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EVALUATION OF SOME CHEMOMETRICS CHARACTERISTICS WITH ARCHAEOMETRIC VALUE FROM THE VARIATION OF WATER BALANCE FOR WOOD

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Abstract:
The paper presents the normal range of variation of water balance for different wood essences, used in the preservation - restoration of cultural heritage artifacts. The evaluation uses two dynamic processes: hydration - dehydration, between the minimum level of hygroscopic water, with no sudden contractions, with microstructural destructions of the fibrils (<0.5%), and the fiber saturation point (between 31 and 36%, depending on the variations essence). In the variation area of the two curves, a series of chemometric features with archaeometric function (used in dating) or with the potential to assess the impact of preservation treatments on the conservability of the studied artefacts are identified. These aspects have a degree of absolute novelty, being studied for the very first time by our laboratory. Samples used in this study were beech and oak.

Key word: *wood essences; dehydration; hydration; chemometric study; archaeometic study.*

INTRODUCTION

Wood is a natural and renewable material with many uses. Due to its natural structure, it is susceptible to biological degradation. Due to biological degradation, the structure of wood changes, which results in a significant reduction in the economic and practical value of this material; therefore, the importance and necessity of wood protection against destructive factors are well defined (Verma et al. 2009).

The moisture in the wood is in two basic forms: water in the cell wall and free water in the form of liquid that is in the pores of wood. The water in the wood is balanced with the relative humidity of the surrounding air. For example, in relative humidity of zero percent, moisture content of wood is also zero. With increasing relative humidity, the moisture content of the equilibrium gradually increases and in the relative humidity of 100%, the cell wall becomes saturated (Siau 1984, Wadsö 1993, Siau 1995).

In excess of this moisture, which is called the fiber saturation point (FSP), the excess water is available in the form of free water. Between the wood and the wet soil that is in contact with it, there is a state of equilibrium, and this also includes free water. Green wood contains free water, which is exposed to hot and dry air. To understand the transport properties, moisture profile determination and water state characterization during water uptake and drying should be carried out. The presence of free water in the wood tends promote decay (Babbit 1940).

Wood moisture has a dramatic effect on all its physical properties. By increasing water, the wood is bulky, its mechanical strength decreases, its thermal and electrical conductivity increases, and the diffusion of water increases. These changes tend to slow down and continue to saturate the cell wall, as wood properties change very little past the saturation point. Moisture content of wood to the point of saturation of the fiber has a significant effect on the properties and processes of transfer. Therefore, to study the permeability, the capillary behavior, thermal conductivity and moisture distribution in wood, factors and methods one needs to study to the control of relevant factors and methods (Krabbenhoft 2003, Verma et al. 2009, Perré 2002, Kowalski 2003).

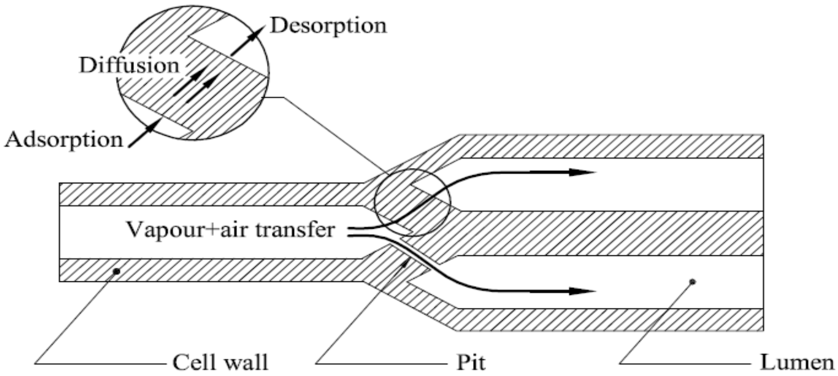

Fig. 1.
Water vapour and air transfer (Krabbenhoft 2003).

For authentication of old wood artifacts, in the specialty literature there are many reference works that have studied either a certain artifact or a structural component in this regard, use of chemical and physico-structural analysis data from wood samples with different sessions from time of putting it into work or cutting, has been evaluated through a series of archaeometric or chemometric features with archeometric value. For example, elemental composition, hygroscopic moisture, ash and extractable components, along with the morphology and distribution of anatomical components, porosity, specific weight, etc. are archeometric features, which by corroboration allow the dating of the old wood (Sandu et al. 1998, Sandu 2003, Vasilache et al. 2009, Sandu et al. 2015, Spiridon et al. 2017).

MATERIALS AND METHODS

In this research, two species of beech (Fagus) and oak (Quercus) were used.

The beech is most widespread in Central and Western Europe, although it can be found as shrub or tree between the 40th and 60th degrees of latitude. Beech can found in mixed woodlands as well as in beech woods particularly in lowlands but also in low mountainous regions.

The European beech (Fagus sylvatica) is the most useful of beech timbers and is therefore known simply as beech.

Beech trees can grow to 300 years or more, although trees of between 100 and 140 years old are typically felled. They can reach a height of 30 to 35 metres.

Beech belong to the family of heartwood trees. Sap and heartwood have an even pale yellow to reddish-white colouring, red-brown when steam-treated. The wood has an even fine-pored structure without noticeable markings. Older trees (over 80 years old) can develop a reddish core of irregular colour intensity and shape. Its Density is 0.73g/cm^3.

Beech wood is medium to heavyweight. It is very hard and tough. It has good strength properties and high abrasion resistance.

Beech can shrink considerably and is subject to movement more than other woods. It should not be subject to moisture fluctuations before or during working.

Despite its hardness, beech wood can be worked easily. It can be cut, planed, drilled and milled. When steam-treated it is well-suited, like the ash, to bending into form.

Surface finishing is straightforward. It can be stained, painted and polished. As compensation for its low durability it is well suited for impregnation (Parsa Pajouh et al. 1932).

In Figures 2 and 3 is shown SEM microphotography and an optical microscope image for a beech sample.

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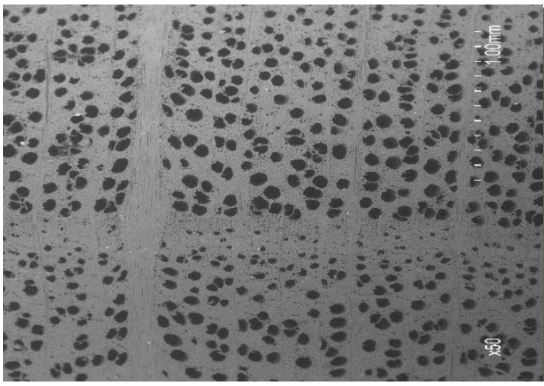

Fig. 2.
SEM microphotography of Beech.

Fig. 3.
Optical Microscope image of Beech.

Oak is commonly used to describe the two most common Northern European botanical variants: (*Quercus robur L.; Quercus petraea (Mattuschka) Liebl.; Quercus pubescens Willd.*). Their properties are however so similar that their wood is simply known as oak wood. Oak grows commonly throughout Europe and Asia Minor, with the exception of the very northern and southern areas. Oak is particularly widespread in France. It is one of the most important European trees altogether.

Oaks can often be several hundred years old and can reach a height of up to 50m, though 20m to 40m is more common. Oak grows rapidly in height but its body is not as extensive as other kinds of trees.

Oak wood can be differentiated between sapwood and heartwood: the thin sapwood is grey-white in colour, the heartwood is coloured yellow-brown to mid-brown and darkens considerably with time. The springwood can easily be identified by its larger pore structure. When cut longitudinally the vertical pores have a grooved structure. Its Density is 0.69 g/cm^3.

Oak wood dries slowly. This means that artificial drying should be undertaken with care to avoid cracking and warping. Oak shrinkage is negligible and stability is good.

It can be worked easily with most tools and machinery, it can be split easily and is well suited for use as a veneer. Nails and screw-fixings are straightforward. Surface finishing is generally not a problem. Its high tannic acid content can lead to coloration when in contact with iron due to chemical reactions Parsa Pajouh et al. 1932).

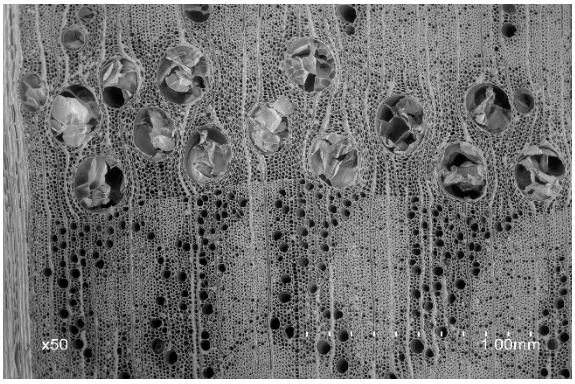

Fig. 4.
SEM microphotography of Oak.

Fig. 5.
Optical Microscope image of Oak.

From both species of beech and oak wood, 3 samples were prepared in the size of 1×1×4cm (R×T×L). After weighing and measuring the dimensions, the samples were all numbered, and samples were placed in a desiccator to reach the minimum available water in each sample. After reaching the minimum amount of water in the wood, the hydration step began. This was repeated with a protocol of six times every five minutes, three times per 10 minutes, three times per 30 minutes, and then every hour until reaching the constant water volume point. After reaching the constant volume of water at the hydration stage, the dimensions of the samples were measured and they were placed in another desiccator to perform the dehydration test. The same protocol was used for this step.

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RESULTS AND DISCUSSION

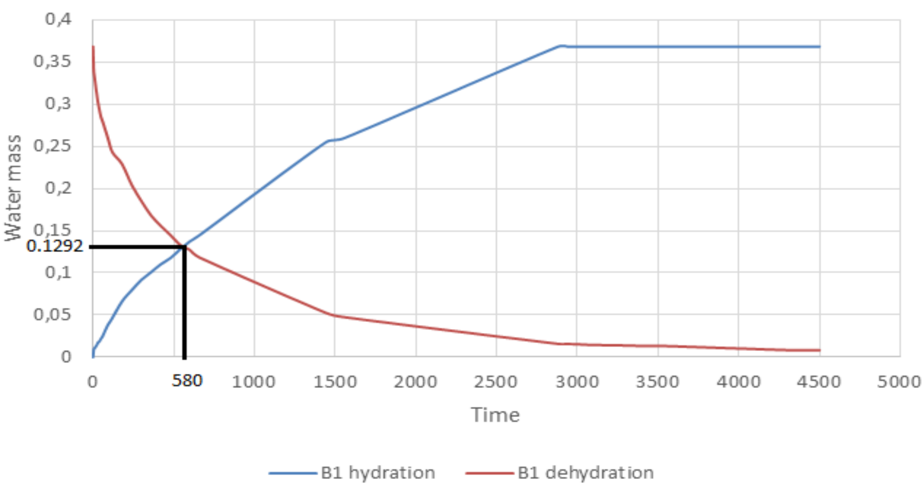
In Tables 1 we can see the results of constant mass of water in hydration and dehydration, time and the mass of reversible water at the intersection of the two curves in the beech and oak woods and and the average of time and mass values at the intersection of the two curves. After the tests, the data is entered in the Excel program and the corresponding diagrams are plotted.

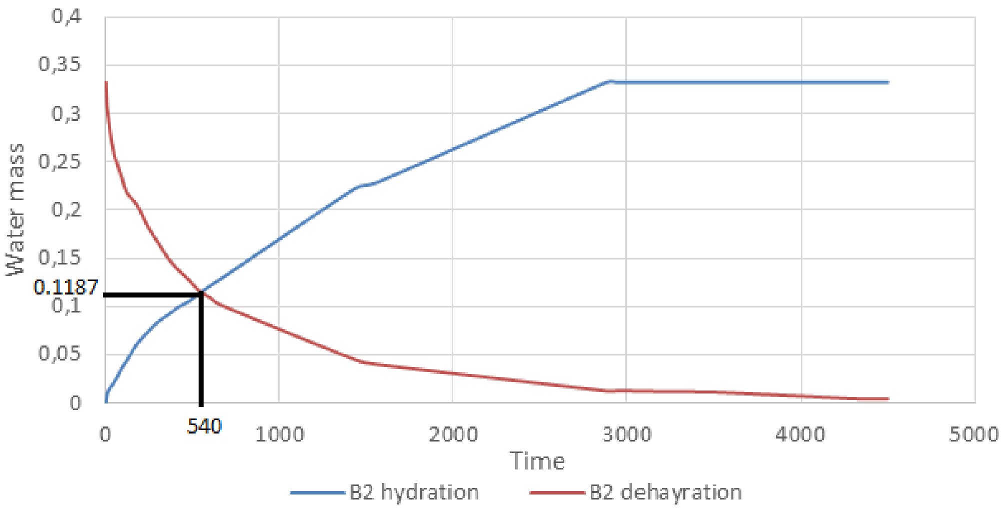
Table 1

The values of the chemometric characteristics involved in study for beech and oak wood

Samples		Hydration (maximum mass, g)	Dehydration (minimum mass, g)	Point of intersection of curves		Average Tc (minutes)	Average Mc (g)
				Time, Tc (minutes)	Water mass, Mc (g)		
Beech	B1	0.3684	0.0082	580	0.1292	603	0.1376
	B2	0.3325	0.0042	540	0.1187		
	B3	0.4313	0.0110	690	0.1650		
Oak	O1	0.2729	0.009	680	0.1158	660	0.1162
	O2	0.2691	0.0051	660	0.1126		
	O3	0.2959	0.0036	640	0.1204		

In Figures 6 and 7, presenting the beech and oak woods diagrams, the smallest and most water volume in the wood, as well as the intersection points in the hydration and dehydration, can be observed.





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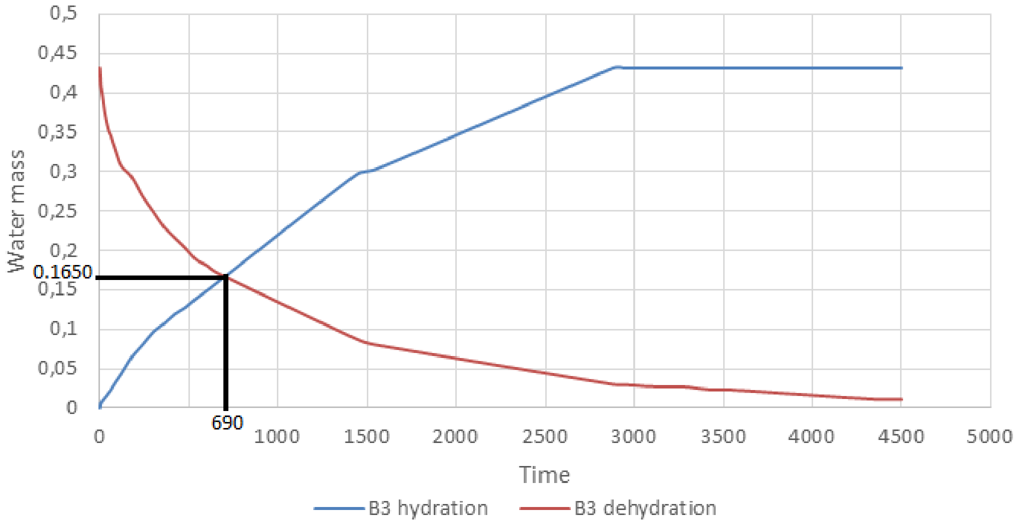
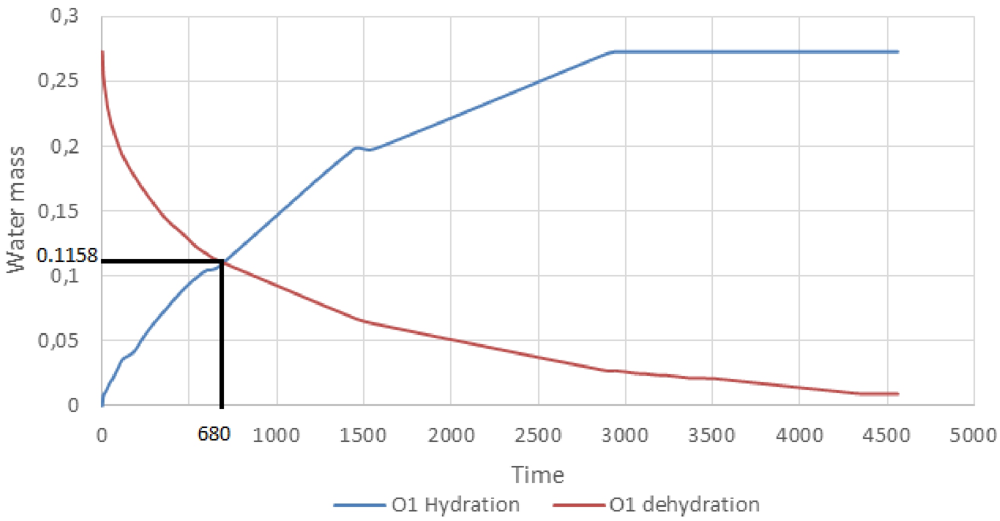
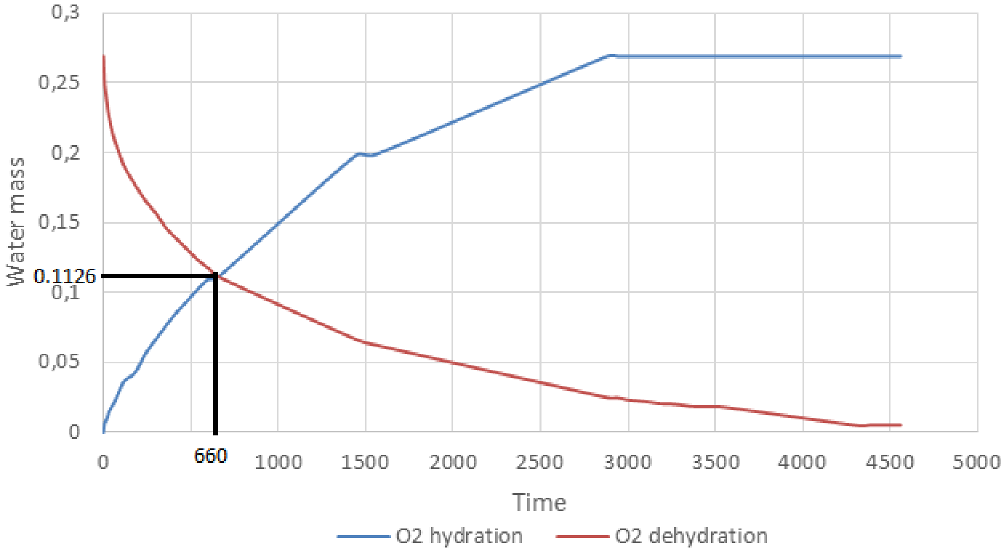


Fig. 6.
The smallest and most water volume in the beech wood.





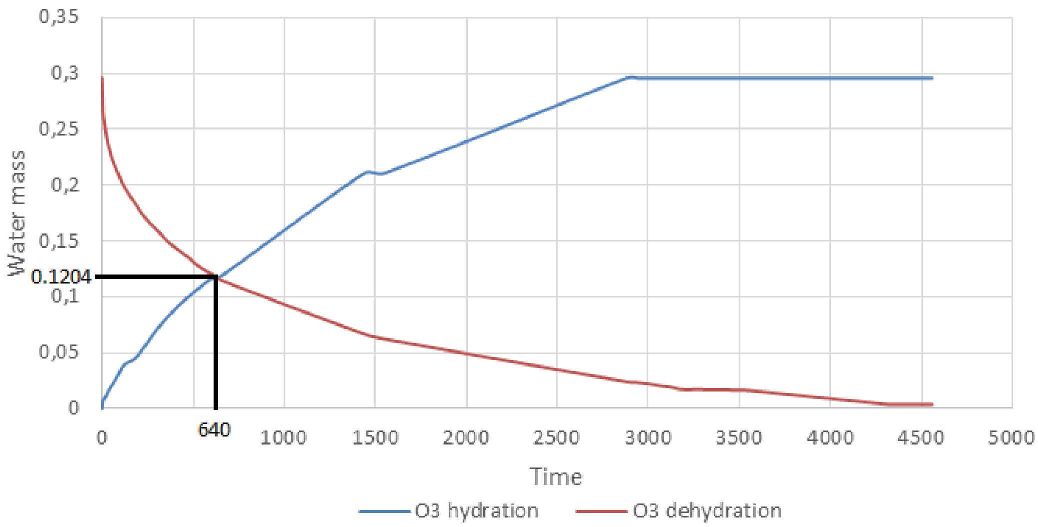


Fig. 7.
The smallest and most water volume in the oak wood.

Graphs show that for beech the intersection time of the two curves varies between 540 and 690 minutes, and the water mass varies between 0.1180 and 0.1650. In the oak the critical time is between 640 and 680, and the water mass varies between 0.1126 and 0.1204.

Making an average of the intersection points of hydration and dehydration curves it is found that for beech the average time is 603 minute, and the average water mass of 0.1376g, but for oak the average time is 660 minutes and the average mass is 0.1162.

This difference can be due to high density in beech wood. Density in the beech wood is 0.73g/cm^3 and in the oak wood is 0.69g/cm^3. The other reason can be due to the structure of wood in the oak and in beech wood.

CONCLUSIONS

The information obtained on the hydration/dehydration processes for beech and oak woods confirms that they occur by similar mechanisms. The correlation of the two processes: hydration and dihydration, described by the intersection of the curves, are represented by the equilibrium time, and the equilibrium water content. Note that equilibrium time is the same for both species, instead the water equilibrium is higher in beech and lower in oak. Both species are in the group of semi-heavy wood, but oak wood is a thick texture and beech wood with a compact texture. And this difference in tissue can be due to the difference in water weight in beech and oak wood samples.

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