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DOKTORAL (PhD.) THESIS

about

Examination and comparative analysis of the factors influencing the high-value utilization of oak

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Abstract

The dissertation makes a comprehensive examination of the high quality oaks, which have highest value in wood utilisations. It shows the physical and mechanical properties of friezes of Sessile oak (Quercus petraea) from four typical Hungarian forests/regions (Zemplén, Mecsek, Zala, Somogy) and American white oak (Quercus alba). It separates the friezes by the growing site, natural drying time and the degree of degradation occurring during natural drying. The aim of the study was to determine how the species, the different origins, the exposures in the friezes, and certain anatomical features relate to the expectations of high value-added uses.

In conclusion, the thesis looks at how specific wood properties such as the homogenity of annual rings, the wood density, shrinkage and swelling characteristics, tyloses, compressive strength, modulus of elasticity affect usage and how these properties meet with the needs of especially barrel manufacturing.

1. Introduction

Thanks to the good natural capacities of Hungary deciduous timber in our forests has an outstanding quality for what there is a great demand in the wood production industry across the county and abroad as well. After black locust the second biggest area is occupied by white („noble") oaks amongst broadleaf tree species (21%). Annual logging of oaks is 1 – 1,2 million m^3 (in 2010 it was 1,102 million m^3) (MGSZH, 2011), which also stands on the second place after black locust.

In Hungary we divide white oaks into two groups regarding usage (production, trade): „noble" oaks (English oak, Cornish oak and Downy oak) and turkey oak. The USA plays the most important role in international oak trade. There they divide timber in two groups regarding its aesthetic value; these are white and red oaks. (BROKMANN, 1996).

In the most up-to-date quality assurrance systems all life phases of the most valuable raw maretials are controlled before usage. From production trough transport and storage to processing and after that when the product is used, changes of the material are tracked. In case of wood products the valuable raw material suffers unavoidable quality degradation because of the special material properties and preparation procedures about which no material science research has been done before. To fill in this gap I started to deal with physical and mechanical degradation of multiannual open-air natural dried timber, what even raised the attention of the industry. The anatomic structure, the physical and mechanical characteristics of wood play a very important role in wood production, product yield and waste production, which can cause significant economic drawbacks if it degrades during storage or preparation.

Previous studies showed that it transpired through practice that some oak timber from given sites is preferred by winemakers and bacause of this by barrel producers as well. It is still unexplored how the difference in the wine's chemical characteristics come forward thanks to the physical and mechanical of timber used for barrelmaking.

The taste of wine and the quality of the barrel are influenced by the following factors:

- **Species of the used oak**
- **originating (growing) site of the tree**
- **ageing time and method of the stavefrieze**
- time and temperature of burning
- Volume of the barrel
- ageing time of the wine
- age of the barrel and repetition of use.

The anatomic structure, the physical and mechanical characteristics of wood play a very important role in production yield and waste production. According to the research goal I examined and compared those wood science relationships of the first three points of the abovementioned list which are important for the barrel production technology (mechanical characteristics) and knowing their influence is necessary for usage (physical characteristics).

2. Goal of the research

During the research I examined sessile oak from 4 typical sites of Hungary (Zemplén, Mecsek, Zala, Somogy), and north-american white oak from Wisconsin, USA. Within the different origins I separated upper, middle and lower level stored material inside the natural dried stavestacks.

The aim of my research was basically to determine the effects of different species, origins, positions inside the stack and some anatomic characteristics. I would like to reveal how specific wood properties such as the homogenity of annual rings, wood density, shrinkage and swelling characteristics, tyloses affect usage and how these properties meet with the needs of a barrel as a ready made product. Out of the mechanical examinations I considered compressive strength and the modulus of elasticity important since these stresses also appear at a barrel during use.

3. Methods of the research

3.1 Raw material

During the research - considering industry demands - I examined sessile oak from 4 typical sites of Hungary (Zemplén, Mecsek, Zala, Somogy), and north-american white oak from Wisconsin, USA. Within the different origins I separated upper, middle and lower level stored material inside the natural dried stavestacks.

The strict requirement system for the raw material of barrel making lays mostly on visual classification; its most important parameters are log diameter, straight, cylindrical log surface homogenic structure lacking any defects. Length of the stavefrieze is 95-110 cm, thickness 29-32 mm, and its with is between 40 and 110 mm. The 1 m and 1,4 m wide stacks were stocked on two levels. We distinguised 5 factors according to the place of origin, 2 according to storage (winter, summer), another 2 according to ageing time (2 years and 3 years). I separated upper, middle and lower level stored material inside the natural dried stavestacks and I examined them according to the abovementioned factors.

- Upper level („F"): samples taken from the upper two rows of the upper stack,
- Middle level („K"): samples taken from the lower two rows of the upper stack,
- Lower level („A"): samples taken from the lower two rows of the lower stack.

Sampling and material preparation was done after the relevant standard (MSz-EN 319-76). I sorted the studied material based on the following factors:

- **species: sessile oak, american white oak**
- **place of origin: Mecsek, Somogy, Zala, Zemplén, America**
- **ageing (storage) circumstances: open-air drying, 2 story stacking, position: lower A, middle K, upper F**
- **time of stacking: summer stacking N, winter stacking T,**
- **ageing time: 2 years, 3 years**

I made the preparation of the test bars in accordance with the abovementioned factors and considering the research standards for each group. The demand of statistic evaluation made a sampling number of 30 pieces per factor and per analysis necessary, in other words I made the studies mentioned below on at least 60*30pcs, so at least 1800 pcs of test bars per analysis.

- Moisture content,
- Density,
- Chordwise and radial swelling,
- Average growth ring width, proportion of latewood,
- Compressive and elastic strength,
- Modulus of elasticity.

4. Theses of the dissertation

1. With my research I proved that with open-air drying – which plays a key role in the production of high quality wood products – the raw material cannot reach the necessary moisture content in case of every factor. According to literature data it is possible to reach 12-20 % of net moisture content in sawn timber by 1 year open-air drying in middle-european climate. Denying this I proved during my study that 1 year open-air drying is not effective under all circumstances. Under the circumstances in Hungary the abovementioned moisture content only develops to the end of the 3rd year in sessile oak while uncovered open.air drying. I verified that the extreme moisture content differences in the stacks after the second year decrease and even out which gives more homogenic stacks in point of moisture.

2. I proved with my research that the final moisture (3 years later) of sessile oak logs processed at the end of the vegetation period (fall-winter), and in spring and the stavefrieze made of them is not affected by the time of log processing and stavefrieze stacking. The fact of winter or summer stacking has no detectable effect on the examined physical and mechanical parameters besides final moisture content, so there is no need to distinguish the two stacking times during raw material preparation.

3. With my research I revealed that there is no significant difference in density among the raw materials of various sessile oak origin sites so we can talk about identical quality in point of density. The measured values coincide totally with the literature regarding this.
   Minőségi termék- és hordógyártás szempontjából a különböző hazai származású kocsánytalan tölgy alapanyagok azonos minőségűnek tekinthetők, gyártástechnológiai módozatokat nem igényelnek, azonos technológiával egységes minőségű termék biztosítható.

4. With the study I showed that the swelling values of hungarian higher-grade sessile oaks excedd literature values by far (for d_h instead of 7,8 % it is 9,4 %, for d_s instead of 4,0 % it is 4,8 %). The measured higher values make it necessary to review and correct current hoop sizing based on literature values, and thereby lessening hoop and pin breakage.

5. I proved experimentally by examining the effects of stack levels that there are no suggested significant quality differences between the levels so the place inside the stack does not affect the mechanical parameters of oak raw material.

6. I revealed during the research that the average growth ring with of american white oak is bigger than the measured values of hungarian oaks while the rate of latewood shows the opposite tendency. The almost 10 % excessive density of american white oak is caused by the stronger inclination for tylosys and material building-up. Result of this is that elastic strength and elasticity values of american white oak are lower compared to hungarian sessile oaks.

7. With my study I pointed out unambiguously that outm of the oaks originating from different sites elasticity of the Zemplén, Mecsek and Zala material had higher values i. e. it was better than the Somogy and the american material. To lower the number of waste production, in other words the stave breakage during stave retraction the raw material from the three abovementioned areas is suited better for barrel making because of their better elastic characteristics.

5. Utilization of the study's results

Barrel production is based on age-long traditions which were established by experience without the knowledge of modern material sciences.
With my research I revealed how specific wood properties such as the homogenity of annual rings, wood density, shrinkage and swelling characteristics, tyloses affect usage and how these properties meet with the needs of a barrel as a ready made product. Out of the mechanical examinations I considered compressive strength and the modulus of elasticity important since these stresses also appear at a barrel during use.

In the most up-to-date quality assurrance systems all life phases of the most valuable raw maretials are controlled before usage. From production trough transport and storage to processing and after that when the product is used, changes of the material are tracked. In case of wood products the valuable raw material suffers unavoidable quality degradation because of the special material properties and preparation procedures about which no material science research has been done before. To fill in this gap I started to deal with physical and mechanical degradation of multiannual open-air natural dried timber. The anatomic structure, the physical and mechanical characteristics of wood play a very important role in wood production, product yield and waste production, which can cause significant economic drawbacks if it degrades during storage or preparation.

My research revealed that there is no significant difference in the stave position isnside the stack, the places of origin within a given species plays very little role in material quality, but based on production technology and the mechanical stresses working on the product it is possible to set up a rank list according to the place of origin.

6. Scientific publication about the topic

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