Journal of Advances in Biology & Biotechnology
6(1): 1-7, 2016; Article no.JABB.25111
ISSN: 2394-1081

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Surface Colour Changes of Turkish Hazelnut Wood Caused by Heat Treatment

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Authors' contributions

This work was carried out in collaboration between both authors. Authors HTS and SK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HTS and SK managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2016/25111
Editor(s):
(1) James W. Lee, Department of Chemistry and Biochemistry, Old Dominion University, USA.
Reviewers:
(1) Leo Baldenegro, Center of Engineering and Industrial Development, Mexico.
(2) Matheus Poletto, Universidade de Caxias do Sul, Brazil.
Complete Peer review History: http://sciencedomain.org/review-history/14495

Original Research Article

Received 18th February 2016
Accepted 19th March 2016
Published 6th May 2016

ABSTRACT

The influence of thermal treatment conditions on natural colour of Turkish hazelnut wood was investigated. It was realized that the elevated temperature and prolonged treatment time usually effects on darker tone on wood samples. However, the greatest lightness (ΔL) changes occurred in 180ºC and 10 hour treatment (37% decreases) followed by 180ºC and 6 hour (25% decrease) and 120ºC and 6 hour (24% decrease) treatment conditions, respectively. Moreover, the greatest changes for coordinate a* (green-red) were also realized at 180ºC and under 10 h treatment conditions.

For FT-IR analyses, the heat treated hazelnut sample exhibited the diminished absorption in 900–1200 cm^{-1} region relative to the polysaccharides where a less complex in-plane C-C vibration was dominant.

Keywords: Turkish hazelnut; heat treatment; wood colour; hemicellulose.

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1. INTRODUCTION

Tiemann (1915) was one of the first scientists to report on the effect of high-temperature treatment upon the physical properties of wood. Stamm and Hansen (1937) also reported, heating of black gum at 205ºC, resulting in a reduction in hygroscopicity. Further studies of this approaches led to the development of commercial processes, such as; *thermowood*, *plato* and *perdure* processes around the world [1].

The heat treatment of woods has usually performed between the temperatures of 100ºC to 250ºC. The temperatures lower than 150ºC resulting in slight changes in properties and higher temperatures especially above 300ºC resulting in unacceptable degradation to the substrate [1,2].

It is well explained that when wood is heated, some changes to the chemical constituents of the cell wall occur, accompanied by weight loss and some modifications. The high temperature effects producing various some breakdown products and chemicals including volatile extractives and water, resulting in colour changes on wood surfaces [2,3]. However, the change in natural colour of woods could be due primarily to changes in cell wall chemicals. Several studies have shown that mass loss and some other properties obey first order kinetic process, although it has shown that this closely related to treatment variables [1].

It was proposed that the thermal degradation starts by hemicelluloses and the released acetyl products (e.g., acetic acid) acts as an catalyst which favors further polysaccharide decomposition [1,4,5]. However, amorphous parts of cellulose has also degraded resulting in an increase of cellulose crystallinity [6,7]. Moreover, there is a cleavage of beta-O-4 linkages and a reduction of methoxyl content in lignin structure [8].

It was speculated by Yixing and his group (1994) that the temperature and time of heat treatment affected on big extent for wood colour, in which the temperature was more evident than others [3]. This phenomenon had the relation to the migration and volatilization of colour extract in heating process as well as the oxidation of lignin in high temperature. Nuopponen and his group (2004) reported that lignin content of the woods was increased as a result of degradation of wood hemicelluloses, which started the temperature below 200℃ [9].

In outdoor applications, changes in the natural colour of wood have a clear indicative of the photo-degradation process of cell wall constituents [10]. However, in the controllable heating process, it is usually effects on a darker tonality of woods which are the formation of degradation products from cell wall chemicals [4,5,11] and from the extractives [1,12].

Hazelnut is a name given to the genus *Corylus* (*Betulaceae*) which includes about ten species. The Turkish hazel (*Corylus colurna* L.) tree is one of the wild species within the genus *Corylus*. However, this tree is native to southeast Europe and southwest Asia, from the Balkans through northern Turkey to northern Iran. It is the largest species of hazel, reaching a height of 35 m, with a stout trunk of up to 1.5 m diameter. It prefers well drained chalky soils [13,14].

An extensive literature and conducted research was reported to heat treatment effects on wood substrates. However, at present, there is no any literature available for the effect of the heat treatment on surface colour characteristics of Turkish hazelnut (*Corylus colurna L.*) wood that are naturally grown in Turkey. However, it is one of the under-utilized species although it has limited use to manufacture veneer, furniture, decorative inlays and novelty items. The fine lustrous wood is pinkish brown and it polishes beautifully. Moreover, the thermal modification has been recognized as a useful method to improve the certain properties of woods. The heat process is also considered as environmentally friendly as it is made without adding any toxic chemicals. The improved characteristics of heat-treated hazelnut wood would make this specie more desirable to manufacture value-added products with possible potential opportunities [15,16].

The objective of this study is to discuss the natural colour characteristics and the influence of thermal treatment conditions on natural colour of Turkish hazelnut wood was investigated. It was believed that the thermal treatment conditions have considerable effects on surface colour characteristics of this wood substrate.

2. MATERIALS AND METHODS

Turkish hazelnut (*Corylus colurna* L.) wood samples were obtained from Kastamonu region in Turkey. The area from which the trees were taken was at an elevation of 1.290 m and had a slope of 30%. Lumber from the logs was prepared by Oney Kaplama San. A.Ş. The ten samples for each treatment conditions were cut in the form of 5 (tangential) × 5 (radial) × 5 cm (longitudinal) pieces.

The heat treatment were applied at three temperatures (120, 150 and 180ºC) and three durations (2, 6 and 10 hours) in a small heating unit controlled (±1ºC sensitivity) under atmospheric pressure. After the treatment, the treated and untreated samples were conditioned to 12% moisture contents in a conditioning room in 65% (±5) relative humidity at 20 (±2ºC).

Control and heat-treated wood ground samples that were obtained surface of substrates were used for FT-IR spectroscopy measurement. The dried samples were embedded in potassium bromide (KBr) pellets, and were analyzed by using a Schimatzu FT-IR spectroscopy model IR–21 Prestige. They were recorded in the transmittance mode in the range of 4.000–400 cm^{-1}.

The colour measurements were performed using a Datacolor 110P spectrophotometer at ambient temperature. The device was calibrated against a white and black working standard supplied with the instrument. Measurements were made using D65 illumination and standard observer. All the calculations were automatically done with using Datacolor Tools QCX quality control software.

The CIE colour parameters (L*, a*, and b*) were obtained and the difference in the lightness (L*), chroma coordinates (Δa* and Δb*) and the total colour difference (ΔE) were also determined using standard formulas. The CIE (1931) of colour specification (X), (Y), (Z) had also utilized for better presentation of hypothetical red, green and blue stimuli values of samples. The yellowness properties (ASTM E313) of untreated and heat treated substrates were also performed.

3. RESULTS AND DISCUSSION

The typical surface colour properties of Turkish hazelnut (*Corylus colurna* L.) wood were summarized in Table 1. The measured results were indicated that Turkish hazelnut wood substrate has red (X), green (Y) and blue (Z) stimuli values of 30.05, 28.19, and 17.33, respectively. However, according to more recent CIE L*a*b* color system (1976), it has the lightness (L) and hue (h) value of 60.06 and 58.32, respectively. It has also had colour property values of 13.08 for coordinate a* (green/red) and 21.19, for coordinate b* (blue/yellow). With having these measured results, it is reasonably describe natural colour of Turkish hazelnut wood that it look like a yellowish colour with having lustrous appearance.

Table 2 shows a comparative the CIE L* a* b* colour chroma coordinates (reported as ΔL, Δa and Δb) of substrates at varying temperatures and durations. The results clearly indicate that heat treatment diminished the natural colour properties. However, the behavior of the chroma coordinates differed at various treatment conditions. It can be revealed that the elevated temperature and prolonged treatment time usually effects on darker tone (decreasing lightness, -Δ L). The greatest lightness lost were occured in 180ºC and 10 hour treatment (37%) followed by 180ºC and 6 hour (25%) and 120ºC and 6 hour (24%) treatment conditions, respectively.

The green (-a) to red (+a) and the blue (-b) to yellow (+b) colour characteristics of samples were also significantly influenced by temperature and time. The greatest changes for coordinate a* were realized at 180ºC and under 10 h treatment conditions (a= -1.76; 13.5% change). This level of treatments was also give the highest coordinate b* (b= -4.44; 21% change). It is reasonably to explained that, elevated temperature and prolonged treatment time usually effects more green (-a) and blue color (-b). However, at lower treatment conditions, the colour of Turkish hazelnut wood changed notably towards, redder, revealed by the colour measurements. It was also realized that 180ºC treatments adversely influenced the overall colour properties compared with those of lower temperature treated wood samples.

However, these modifications are not surprising; because a number of researchers have already reported a definite correlation between heat treatment conditions and colour changes of woods [4,11,17,18]. Esteves and his group (2008) proposed for pine and eucalypt woods that the contribution of red (a) and yellow (b) colour decreased with heat treatment and samples became darker [11]. The results found for Turkish hazelnut consistent with this information's.

Table 1. Surface colour characteristics of Turkish hazelnut wood measured by CIE (1931 and 1976) colour system

Colour parameter		Value (metric)
Tristimulus of the CIE system (1931)	X (red stimuli)	30.05
	Y (green stimuli)	28.19
	Z (blue stimuli)	17.33
L* (lightness)		60.06
a* (green-red)		13.08
b* (blue-yellow)		21.19
C (chroma)		24.96
H (hue)		58.32

Table 2. Surface colour characteristics of heat treated Turkish hazelnut wood measured by CIE Colour (1976) system

Treatment time (hour)	ΔL	Δa	Δb
120ºC			
2	-8.98 (1.06)	0.87 (0.59)	-2.64 (0.42)
6	-14.96 (0.66)	0.89 (0.14)	0.32 (0.55)
10	-9.36 (3.05)	0.44 (0.26)	-1.98 (1.33)
150ºC			
2	-6.73 (1.07)	0.67 (0.51)	-2.17 (0.2)
6	-8.02 (0.92)	0.3 (0.67)	-2.71 (0.59)
10	-14.7 (0.81)	0.85 (0.26)	-1.08 (0.94)
180ºC			
2	-13.86 (0.44)	0.96 (0.23)	-0.05 (0.28)
6	-15.1 (1.14)	-0.9 (0.12)	-3.41 (0.47)
10	-22.77 (2.18)	-1.76 (0.68)	-4.44 (1.39)

[+] *Numbers in parenthesis are standard deviations*

For verifying darker tone on heat treated substrates, the surface yellowness properties (reported as index) was achieved and plotted at varying treatment temperature and durations (Fig. 1). It appears that all treatment conditions significantly influenced yellowness values of the samples. Untreated (O) hazelnut woods have characteristic high yellowness value of 52.01. However, the heating had lead to a variety of processes occurring, and the various reaction pathways can act synergistically within the wood substrate. These effects fade of natural colour of substrate. The lowest yellow colour value was determined for samples in 150ºC and 6 h conditions (-2.67).

Fig. 2 shows that heat treatment conditions (temperature and time) well correlated with colour total difference (ΔE) values of Turkish hazelnut woods. However, the level of colour difference was found to be extensive on samples in all conditions. Even low temperature and treatment time, as low as 2 hours at 120ºC provides effective total colour difference (ΔE= 9.42). The highest ΔE value was found to be 23.5 at 180ºC and 10 h treatment conditions. Although the thermal modification of wood consisted very complex reactions and far from fully understood, it can be readily appreciated that there are nonetheless distinct changes in the nature of the reactions taking place as the temperature and duration is increased. The results clearly indicate that the temperature and time of heat treatment affected on big extent for substrate's natural colour.

A number of studies have been conducted on the reasonably explanation for heat treatment for woods. However, most studies have shown that the natural colour properties of species are modified upon heating conditions. Consistently, the decrease of the lightness of heat treated woods because of changes in the basic structure of cell wall constituents. However, the decreases in the colour properties depended on the treatment conditions and on the chemical constituents of woods, which is attributed to the depolymerization reactions of wood polymers during the thermal degradation [3,17]. Particularly, extractives and hemicelluloses, which are less resistant to heat than cellulose, are the primary factors for fade natural colour in high-temperature treatments [5,9]. Moreover, as mention in introduction section, the heat treated wood became darker due to chemical groups [1,4]. The similar result is also realized for Turkish hazelnut wood samples.

The FT-IR spectra of various level heat treated samples were obtained in range of 400–4000 cm^{-1}. However, the characteristic spectrum of cellulose structure concentrate in the range of 800–2000 cm^{-1} and the major peaks in this range had been identified. The FT-IR spectra of both untreated (Fig. 3a) and heat treated Turkish hazelnut (Fig. 3b) exhibit multi-modal transmittance in the range of 1000-2000 cm^{-1} region. However, the band at 900–1150 cm^{-1} is attributed to C-C out of the plane stretching, C-C-O stretching at 1060 cm^{-1}; C-O-C symmetric stretching 1150 cm^{-1} (Fig. 3a). The heat treated hazelnut sample exhibited the diminished absorption in 900–1200 cm^{-1} region (Fig. 3b) relative to the polysaccharides where a less complex in-plane C-C vibration is dominant. Unsal et al. (2003) and Mitsui et al. (2008) found that heat predominantly affects degradation of amorphous region as well as H-bonds in cellulose structure [7,18]. The result found with FT-IR evaluation of Turkish hazelnut that treated with various heat conditions, support this information.

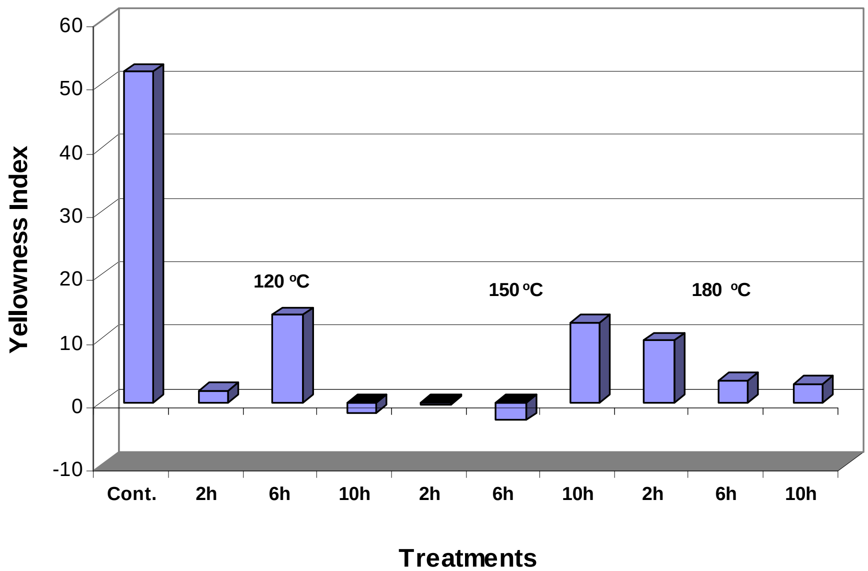

Fig. 1. Surface yellowness properties of heat treated Turkish hazelnut wood measured by CIE colour (1976) system

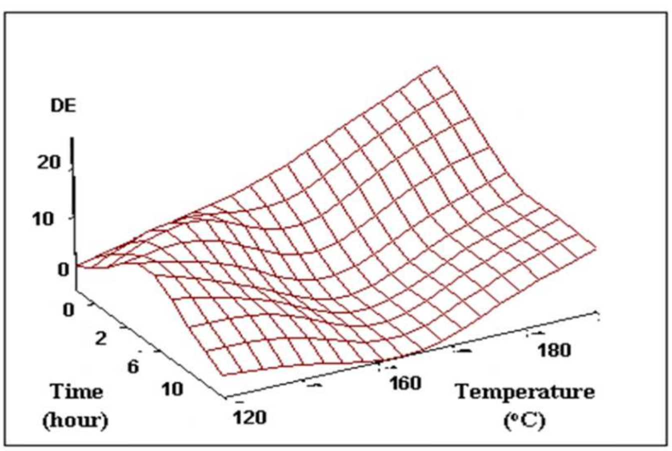

Fig. 2. Temperature and time effects on total colour difference (ΔE) of Turkish hazelnut wood

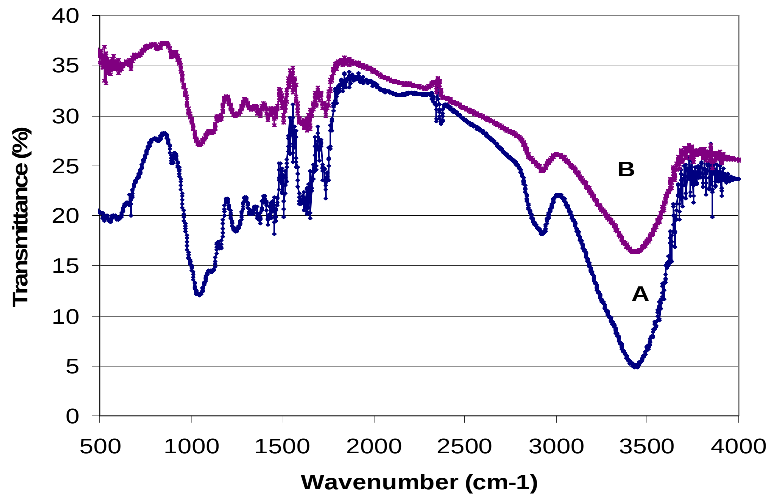

Fig. 3. Comparative FTIR spectra of untreated (a) and heat treated (at 150ºC and 6 h) of Turkish hazelnut wood

Heating affects in all cell wall chemicals, although hemicelluloses are degraded to a greater extent than the other macromolecular components. This situation for hemicelluloses is the presence of acetyl groups that to the formation of acetic acid, thereby causing acid-catalyzed degradation of the polysaccharides. A probable pathway for the heat degradation of hemicelluloses via free-radical intermediates was proposed in detail by Fengel and Wegener (1989).

4. CONCLUSION

The results clearly indicate that the temperature and time of heat treatment affected on big extent for Turkish Hazelnut wood's colour. However, this phenomenon probably related to modification of polysaccharide structures with migration and volatilization of colour extract in heating process, or the rapid oxidation of lignin and some chemical element in high temperature. In general, the results of this study on the effect of heat treatment on Turkish Hazelnut are compatible with the findings in the literature on the effect of heat treatment on different wood species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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