Influence of Combined Hydro-thermal Treatment on Aesthetical Properties of Turkey Oak (*Quercus cerris* L.)

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ABSTRACT

Turkey oak (*Quercus cerris* L.) is one of the most widely distributed species along the Apennines in the Southern Italy. However a less technological quality maintains this kind of wood principally for energy destination. Moreover, chromatic differences inside the wood structure are much more evident than in other species, with a quite white sapwood and a dark grey heartwood, frequently accomplished by a presence of black heart. The aim of this research was to evaluate the possibility of reducing aesthetical limiting factors of Turkey oak. This was made by investigating on the combined effect of steaming treatment (in an autoclave) and heat (in a oven) on green wood of Turkey oak. Specimens without any defects were used for the tests. Sapwood and heartwood of samples were also separated. Steaming treatment was carried out for 2-6 h at 100 °C, 120 °C and 135 °C and then the same samples were used for a heat treatment for 2 h at 120 and 180 °C. Colour change of the wood specimens was tested in comparison with untreated ones. The colour results were given in the CIE L*a*b* colour co-ordinate system. In addition, spectral reflectance measures were obtained by using a spectroradiometer provided with a plant probe, in the range between 300 and 1.100nm of the electromagnetic spectrum. It is shown that significant colour changes could be obtained by using combined hydro-thermal treatment. With rising temperature the colour change of wood was higher. Turkey oak wood was more sensitive to the steaming temperature at 135 °C combined with heat treatment at 180°C. Intermediate treatments assured more reliable results on homogenization of hue, while treatments at “ST100+H180” and “ST120+H180” highlighted noticeable results for lightness. In terms of colour spectra, the combined effect between steaming and heat treatment at 120°C seems to be moderate. Such treatments could lead to improve aesthetical properties.

INTRODUCTION

Turkey oak (*Quercus cerris* L.) is one of the forest species with the largest planted area in Italy, especially on Apennines mountain range system. Since timber forests with prevalence of Turkey oak amount to about one million of hectares, it could represent an important resource for mountain economies. In addition, its natural range is from Europe to South West Asia, naturalized in Britain. However a less technological quality maintains this kind of wood for only the poorest destination, i.e. firewood. The principal limiting factors are: less dimensional stability, elevate internal tensions, strong swelling and shrinkage and low durability. Also a less appealable colour surface plays a decisive role for the penetration of this wood in the furniture market (Tolvaj and Molnar 2006).

In fact, chromatic differences inside the wood structure of Turkey oak are much more evident than in other species, with a quite white sapwood and a dark grey heartwood, frequently accomplished by a presence of black heart. Hydrothermal treatments are also used to improve numerous technological properties, such as colour characteristics of wood surfaces. Several authors have reported a general darkening and a red shift of tissues after heat and water treatments (Mitsui *et al*. 2001, Tolvaj and Molnar 2006, Esteves *et al*. 2008), justified through an appearance of coloured compounds derived from hemicelluloses, lignin and extractives oxidation and degradation, or the formation of chinons derived from oxidation reactions (Sundqvist 2004). It is also recognized a reduction of colour differences between sapwood and heartwood (Varga and van der Zee 2008). Both darkening and colour homogenizing of wood are related to the treatment intensity and in most of cases they are very appreciated considering that a pale colour is often underestimate by the great part of the wood markets (Esteves et al. 2008). Literature is very rich in studies on improvement of technological properties for a lot of species, but there is not a great interest for Turkey, despite of its great potential.
The aim of this paper is to evaluate the possibility of reducing Turkey oak's aesthetical limiting factors. Colour analysis and spectral reflectance measures are performed for different combined steaming and heating treatments.

MATERIALS AND METHODS

Trees come from a high Turkey oak (*Quercus cerris* L.) forest located in the Basilicata Region (Southern Italy). The samples employed in this study come from green lumber in order to guarantee that any natural or artificial ageing cycle had distorted the physical characteristics of wood (Esteban *et al*. 2005). Wood specimens measured 50x6x200 mm (tangential, radial and axial). Sapwood (SW) and heartwood (HW) were distinguished for each treatment. Steaming treatment was carried out in a steam chest for 2-6 h at 100, 120 and 135°C. A part of samples were placed in an oven for 2 h at 120 and 180°C. Colour change of the wood specimens was tested in comparison with untreated ones. Eleven different treatments were performed as indicated in Table 1.

Colour parameters were used to evaluate the colour change, according to the CIE L*a*b* system. Spectral reflectance measures were obtained in the range of 300-1.100 nm by using a spectroradiometer provided with a plant probe. Colour variations were determined in agreement to Esteves *et al*. (2008), as following (exemplified for ΔL^*):

$$\Delta L^* = ((L^*_{treated} - L^*_{untreated}) / L^*_{untreated}) \times 100 \qquad (1)$$

While the difference after treatments between heartwood and sapwood was determined as following (exemplified for L^*):

$$\Delta L^*_{SW-HW} = ((L^*_{SW} - L^*_{HW}) / L^*_{HW}) \qquad (2)$$

RESULTS

Darkening (ΔL*<0) increased significantly with treatment intensity, according to Esteves *et al.* (2008) (Table 1). Δa* and Δb* presented a high variability, with a slightly rise for Δa* and a consistent decreasing of Δb* after an initially increase. This indicates a red shifting of wood colour, as shown also by a significant decrease of Δh°. Analogous results are reported by Tolvaj and Molnar (2006). ΔC* showed similar behavior compared to Δb*.

Table 1: Variation in colour parameters. Ctrl= control. ST=steaming. H= heating. The different letters indicate significantly different means at p<0.05

Treatment	ΔL* [%]		Δa* [%]		Δb* [%]		ΔC* [%]		Δh° [%]		Samples [No]
Ctrl*(absolute value)*	L*=*59.4*		a*=*5.9*		b*=*18.7*		C*=*19.7*		h°=*72.6*		*150*
ST100	-3.4	*ab*	56.2	*abc*	18.1	*def*	21.2	*cd*	-5.9	*b*	40
ST120	-10.9	*bcd*	59.3	*bc*	9.4	*cde*	15.2	*bc*	-10.1	*c*	40
ST135	-18.2	*de*	72.1	*bcd*	3.3	*bc*	11.0	*bc*	-13.6	*de*	40
Ctrl+H120	1.2	*a*	27.3	*a*	20.1	*ef*	20.4	*cd*	-0.7	*a*	10
ST100+H120	-8.3	*bc*	50.5	*ab*	12.4	*cdef*	15.6	*bc*	-6.3	*b*	10
ST120+H120	-17.9	*de*	86.9	*cde*	23.0	*f*	30.8	*d*	-11.4	*cd*	10
ST135+H120	-13.0	*cde*	82.3	*bcde*	12.6	*cdef*	20.8	*cd*	-13.0	*cde*	10
Ctrl+H180	-19.6	*e*	102.9	*de*	5.1	*bcd*	13.2	*bc*	-14.9	*e*	10
ST100+H180	-21.0	*e*	105.1	*e*	11.0	*cdef*	18.8	*cd*	-14.6	*e*	10
ST120+H180	-29.5	*f*	80.7	*bcde*	-5.3	*ab*	4.7	*ab*	-18.4	*f*	10
ST135+H180	-32.7	*f*	77.4	*bcde*	-13.4	*a*	3.4	*a*	-19.6	*f*	10

At increasing of treatment intensity a progressive lightness homogenization occurred, even if for "ST135+H180" the difference between SW and HW amplified (Table 2). On the contrary, severe treatments (H180) emphasized the differences, as suggested by Sundqvist (2004). No relevant evidence was achieved for other parameters.

Table 2: Difference between colour coordinates in SW and HW

Treatment	ΔL^*_{SW-HW}	Δa^*_{SW-HW}	Δb^*_{SW-HW}	ΔC^*_{SW-HW}	$\Delta h°_{SW-HW}$
Ctrl	29.8	51.5	36.6	38.0	-2.8
ST100	14.6	33.6	31.2	31.6	-0.4
ST120	12.3	36.6	20.5	23.3	-4.7
ST135	11.7	31.5	14.1	17.8	-5.4
Ctrl+H120	15.9	29.7	21.1	22.1	-1.6
ST 100+H120	17.4	19.6	31.3	29.8	2.6
ST120+H120	12.7	13.5	19.6	20.5	-1.1
ST135+H120	13.1	25.8	24.5	24.7	-0.4
Ctrl+H180	17.8	20.9	9.9	12.1	-2.7
ST100+H180	-1.1	62.2	23.1	29.5	-9.1
ST120+H180	-6.9	46.5	7.8	16.6	-11.9
ST135+H180	9.3	47.2	21.0	27.7	-7.9

The mean spectral reflectance curves of treated wood samples are strongly distinct respect to untreated one (Figure 1). In the visible region the lowest value of reflectance was observed in the "ST135+H180" treatment, while in the Near Infra Red (NIR) the strongest treatments rise up the untreated curve at higher wavelengths than other treatments. Spectral reflectance curves showed that red shifting of colour is related to a more pronounced reflectance reduction in the blue-green region, rather than a reflectance increase in the red spectrum.

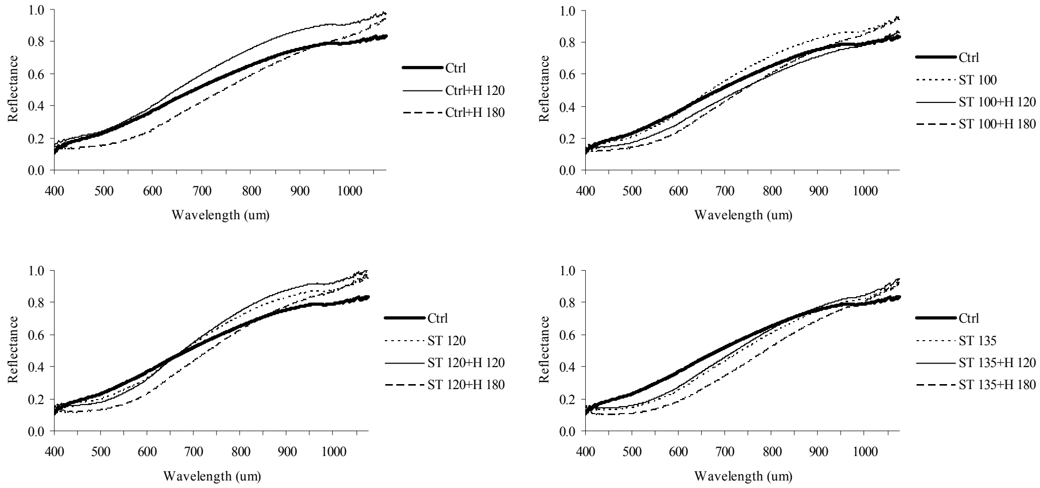

Figure 1: Reflectance spectra in similar treatments between 400-1074 um.

CONCLUSIONS

The combined steaming and heating treatment modified the colour surface, leading to darkening, red shifting and homogenization. Heating seems to have a major effect compared to steaming, principally on lightness and hue. Regarding to homogenization of colour, severe treatments highlighted noticeable results for lightness; however for the strongest treatment ("ST135+H180") a negative effect was obtained. On hue point of view moderate treatments are preferred.
Tested treatment could represent an interesting potential to improve the wood quality of Turkey oak, so that it can be used in alternative to other more valuable oak woods.

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