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SOME MECHANICAL AND PHYSICAL PROPERTIES OF AD-KD 5 IMPREGNATED AND THERMALLY MODIFIED SCOTS PINE WOOD

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ABSTRACT

The purpose of this study is to determine some mechanical properties such as modulus of rupture (MOR) and some physical properties such as glossiness, color, surface roughness, and water absorption (WA) of adolit-KD 5 (AD-KD 5) impregnated and then heat treated of Scots pine (*Pinus sylvestris* L.) wood specimens. Heat treatment of Scots pine (*Pinus sylvestris* L.) wood was carried out by hot air in an oven for 2, 4, and 8 h at 150 and 175°C. Before the heat treatments, wood specimens were impregnated with 3% aqueous solution of AD-KD 5 which is a copper based chemical according to ASTM D 413-76.

While MOR, glossiness, and colors of wood specimens impregnated with AD KD 5 were lower than that of the un-impregnated control specimen, WA of Scots pine impregnated with AD KD 5 was higher than that of the un-impregnated control specimen before heat treatments. Also, AD KD 5 impregnation caused an increase in surface roughness of Scots pine before the heat treatments.

Results showed that oven heat-treated wood became darker in tone. While, a^* coordinate (red component) increased as temperature increased, b^* coordinate decreased at temperatures tested. As a result of heat treatment, a decrease was observed in MOR, WA, glossiness, and surface roughness of Scots pine wood specimens. Moreover, increasing treatment temperature and duration, resulted in decreasing values of MOR, WA, glossiness, and surface roughness.

KEYWORDS: Impregnation, heat treatment, mechanical properties physical properties.

INTRODUCTION

Thermal treatment or heat treatment is a way of drastically changing the properties of wood and in some sense of producing a "new material". During the last decade, heat-treated wood has been commercialized and produced on a large scale (Sundqvist 2004). The maximum temperature during the heat treatment varied from 180 to 280°C and from 15 minutes to 24 hours depending on the process, wood species, sample size, moisture content of the wood, the desirable mechanical properties, resistance of biological attack, and the dimensional stability of the final product (Kamdem et al. 2002). Heat treatment of wood changes its chemical composition by degrading both cell wall compounds and extractive (Esteves et al. 2008a). The main purpose of heat treatment is to achieve new material properties, rather than dry wood, material properties such as increased biological durability (Kamdem et al. 2002, Boonstra and Tjerdsma 2006, Mazela et al. 2003, Sailer et al. 2000), improved dimensional stability (Tejada et al. 1997, Yildiz 2002, Tjeerdsma et al. 1998, Kocaefe et al. 2008), a darker color like the one seen in most tropical woods and considered to be an advantage in terms of aesthetic in some applications (Bekhta and Niemz 2003, Bourgois et al. 1991, Mitsui et al. 2001, Yildiz 2002), reduction in hygroscopiticity (Stamm and Hassen 1973, Militz 2002, Borrega and Kärenlampi 2010, Obataya et al. 2002), reduction in water absorption (Youngdong and Xiaomei 2006, Živković et al. 2008, Metsä-Kortelainen et al. 2006) and increased surface quality (Yildiz 2002, Unsal and Ayrilmis 2005, Korkut et al. 2008, 2009). However, although heat treated wood shows the advantage in terms of aesthetic properties (uniform and effective change in color) and some technical guidelines (much reduced swelling and shrinkage and improved resistance to the fungus), it has some shortcomings when compared to normal wood. The mechanical properties are substantially reduced, so that the material generally used for fully supported the structure (Vukas et al. 2010). Moreover, as a result of heat treatment, the wood becomes more brittle, and its mechanical strength and technological properties decrease in relation to the level of heat treatment (Gunduz et al. 2008). Also, Westin et al. (2006) noted that thermal treated wood is susceptible to some biodegrading agents and soil- inhabiting decay organisms. Therefore, it is not recommended in ground contact use (Jämsä and Viitaniemi 2001). Aside from wood modification, preservative treatment is effective and can extend the service life of wood and wood products (Ahmed and Moren 2012). However, many of the effective poisonous chemicals are also questionable. Increased public concern on the environmental effect of many wood preservatives has emerged. The focus on copper-based preservatives has increased following concerns about environmental effects of chromium and arsenic and resulting restrictions on the use of chromated copper arsenate (CCA) (Freeman and McIntyre 2008). So, a copper-based wood preservative, adolit KD 5 was selected in our study. It contains 20.53 % copper (II) hydroxidecarbonate, 10.0 % didecylpolyoxethylammonium borate, and 8.0 % boric acid (Ozgenc et al. 2012).

In this study, it was aimed to investigate some mechanical properties such as modulus of rupture and some physical properties such as color, glossiness, surface roughness, and water absorption of Scots pine (*Pinus sylvestris* L.) impregnated with AD-KD 5 which is a copper based impregnation chemical before heat treatment.

MATERIAL AND METHODS

Preparation of test specimens and chemicals

Air-dried sapwood specimens of Scots pine (*Pinus sylvestris* L.) were prepared for impregnation treatment with dimensions of 20 (radial) x 20 (tangential) x 360 (longitudinal)

mm for MOR test, 20 (radial) x 20 (tangential) x 10 (longitudinal) mm for WA test, 6 (radial) x 75 (tangential) x 150 (longitudinal) mm for glossiness, color, and surface roughness tests. An aqueous solution of AD-KD 5 was dissolved in distilled water to a concentration of 3 percent. All specimens were conditioned at 20°C and 65 % relative humidity for two weeks before tests. Ten replicate specimens were used for each treatment.

Impregnation method

Wood specimens were impregnated with 3 percent aqueous solution of AD-KD 5 according to ASTM D 1413 (1976). Retention was calculated from the following equation:

$$\text{Retention} = \frac{G \times C}{V} \times 10 \quad (\text{kg.m}^{-3}) \qquad (1)$$

where: G- the amount of solution absorbed by wood that is calculated by T_2- T_1
T_2 - weight of wood after impregnation (g)
T_1 - weight of wood before impregnation (g)
C - solution concentration as percentage,
V - the volume of the specimen as cm^3.

Heat modification

Heat treatment was performed using a temperature-controlled laboratory oven. Two different temperatures (150 and 175°C) and three treatment durations (2, 4, and 8 h) were applied to wood specimens under atmospheric pressure and in the presence of air.

Modulus of rupture (MOR)

The modulus of rupture of wood specimens was performed according to TS 2474 (1976). The MOR of wood samples treated with AD-KD 5 was calculated using the following equation:

$$\text{MOR} = \frac{3 \times P \times I}{2 \times b \times h^2} \quad (\text{kg.cm}^{-2}) \qquad (2)$$

where: P - the maximum load (kg),
I - span (cm),
b - the width of specimen (cm),
h - thickness of specimen (cm),
Y - the deflection (cm).

Water absorption test

Water absorption test was conducted according to AWPA M-10 (AWPA M-10 1977). In the applied method, specimens were submerged in distilled water for 96 h after being evacuated for 90 min at 760 mm Hg^{-1}. Saturated weights of the specimens were measured immediately after the given water absorption period. Specimens were then dried at 103 ± 2°C and reweighed to determine their oven dried weights. Water absorption levels (WA) were calculated by following equation:

$$WA = \frac{W_{wf} - W_{oi}}{W_{oi}} \times 100 \quad (\%) \quad (3)$$

where: W_{wf} - the saturated weights of specimens after water absorption period,
W_{oi} - the oven-dried weights after water absorption period.

Glossiness test

The glossiness of wood specimens was determined using a glossmeter (BYK Gardner, Micro-TRI-Gloss) according to ASTM D523-08 (2008). The chosen geometry was an incidence angle of 60°. Results were based on a specular gloss value of 100, which relates to the perfect condition under identical illuminating and viewing conditions of a highly polished, plane, black glass surface.

Color test

The color parameters a*, b*, and L* were determined by the CIELAB method. The L* axis represents the lightness, whereas a* and b* are the chromaticity coordinates. The + a* and -a* parameters represent red and green, respectively. The +b* parameter represents yellow, whereas -b* represents blue. L* can vary from 100 (white) to zero (black) (Zhang 2003). The colors of the specimens were measured by a colormeter (X-Rite SP Series Spectrophotometer) before and after heat treatment. The measuring spot was adjusted to be equal or not more than one-third of the distance from the center of this area to the receptor field stops. The color difference, (ΔE*) was determined for each wood as follows (ASTM D 1536–58 T 1964):

$$\Delta a^* = a^*f - a^*i \quad (4)$$

$$\Delta b^* = b^*f - b^*i \quad (5)$$

$$\Delta L^* = Lf^* - L^*i \quad (6)$$

$$(\Delta E^*) = [(\Delta a^*)2 + (\Delta b^*)2 + (\Delta L^*)\ 2]\ 1/2 \quad (7)$$

where: Δa*, Δb*, and ΔL* are the changes between the initial and final interval values.

Surface roughness

The Mitutoyo Surftest SJ-301 instrument was used for surface roughness measurements according to DIN 4768 (1990). Three roughness parameters which are mean arithmetic deviation of profile (*Ra*), mean peak-to-valley height (*Rz*), and and root mean square (*Rq*) and these parameters were widely employed in former studies to evaluate surface characteristics of wood and wood based materials (Hiziroglu 1996, Hiziroglu and Graham 1998). *Ra* is the average distance from the profile to the mean line over the length of assessment. *Rz* can be calculated from the peak-to valley values of five equal lengths within the profile *Rq* is the square root of the arithmetic mean of the squares of profile deviations from the mean line (Mummery 1993).

RESULTS AND DISCUSSION

Modulus of rupture

Tab. 1 shows AD-KD 5 retention level and MOR of Scots pine wood specimens. Retention of AD-KD 5 was found to be as 20.3 $kg.m^{-3}$. The MOR values of untreated wood specimens were higher compared to those of AD-KD 5 impregnated wood specimens. Our results showed

that AD-KD 5 treatment decreased the MOR of Scots pine wood specimens. In our study, a waterborne type preservative such as AD-KD 5 chemical was used. Waterborne preservative formulations do react with the cell wall components and can cause cell wall hydrolysis, and this reaction causes strength reduction (Winandy 1988). In our study, AD-KD 5 treatment decreased 3.16 % of MOR for Scots pine. Simsek et al. (2013) found that 4 % aqueous solution of AD-KD 5 and CCB treatments decreased 9.28 and 10.66 % of MOR for Scots pine. Our results are lower than the data from Simsek et al. (2013). It may be due to using a lower concentration level of AD-KD 5 in this study. In our study 3% aqueous solution was used and retention level was a lower compared to retention levels of the aforementioned study. Our results showed that heat treatments decreased the MOR of Scots pine wood specimens. In our study, heat treatments decreased 7.11 to 31.53 % of MOR for Scots pine. Korkut and Hiziroglu (2009) investigated the effect of heat treatment on MOR of Hazelnut wood. They found that MOR of heat treated at 180°C for 10 h was 31.86 % lower than unheated wood specimens. Another similar study, Korkut (2008) noted that MOR of heat treated Uludag fir wood at 180°C for 10 h was 29.28 % lower than unheated control specimen. The decreases in the strength properties can be explained by the rate of thermal degradation and losses of substance as a result of treatment process. This deterioration might be explained as due to hemicellulose degradation (Won et al. 2012). The primary reason for the strength loss is the degradation of hemicelluloses, which is less resistant to heat than cellulose and lignin. It is well-known fact that changes of hemicelluloses play key roles in the strength properties of wood heated at high temperatures (Hillis 1994). Dwianto et al. (1996) reported that degradation of hemicelluloses causes the cross-linking reactions in matrix substance and the crystallization of microfibrils as well as the relaxation of stresses stored in microfibrils and matrix substance. Our results showed that MOR values of Scots pine wood specimens decreased with increasing treatment temperature and duration. These results are in accordance with the findings of some of the earliest experiments conducted (Korkut 2008, Esteves et al. 2008b, Korkut and Hiziroglu 2009).

Tab. 1: MOR of Scots pine after thermal modification [a].

Impregnation/Temp.	Duration (hours)	Retention ($kg.m^{-3}$)	MOR ($kg.cm^{-2}$)	Difference (%)
Control	-	-	1110 (92)[b]	-
AD-KD 5	-	20.3	1075 (39)	-3.16
	2		1031 (98)	-7.11
AD-KD 5+ 150°C	4	-	994 (159)	-10.45
	8		938 (118)	-15.49
	2		871 (96)	-21.53
AD-KD 5+ 175°C	4	-	813 (174)	-26.76
	8		760 (55)	-31.53

[a] Ten replication were made for each treatment group.

[b] Values in paranthesis are standard deviations.

Water absorption

Water absorption levels (WA) of Scots pine wood impregnated with AD-KD 5 and then heat treated are given in Tab. 2. Results indicated that the WA levels of Scots pine impregnated with AD-KD 5 were higher than the control specimen. As a waterborne inorganic salt, AD-KD 5 may be hygroscopic and hygroscopic structure of AD-KD 5 affects the water

absorption levels of Scots pine wood. Our results showed that heat treatments decreased WA of Scots pine. In our study, heat treatments decreased 2.15 to 12.61 % of WA for Scots pine. As heat treatment reduces the number of free hydroxyl group, it slows the receiving water and the cell walls absorb less water (Vukas et al. 2010). With the degrading of carbohydrates after heat treatment, the concentration of water-absorbing hydroxyl groups decreases resulting in slow water uptake and absorption (Kartal et al. 2007; Kamdem et al. 2002). Our results showed that the water absorption of these specimens decreased with temperature and time. Kartal et al. (2007) investigated that WA of boron treated and heat modified wood. They reported that in general, the higher the treatment temperature and the longer the treatment time, the lower the amount of absorbed water, with the exception that the specimens heat treated at 180°C for 2 h showed higher water absorption. Li et al. (2011) investigated the effect of heat treatment on WA levels of Douglas fir wood. They found that higher treatment temperature and longer treatment time resulted in lower WA of Douglas fir wood. Renmei and Xiaohui (1995) and Youngdong and Xiaomei (2006) noted that water absorption decreases with the increase of heat-treatment temperature. The results of this study are consistent with these findings.

Tab. 2: Water absorption levels of Scots pine after thermal modification [a].

Impregnation/Temp.	Duration (hours)	Water absorption (96 hours) (%)	Difference (%)
Control	-	61.65(2.12)[b]	-
AD-KD 5	-	63.87(4.05)	+3.6
AD-KD 5 + 150°C	2	60.32(4.30)	-2.15
	4	59.29(3.78)	-3.82
	8	57.74(4.21)	-6.34
AD-KD 5 + 175°C	2	58.97(4.73)	-4.34
	4	55.75(3.69)	-9.57
	8	53.87(2.76)	-12.61

[a] Ten replication were made for each treatment group.

[b] Values in paranthesis are standard deviations.

Glossiness

Glossiness values of the wood surfaces at a 60° incidence angle measured before and after heat treatment are given in Tab. 3. Glossiness a property of reflecting light in a mirror-like fashion is very important for an aesthetic and decorative appearance of coated wood surface (Cakicier et al. 2011). The highest glossiness value was 4.80 for un-impregnated and un-heated Scots pine wood specimen. Glossiness value of only AD-KD 5 impregnated Scots pine wood was 2.24. Therefore, pre-treatment with copper based formulation such as AD-KD 5 caused a high decrease on glossiness of wood. The impregnation process with the solution might limit the glossiness to a point in Scots pine, probably owing to the absorption and dispersion of the reflected rays by salt crystals prominent in the large lumens of the tracheid of the wide early wood sections of the grains. Thus, the presence of this photoactive ion on the wood surface was assumed to cause the same losses in glossiness of wood (Yalinkilic et al. 1999). Heat treatments decreased gloss values of Scots pine specimens to some extent. The glossiness values of Scot pine wood decreased 11.11 to 33.33 % after heat treatments. Our results showed that glossiness values of Scots pine wood specimens decreased with increasing treatment temperature and duration and this was consistent with the findings in previous studies (Aksoy et al. 2011, Korkut et al. 2013).

Tab. 3: Glossiness values of Scots pine before and after thermal modification [a].

Impregnation /Temp.	Duration (Hours)	Before thermal modification	After thermal modification	Difference (%)
		60°	60°	60°
Control	-	4.80(0.62)[b]	-	-
AD-KD 5	-	2.24(0.35)	-	-
AD-KD 5 + 150°C	2	2.06(0.30)	1.80(0.23)	-12.62
	4	2.00(0.25)	1.72(0.19)	-14.00
	8	1.96(0.05)	1.62(0.08)	-17.34
AD-KD 5 + 175°C	2	1.98(0.33)	1.76(0.36)	-11.11
	4	1.86(0.18)	1.38(0.08)	-25.80
	8	1.74(0.29)	1.16(0.24)	-33.33

[a] Ten replication were made for each treatment group.

[b] Values in paranthesis are standard deviations.

Color changes

Tab. 4 shows the L^*, a^*, b^*, and ΔE^* parameters of Scots pine before and after heat treatments. As can be seen from Tab. 2, pre-treatment with AD-KD 5 before heat treatment highly decreased L^*, a^*, and b^* of Scots pine wood specimens before heat treatment. Our results showed that L^* and b* values decreased after heat treatment, whilst a* increased. The decrease in L^* at all temperatures indicates that the specimens became darker with the treatment time. Darkening with heat treatment increased with treatment temperature and duration and this is consistent with earlier findings (Matsuo et al. 2010, Mitsui et al. 2003, Militz 2002, Akgul and Korkut 2012). The darkening of heat- treated Scots pine might be related to a reduction in holocellulose content as the temperature increases (Bourgois et al. 1991). As wood is heated, acetic acid is formed from acetylated hemicelluloses by hydrolysis (Forsman 2008).

Tab. 4: Color changes of Scots pine before and after thermal modification [a].

Impregnation/ Temp.	Duration (hours)	Before thermal modification			After thermal modification				After thermal modification		
		*Li**	*ai**	*bi**	*Lf**	*af**	*bf**	*ΔL**	*Δa**	*Δb**	*ΔE**
Control	-	75.57(7.85)[b]	7.09(1.11)	31.50(4.68)	-	-	-	-	-	-	-
AD-KD 5	-	52.75(3.05)	0.21(0.07)	23.47(2.15)	-	-	-	-	-	-	-
AD-KD 5+150°C	2	51.53(3.04)	-0.19(0.05)	22.12(3.03)	45.86(3.28)	4.15(1.54)	21.74(3.13)	-5.67	4.34	-0.39	7.19
	4	52.44(4.51)	-0.26(0.17)	22.34(2.11)	45.62(5.48)	5.86(1.66)	21.92(2.10)	-6.82	6.12	-0.42	9.25
	8	53.00 (2.45)	-0.67(0.19)	23.33(3.36)	45.32(5.97)	6.78(1.66)	22.74(2.07)	-7.67	7.45	-0.59	10.73
AD-KD 5 +175°C	2	52.78(2.21)	-0.48(0.09)	22.98(7.71)	43.59(4.95)	6.38(1.72)	22.36(2.01)	-9.19	6.86	-0.62	11.58
	4	54.77(7.70)	-1.39(0.49)	22.77(3.36)	35.16(4.85)	7.69(1.39)	17.16(2.99)	-19.61	9.08	-5.61	22.52
	8	55.22(1.27)	-1.43(0.33)	22.22(1.20)	31.09(5.81)	7.77(1.89)	12.49(6.40)	-24.13	9.20	-9.73	28.03

[a] Ten replication were made for each treatment group.

[b] Values in paranthesis are standard deviations.

The released acid serves as catalyst in the hydrolysis of hemicelluloses to the soluble sugars (Thermowood Association 2003). The heat caramelizes the sugar to a brown color that affects the color of wood. As the degradation of hemicelluloses accelerates with temperature, the color will become darker with increased treatment temperature (Forsman 2008). The Δa^* values were found to be 4.34- 9.20 for heat treated Scots pine wood specimens. Positive values of Δa^* after heat

treatment show a tendency of wood surface to become reddish. The increase of the chromaticity coordinate (Δa^*) may be explained by the modification of some chromophoric groups of lignin (Grelier et al. 2000). Our results showed that the Δa^* of heat-treated Scots pine increased with treatment temperature and duration. Pincelli et al. (2012) investigated the effect of thermal rectification on colors of eucalyptus and pine wood. They noted that the green-red coordinate (a^*) tended to be homogenized for both species, as it decreased in eucalyptus, and increased in pinus, as the maximum temperature in thermal treatment increased. Aksoy et al. (2011) reported that the Δa^* of heat-treated Scots pine increased with treatment duration and temperature, it became more reddish. Our results are in good agreement with these researchers' findings. Negative values of Δb^* indicate a tendency of wood surface to become bluing after heat treatments. While heat treatments resulted in a slight decrease in the Δb^* values of the Scots pine wood at 150˚C for 2 4, and 8 h and at 175˚C for 2 h, it drastically decreased at 175˚C for 4 and 8 h. The Δb^* values were found to be (-0.39) – (-9.73) for heat treated Scots pine wood specimens. Bekhta and Niemz (2003) noted that a considerable decrease in yellow color after treatments above 150ºC. This is a result suggesting that considerable chemical changes, involving volatilizing of some compounds (probably extractives) that confer yellow color to pinus wood, might have occurred in treatments above 160ºC (Pincelli et al. 2012). Our results are consistent with this researchers' finding. The yellow color is associated with the presence of chromophores in the lignin and extractives, as well as organometallic compounds in extractives. Untreated wood has quinonoids and stilbene structures in its lignin, which confer part of its yellow color (Falkehag et al. 1966). It is believed that thermal rectification has caused changes, to some extent, in the structure and/or quantity of these wood compounds (Pincelli et al. 2012). The total color changes ΔE^* of Scots pine wood was changed from 7.19 to 28.03. ΔE^* of Scots pine wood specimens were drastically increased after heat treatment at 200˚C. Moreover, ΔE^* of Scots pine wood increased with temperature and duration.

Surface roughness

Surface roughness parameters such as *Ra*, *Rz*, and *Rq* values of impregnated and heated Scots pine wood are given in Tab. 5. Un-impregnated and un-heated control specimens had an average *Ra*, *Rz*, and *Rq* values 2.44, 17.08, and 3.25, respectively. Our results showed that impregnation with AD-KD 5 increased surface roughness of Scots pine. The increase of *Ra* was 43, *Rz* was 16, and *Rq* was 23 %, respectively. Ayrilmis et al. (2006) investigated the effect of various fire retardants on surface roughness of plywood. They found that samples treated with 6 % concentration of boric acid had the highest R_z value. Also, they reported that The *Rz* values of borax, boric acid, and monoammonium phosphate at higher concentrations (6 or 11 %) were always rougher than the lower concentrations (3 %) except for 11 % concentration of diammonium phosphate. The wooden materials with rough surface requires much more sanding process compared to one with smooth surface, which leads to decrease in thickness of the material and, therefore, increases the losses due to the sanding process (Dundar et al. 2008). However, the roughness of wood is a complex phenomenon. Several factors such as anatomical structure of wood, growing characteristics, machining properties and pre-treatments of wood before machining should be considered for the evaluation of the surface roughness of wood (Aydin and Colakoglu 2003, 2005, Temiz et al. 2005). Our results showed that heat modification decreased surface roughness of heated Scots pine wood specimens. The highest decrease of *Ra*, *Rz*, and *Rq* were 20, 12.20, and 25.86 % for samples treated at 175˚C for 8 h, respectively. This increase in smoothness is very important for many applications of solid wood. In addition, losses occurring in the planning machine are reduced and high quality surfaces are attained. (Unsal and Ayrilmis

2005). Bakar et al. (2013) investigated the surface roughness of heat treated rubber wood, red oak and eastern red cedar. They found that *Ra* values of heat treated rubber wood, red oak, and eastern red cedar exposed to a temperature of 190°C for 2 h had corresponding values of 23.09, 34.19 and 33.87 % reduction in *Ra*, respectively. Unsal and Ayrilmis (2005) investigated the surface roughness heat treated of Turkish river red gum wood. They found that *Ra* values of heat treated Turkish river red gum wood were reduced by up to 27.9 % at 180°C for 10 h when compared with the control samples. Another similar study, Korkut et al. (2009) found that *Ra* and *Rz* values of heat treated European hophornbeam were reduced by 21.52 and 25.34 %, respectively. Our results are in good agreement with these researchers' findings. According to our results, higher temperature and duration resulted in lower surface roughness of Scots pine wood. These results are in accordance with the findings of some of the earliest experiments conducted (Korkut et al. 2009, Gunduz et al. 2008, Korkut and Guller 2008).

Tab. 5: Surface roughness of Scots pine before and after thermal modification [a].

Impregnation/Temp.	Duration (hours)	Before thermal modification			After thermal modification			Difference (%)		
		Ra	Rz	Rq	Ra*	Rz*	Rq*	Ra*	Rz*	Rq*
Control	-	2.44(0.61)[b]	17.08(3.13)	3.25(0.82)	-	-	-	-	-	-
AD-KD 5	-	3.27(0.85)	19.90(4.14)	4.07(1.00)	-	-	-	-	-	-
	2	3.85(0.91)	23.24(3.53)	4.99(0.98)	3.60(0.90)	21.23(3.75)	4.35(1.20)	-6.49	-8.64	-12.82
AD-KD 5 + 150°C	4	4.05(0.97)	24.41(4.79)	5.07(1.23)	3.60(0.97)	21.92(4.18)	4.40(1.20)	-11.11	-10.20	-13.21
	8	4.25 (0.82)	25.48 (3.37)	5.24(0.94)	3.77(0.59)	22.74(8.70)	4.48(0.94)	-11.29	-10.75	-14.50
	2	4.05(0.82)	22.78(3.54)	4.93(0.98)	3.44(0.82)	21.04(3.01)	4.09(0.70)	-15.06	-7.63	-17.03
AD-KD 5+175°C	4	4.65(0.44)	26.01(4.01)	5.74(0.53)	3.77(0.96)	23.86(5.17)	4.43(1.12)	-18.92	-8,26	-22.82
	8	4.95(1.66)	28.59(9.49)	6.07(2.05)	3.96(1.04)	25.10(6.78)	4.50(0.80)	-20.00	-12.20	-25,86

[a] Ten replication were made for each treatment group.

[b] Values in paranthesis are standard deviations.

CONCLUSIONS

This study was performed to determine some mechanical properties such as MOR and some physical properties such as glossiness, color, surface roughness, and water absorption of AD-KD 5 impregnated and then heated Scots pine (*Pinus sylvestris* L.) at 150 and 175°C for 2, 4, and 8 h.

In our study, Scots pine wood specimens were impregnated with waterborne type preservative such as AD-KD 5 before heat treatment. Our results showed that preservative treatment contributed to lower MOR of Scots pine wood specimens. Also, AD-KD 5 treatment before heat treatment causes decrease in the loss of glossiness and color; and increase in surface roughness and water absorption. Our results showed that gloss, surface roughness, and water absorption of Scots pine wood specimens decreased after heat treatments. Heat treatment induces a strong decrease of luminance (darkening). While a^* parameter increased with the increase in treatment severity, the b^* decreased at temperatures tested 150 and 175°C. According to our results, higher treatment duration and temperature resulted in lower glossiness, surface roughness, MOR, and WA of Scots pine wood specimens.

In conclusion, a literature review indicated that thermal modification of wood was not adequate enough to ensure resistance against different biodegrading agents in outdoor use. It is expected that additional treatment with preservatives would improve wood performance in outdoor application (Ahmed and Moren 2012). Copper compounds are very effective against

numerous fungi and are the basis of numerous formulations of wood preservatives (Mourant et al. 2008). Copper compounds also have advantages: it is relatively easy to create waterborne formulations; it is easy to analyze and determine penetration in wood, and copper slows photo degradation by UV radiation and water (Archer and Preston 2006). Therefore, pre-treatment of Scots pine with a copper based wood preservative such as AD-KD 5 before heat treatment verify effectiveness against different wood-deteriorating organisms.

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