27.06

Species	Type of treatment	Variations in		
		Volume	Density	Porosity
Lime	i	9.8	0.45	62.0
	ii	11.5	0.55	45.0
	iii	8.8	0.48	50.0
Oak	i	11.5	0.69	49.0
	ii	12.3	0.72	46.0
	iii	11.8	0.74	45.0

CONCLUSIONS

By applying the preservation method using propolis in red oil solution, which is the subject of a recent patented invention, the lime wood behaved differently from the oak sample. For both wood species, the shrinkage values varied so: T > R > L, as it was expected. This demonstrates that the treatments with the two organic solutions do not influence strongly the dimensional characteristics.

The differences in ratio T/R values for lime and oak are greater when red oil is used compared to untreated wood and they reduce substantially when treating wood with propolis dispersed in red oil. For the other ratios, T/L and R/L, the differences seem to increase for untreated and wood treated with propolis dispersion in red oil, but decrease for treatment with red oil. This behaviour can be explained by the fact that following the treatment, a great part of the red oil components with hydrophobic activity, leave the wood, while propolis makes a membrane system at the wood cell surface, which is permeable for reversible water. The deep penetration in the volume faze in the lime tree sample, of the propolis organic solution, led to the partial obstruction of the vessels and ducts, which are more reachable than the ones in oak. Instead at the oak samples the solution makes only a superficial layer, the anatomic elements quickly reacting to the atmospheric moisture.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support of the Project POSDRU/86/1.2/S/62307.

REFERENCES

Ciocan A, Sandu I, Hayashi M, Sandu AV, Vasilache V (2009) The implication of two complementary techniques the determination of the degree of penetration of some active compounds during wood treatment, 7th International Conference Wood Science and Engineering in the Third Millennium – ICWSE 2009, Transilvania University Press, Braşov, pp. 452–465

Hayashi M, Vasilache V, Maccioni N, Capretti C, Sandu I (2008) Impact of moisture conditioning on polychrome wood with artificial tempera, Cultural Heritage Meet Practice (ed. J. Kolar, M. Strlic) Proceeding of 8th European Conference on Research for Protection, Conservation and Enhancement of Cultural Heritage, Ed. National and University Library, Ljubljana, pp. 94-96

Hayashi M, Sandu I, Ciocan A, Vasilache V, Sandu ICA (2009) The impact of some active compounds implied in the preservation, upon physical-structural wood's Characteristics, 7th International Conference Wood Science and Engineering in the Third Millennium – ICWSE 2009, Transilvania University Press, Braşov, pp. 441–451

Hayashi M, Sandu I, Tiano P, Maccioni N (2010a) The Effect of Preservative Intervention on the Chemical-Physical and Structural Chracteristics of Panel Painting, Al.I.Cuza University Publishing House, Iaşi

Hayashi M, Maccioni N, Tiano P, Yoshida N, Sano C, Sandu I (2010b) The Effect of Traditional Preservative Interventions for Panel Painting, Hozon Kagaku (Science for Conservation), no. 50:197-205

Hunter AJ (1995) Equilibrium moisture content and the movement of water through wood above fibre saturation, Wood Science and Technology, 29

Sandu I, Sandu ICA (2002) Chemistry of Conservation and Restoration, Corson, Iasi

Sandu I, Hayashi M, Sandu ICA (2007) Evaluation of some physical-structural and chemical characteristics with chronological evolution for old wood for authentication, Proceedings of the IInd, International Conference of the Chemical Society of the Republic of Moldova (Achievements and Perspectives of Modern Chemistry), Chişinău, 1-3 octombrie, pp. 145

Sandu I (2008) Degradation and Deterioration of the Cultural Heritage, Vol. II, ”Al.I.Cuza” University Publishing House, Iaşi

Sandu I, Lupascu T, Sandu ICA, Luca C, Sandu IG, Vasilache V, Hayashi M (2008a) Ecologic organic solution for the treatment against insects and fungal attack of the old wood-made artifacts, Proceedings of the International Conference on Ecological Materials and Technologies ECOMAT, Ed. Printech, Bucureşti, pp. 79-81

Sandu I, Lupascu T, Sandu ICA, Luca C, Sandu IG, Vasilache V, Hayashi M, Ciobanu M (2008b) New method for the evaluation of the cumulative preservation treatment impact on the old wood with echological organic solutions, Proceedings of the International Conference on Ecological Materials and Technologies ECOMAT 2008, Ed. Printech, Bucureşti, pp. 490–494

Sandu I, Lupascu T, Sandu ICA, Luca C, Sandu IG, Vasilache V, Hayashi M, Ciobanu M (2008c) New method for the evaluation of the characteristics on the old wood used in preservation process and authentication, Proceedings of the 2nd International Conference Advances Materials and Systems – ICAMS, Certex, Bucharest, pp. 490–494

Sandu I, Vasilache V, Sandu ICA, Hayashi M, Ciocan A (2009a) A new method for determination of the normal range of variation of the hydrous equilibrium for wood, 7th International Conference Wood Science and Engineering in the Third Millennium – ICWSE 2009, Transilvania University Press, Braşov, pp. 471-478

Sandu I, Lupaşcu T, Sandu ICA, Vasilache V, Sandu IG, Boţan V, Sandu AV, Ciocan AC (2009b) Process for insectofungicization and hydrophobization of age-old wood articles of art, Patent MD3966(B1)/2009.09.30

Sandu I, Lupascu T, Luca C, Vasilache V, Hayashi M, Vlad FD, Sandu IG (2009c) Ecologic organic solution for the insectofungic treatment of the old wood in artefacts, Patent MD3681 (G2)/2009.04.30

Sandu I, Lupascu T, Sandu ICA, Luca C, Vasilache V, Sandu IG, Hayashi M, Sandu AV, Ciobanu M (2009d) Method for detemining the normal range of variation of hydric equilibrium, Patent MD3713 (G2)/2009.05.31

Sandu I, Vasilache V, Sandu ICA, Hayashi M (2010a) New Method of Determining the Normal Range of Hydric-Equilibrium Variation in Wood with Multiple Applications, Revista de Chimie, Bucureşti, vol. 61(12)

Sandu I, Lupaşcu T, Sandu ICA, Vasilache V, Sandu IG, Boţan V, Sandu AV, Ciocan AC (2010b) Process for Insectofungicization and Fireproofing of Age-old Artworks, Patent MD4018(G2)/2010.02.26

Sandu I, Scutarita G, Sandu ICA, Vasilache V (2011a) Modern Materials and Methods of Preservation of Ancient Polychrome Wood, 8th International Conference “Wood Science and Engineering in the Third Millennium” - ICWSE 2011, Ed. Transilvania University of Brasov, pp. 385-395

Sandu I, Lupascu T, Luca C, Vasilache V, Hayashi M, Vlad FD, Sandu IG (2011b) Insectofungicidal Composition as an Alcohol Solution and Process for Preparing The Same, Patent RO123353 (B1)/2011-10-28

Sandu ICA, Vasilache V, Sandu I, Vrinceanu N, Sandu IG, Ciocan AC, Sandu AV (2011c) Process for actively preserving old water-soaked wood, involves submerging the wood into petroleum-based organic solutions containing specified amounts of tannin and propolis, Patent RO126102-A2/2011-03-30

Siau JF (1995) Wood-influence of moisture on physical properties, Virginia Polytechnic Institute and State University, Blacksburg, VA

Unger A, Schniewind AF, Unger W (2001) Conservation of Wood Artifacts: A Handbook, Springer

Vasilache V, Sandu I, Luca C, Hayashi M, Sandu AV (2008) Determination of the conservation state of old wood artifacts, Proceedings of the 2nd International Conference Advances Materials and Systems ICAMS 2008, Ed. Certex, Bucureşti, pp. 501–507

Vasilache V, Sandu ICA, Ciocan A, Sandu I, Hayashi M (2009) Retention of permethrin-red petroleum system during the wood process of preservation, 7th International Conference Wood Science and Engineering in the Third Millennium – ICWSE 2009, Transilvania University Press, Braşov, pp. 466–470

Walker JCF (2006) Primary Wood Processing, Principles and Practice, Springer