The Effect of Thermal Treatment using Vegetable Oils on Selected Properties of Poplar and Robinia wood

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ABSTRACT

Pannónia poplar (*Populus* × *euramericana Pannónia*) and robinia (*Robinia pseudoacacia* L.) were treated at 160 °C and 200 °C in different vegetable oils, in absence of Oxygen, using laboratory equipment. Tree different vegetable oils were used, namely sunflower oil, linseed oil and rapeseed oil. Tree different durations were chosen for the thermal treatment: 2 h, 4 h and 6 h. The aim of the research work was to prove, in what extent the treatments influence some important characteristics of the wood. The investigated properties were: MOR, impact bending, compression strength, ASE and colour. Untreated samples from the same wood material served as control. The treatments decreased the impact bending in case of Robinia and poplar as well. Longer duration of the treatment delivered proportionally lower values in impact bending. The same could be observed regarding the MOR values for Robinia, whereas in case of Poplar the more intensive treatments (longer duration and higher temperature) caused a significant increase in MOR. Regarding the compression strength values the treatments resulted in higher strength values by Poplar, whereas in case of Robinia a clear increase could be observed at 160 °C, and a significant decrease at 200 °C. As a consequence of the treatments the dimension stability could be enhanced for both wood species, so the ASE values increased with increasing duration and temperature. The treatments caused significant darkening for both wood species by all temperatures. The colour coordinates L* and a* (lightness and red hue) shifted to the same direction for both species. The value b* (yellow hue) increased for Poplar, whereas a decreasing was observed for Robinia. Comparing the oils used for this research work, no significant differences in effectiveness could be proved for the investigated properties. An important observation for the practical use was done, as in Robinia wood numerous cracks could be observed in case of wet samples, while practically no damages (cracks, collapses) were observed in Poplar wood using wet samples. The treatments on laboratory scale enhanced the dimensional stability by acceptable decrease in mechanical stability for Robinia and ain increase for Poplar. The results encourage the authors to perform further investigations towards development of technologies for industrial application.

INTRODUCTION

The thermal treatment of wood was a research topic long ago, and the processes were permanently optimized in different countries. The first considerable trials aimed to enhance the biological durability of wood (Stamm *et al*. 1946). Since that time 4 different processes are mostly current in Europe. These are: ThermoWood – Finland, Plato wood – The Netherlands, Retification - France and OHT (Menz Holz) Germany. Basically all of them are based on a heat treatment in absence of Oxygen. The temperature of the treatment ranges between 160 – 260 °C (Leithoff and Peek 1998).

The boiling point of the most vegetable oils is over this upper temperature limit, this fact enables to use these oils in the heat treatment technology of wood. Former investigations (Sailer *et al*. 2000) proved that better wood properties can be achieved by using hot vegetable oils compared to the gaseous atmosphere. Studying the literature the researchers reported about the improvement of the ASE and biological durability in different grades. But some negative aspects of the treatment e.g. decreased mechanical stability and cracks cannot be left out of account. Further challenging phenomenon is the lower UV-stability of the surface (dark colour gets grey). The main aim of our research work was to improve the dimension stability (ASE) of two Hungarian plantation timber species, namely Pannonia Poplar (*Populus* × *euramericana* Pannónia) and Robinia (*Robinia pseudoacacia* L.) using hot vegetable oil treatment. Further tasks were the investigations of different mechanical properties (MOR, MOE, impact bending, compression strength), and the colour change. By using three different types of vegetable oils, the effect of the treating media could be investigated as well.

MATERIAL AND METHODS

Sampling and schedules

Two plantation grown timber species were chosen to the investigations: Pannonia Poplar (*Populus* × *euramericana* Pannónia) and Robinia (*Robinia pseudoacacia* L.). For both wood species 10 middle boards were cut 10 from freshly cut logs. The boards were air dried on normal climate to ca. 13% moisture content (oven dry based). The boards were then cut into smaller laths with the dimension of (18 mm×40 mm×220 mm, RxTxL), which was determined by the size of the equipment used for the hot oil treatment. For each schedule 20 laths were treated, from each board 2 laths were taken randomly. After the treatment the laths were cut into smaller specimen, according to the further investigations. The samples were treated in 3 different vegetable oils, namely sunflower, linseed and raps seed oil. The wood samples were treated at 2 different temperatures (160 °C and 200 °C), and for 3 different durations (2 h, 4 h and 6 h). Combining these parameters 18 different schedules were used for both wood species. The laths were put directly into the hot oil bath, and after the treatment time (2 h, 4 h and 6 h), the specimen were taken out from the bath and placed to normal climate (t = 20 °C, rh = 65%). The treated samples and the controls (untreated material) were kept under this climate condition until they reached the EMC (constant mass). Directly after climatization the colour coordinates were measured on the specimen's surface. The laths were than cut into smaller pieces according to the different investigations. To each tested mechanical and physical property 20 samples were investigated.

Testing of properties:

To the static mechanical properties (compression strength and MOR): Universal Instron testing machine were used. To the dynamic property (impact bending) the Charpy's pendulum was used. Dimensions of the samples. Compression strength, density and ASE and: 18mm x 18 mm x 30mm (RxTxL), MOR and impact bending: 18mm x 18 mm x 220mm (RxTxL), ASE: the samples were dried at 103°C to constant mass, and then placed under water for 7 days. The radial and tangential dimensions were recorded prior and after the water bath. Colour measurements: the colour coordinates were measured in CIELab system on the surface of the laths (18mm×40mm×200 mm) prior and after the treatment by a Konica Minolta CM-2600d device. The colour was measured on 5 places on each lath. The colour properties ΔL^*, Δa^*, Δb^*, ΔC^* were calculated as the difference between the property before and after the treatment, the total

colour change (ΔE*) caused by the different treatments (schedules) was calculated as well.

RESULTS

Compression strength (see Figure 1/a):

- Robinia: the treatment at 160°C increased the compression strength by 5-15%, while the treatment at 200°C caused a loss of 5-10%, depending on the oil used. The treatment time had no clear effect on this property.
- Poplar: the increasing time and temperature resulted in higher compression strength values (15-25%),

MOE (see Figure 1/b):

- Robinia: the increasing treatment and time resulted in proportional decreasing MOE values.
- Poplar: MOE loss could be observed only by the most intensive two schedules, in other cases the MOE showed a slight increase.

Impact bending (data not shown here):

- Robinia: the average impact bending values decreased by 45-70% (depending on the treatment)
- Poplar: the average impact bending values decreased by 10-55% (depending on the treatment)

As a consequence of the treatment the wood material got more brittle.

ASE (see Figures 1/c and d):

- Robinia: the radial and tangential shrinkage decreased by 15-40% and 30-55% respectively.
- Poplar: the radial and tangential shrinkage decreased by 15-35%, regardless of the anatomical direction.

The dimensional stability could be enhanced by the treatment considerably.

Colour properties:

L* / Darkening: both species got darker with increasing treatment temperature and time (Figure 1/e).
a* / red hue: in case of poplar the longer durations and higher temperature resulted in a shifting of colour towards red, while in case of Robinia the 160°C temperature caused increased a* values, but elevating the temperature up to 200°C, the red hue decreased almost to the control values (Figure 1/f).
b* / yellow hue: Robinia and Poplar responded differently (Figure 1/g).
- Robinia: Higher temperatures and longer durations resulted in lower b* values.
- Poplar: Higher temperatures and longer durations shifted the colour towards yellow.

C*ab / saturation of colour: the treatments resulted in more saturated colours in case of Robinia, while the saturation of colour decreased by Poplar.
ΔE* / total colour difference (Figure 1/h):
- Robinia: the total colour change for Robinia reached values between 40-65
- Poplar: the treatment caused a total colour change in the rabge of 25-40.

For both wood species the treatments resulted in a high total colour change, easily detectable by naked eye.
No significant differences could be found for the effect of the vegetable oil's type to the investigated properties.

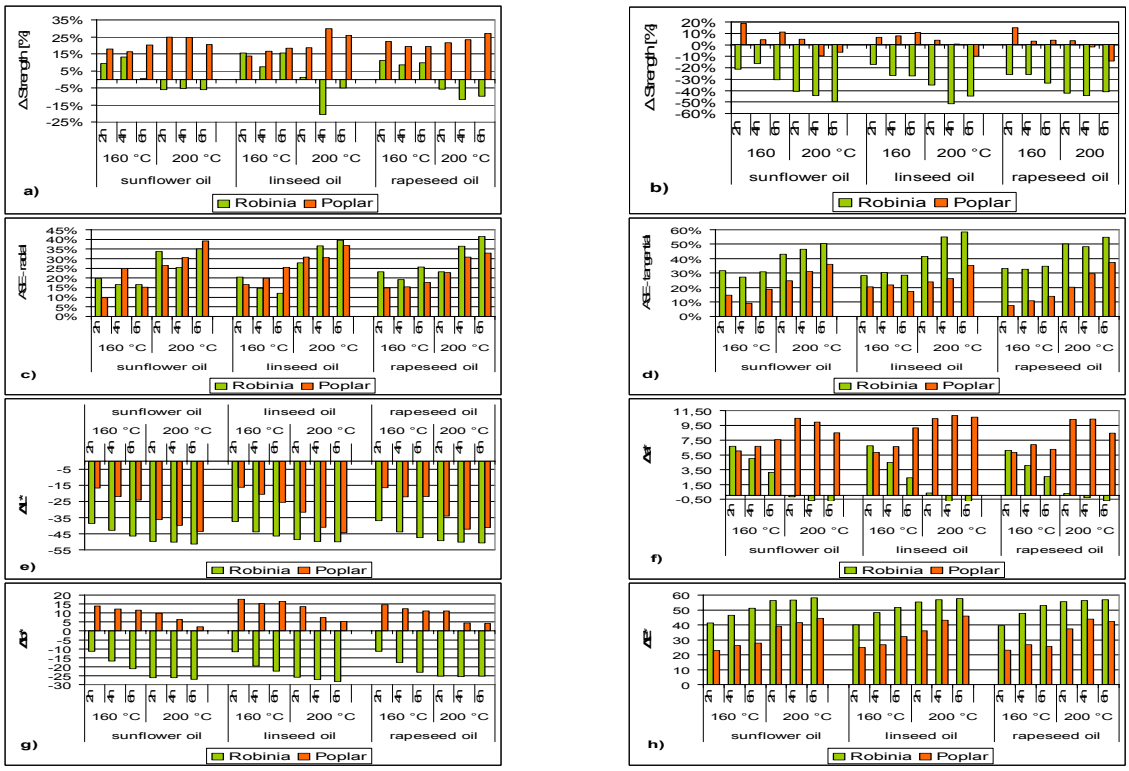

Figure 1: The change of different properties of Robinia and Poplar wood caused by the OHT (a) – compression strength, (b) – MOE, (c) and (d) – radial and tangential swelling, e) - lightness L*, (f) –red hue a*, (g) – yellow hue b*

CONCLUSIONS

As a general conclusion regarding the mechanical properties it can be drawn that the OHT resulted in lower strength values. The compression strength is an exception, as it increased by Poplar after all schedules and by Robinia at 160°C as well. As a consequence of OHT the material became more brittle as the impact bending values decreased. A very positive effect of OHT treatments are the considerable high ASE values, so the dimension stability could be enhanced by both investigated wood species.
Up to our expectations the colour of both species darkened significantly. The colour of the Robinia is more sensitive to the heat treatment, as it showed higher changes in the colour properties. In case of Robinia cracks could be observed after the treatment. The considerable strength losses by Robinia and the increased strength values by Poplar can be explained with the occurrence of cracks. Further investigations are planned to minimize the cracks (size and numbers), as this phenomenon lowers the quality of the wood material. A possible solution can be the use of pre dried wood material (lower than 13%, as it was used here). Regarding the oil types, no significant differences could be observed in terms of the investigated wood properties.

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