EFFECTS OF OUTDOOR ENVIRONMENTAL CONDITIONS ON THE COMBUSTION CHARACTERISTICS OF SESSILE OAK WOOD

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ABSTRACT: Substantial developments have been made in the improvement of usability and economical applicability of wood materials, which are natural products that can resist environmental adversities. The present study was conducted in order to determine the effect of outdoor environmental conditions on weight loss and combustion temperature of a wooden material. Samples of sessile oak (*Quercus petreae* Lipsky), prepared as dictated in ASTM–E 160-50, were impregnated using tanalith-E or wolmanit-CB as reported in ASTM–D 1413–76 followed by being varnished using synthetic or water-based products. The varnished products were left outdoors for 1 year. The highest weight loss occurred in samples that were impregnated using wolmanit-CB (87.2%) and the lowest weight loss was observed in the samples that were left indoors (74.6%). The highest heat source based combustion temperature was determined for the samples left indoors which were impregnated using tanalith-E and varnished using water-based products (530.1 ^{o}C), while the lowest temperature was determined for the indoor products that were impregnated with wolmanit-CB (427.4 ^{o}C). The highest temperature of combustion in absence of a heat source was determined for the indoor samples that were impregnated with tanalith-E (637.4 ^{o}C) whereas the lowest temperature was observed for the indoor sample group that was impregnated using wolmanit-CB and varnished using water-based products (516.9 ^{o}C). The indoor samples yielded more distinctive results with respect to the temperature of combustion with both the highest and the lowest temperatures of combustion identified among the indoor sample groups.

Key words: Oak, combustion, outdoor conditions, varnish, impregnation

INTRODUCTION

Wood material left to remain outdoors deteriorates quickly due to the presence of extensive light, humidity, hot-cold weather, fire and harmful organisms. The most harmful elements for wood material products post-processing have been reported as environmental factors including temperature, humidity, different wavelengths of sunlight and UV radiation as well as the seasonal changes observed in these parameters (Peker, 1997). Wood material wears out under these environmental conditions, degrading both chemically and biologically during this process. Drying, impregnation and surface treatments are among the approaches taken to prevent deterioration (Highley, 1990).

The problems that are associated with the unfavorable properties of wood materials lead to material losses. Among these problems, combustion specifically threatens lives. Varnishing protects wood material against harmful outdoor elements, although the risk of combustion has been reported to be elevated and the burning process to become faster after varnish application owing to the presence of highly ignitable and combustible solvents in the chemical composition of varnish products (Baysal et al., 2003). Impregnation of wood material has been reported to aid in the prevention of ignition in areas with high risks of combustion (Uysal, 1998; Baysal et al., 2004).

A solution of boric acid and borax was reported to improve resistance of eucalyptus (*Eucalyptus comaldulensis* Dehn.) wood at a concentration of 3.5% (Örs et al., 1999a), of Scots pine (*Pinus sylvestris* Lipsky) wood at a concentration of 5.5% (Örs et al., 1999b), of hybrid poplar (*Populus euramericana* Cv.) wood at a concentration of 3% (Sönmez et al., 2002), of tree of heaven (*Ailanthus altissima* (Mill) swingle) wood (Örs et al., 2002a) and of alder wood (C.A. Mey. Yalt.) against combustion and to reduce the ignition enhancing properties of water repellant materials (WRM) (Örs et al., 2002b). Mechanical strength loses of samples impregnated with borax were lower than non-impregnated controls and specimens impregnated with boric acid (Perçin et al., 2015).

Salt-based chemicals such as ammonium compounds or boron compounds, which are currently employed in the prevention of combustion, increase the hygroscopicity of wood material. Consequently, salt-impregnated materials are not recommended for use in humid or wet environments due to the increase of sensitivity to washing. However, the most problematic environment for wood material is outdoors. It is therefore imperative to discover alternative chemical compounds to replace those used in outdoor environments which improve the anti-combustibility of the wood and at the same time prove resistant against adverse outdoor conditions.

This study investigated the weight loss and combustion properties of sessile oak wood which was impregnated with tanalith-E or wolmanit-CB and surface-treated using water-based or synthetic varnish prior to being left outdoors in the Ankara area.

MATERIALS AND METHODS

Materials

Sessile oak (*Quercus petreae* Lipsky) wood, which is frequently employed in the wood processing industry in Turkey, was selected as the material. The wood material was obtained in a randomized manner from a timber processing plant in Trabzon in compliance with TS 2476, taking care to sample healthy, regular-fibred, rot-free, knot-free, normally grown pieces without any reaction wood and devoid of fungal and insect attacks (TS 2476, 1976).

Two frequently employed impregnation chemicals, wolmanit-CB (Wcb) and tanalith-E (T), were used to impregnate the samples.

Two different types of varnish, water-based and organic solvent-based products, were used to varnish the samples. Water-based varnish (Wb) was selected owing to the fact that its chemical formulation lacks volatiles while synthetic varnish (St) was selected because of its regular use in Turkey. The total amount of solid matter and the manufacturer's suggestions were taken into consideration in determining the amount of varnish to be applied on the samples. The total solid matter contents of the varnishes employed in the experiments are listed in Table 1.

Table 1. Total Solid Matter Content of the Varnish Products (%)

Types of Varnish	Amount of Solid Matter %
Synthetic (St)	47.0
Water-based (Wb)	33.0

METHODS

The samples were prepared from regularly fibred, knot-free, crack-free fresh wood samples that were free from thyll formation as dictated in the ASTM E 160 standard so as to obtain pieces with no visible differences in color or density and that were free from fungal and insect attack. The samples were left at 20ºC±2ºC and at 65±5% relative humidity until no change was observed in weight prior to impregnation.

The samples were impregnated using wolmanit-CB or tanalith-E according to the protocols given in TS 788-1. The impregnated samples were initially left in a room with air circulation so as to evaporate the solvents and were then dried at 20±2°C at a relative humidity of 65±3% until constant weight was achieved. Weights were recorded to a precision of 0.01g.

Varnishing was carried out as dictated in ASTM-D-3023. Prior to varnish application, the surface to be processed was lightly sanded to remove fiber blisters and dusted. Manufacturer's recommendations regarding the amount of varnish to be applied were followed. Varnish was weighed on a scale with a precision of 0.01g. The varnished samples were dried at room temperature.

Both the control (untreated) samples and the varnished and impregnated samples were then left outdoors on stands that were prepared according to the ASTM G7-05 standard between 06/01/2012-05/31/2013. The meteorological parameters for Ankara during the period of June 2012 - May 2013 are displayed in Table 2.

Table 2. Meteorological Data for Ankara During the Period of June 2012-May 2013

ANKARA	
Average of temperature (°C)	14.8
Average of the highest temperature (°C)	28.1
Average of the lowest temperature (°C)	3.4
Montly maximum rainfall (mm)	9.8
Montly average relative humidity (%)	57.4
Montly average Daily total sunbath (hours)	5.8

The combustion characteristics were determined as detailed in ASTM E 160-50. Each sample group was weighed prior to combustion and stacked on a gauze tripod. Samples in each layer were stacked perpendicularly to the preceding and proceeding layers. The flame height from the Maker type nozzle below was maintained at 25±1.3 cm when the device was not loaded and the gas pressure read at the manometer was kept constant at 0.5 kg/cm². The temperature of the flue on which the thermocouple was fixed was controlled to maintain a temperature of 315±8°C upon gas combustion.

The changes in temperature, weight loss and extent of retention during combustion with or without glow were employed as parameters in the graphical and statistical analyses. Multiple variance analysis (ANOVA) was conducted using MSTAT-C statistical evaluation software. For the cases where the difference between groups was determined as significant, the differences between the mean values were compared by employing the Duncan test. This allowed for the identification of the success rankings, which were among the factors that were under investigation using the least significant difference (LSD) critical values for the determination of homogeneity groups.

RESULTS AND FINDINGS

The mean retention values for the sessile oak wood samples were highest when wolmanit-CB was used as the impregnating chemical (2.48 kg/m^3) and lowest when tanalith-E was used as the impregnating chemical (1.26 kg/m^3) (TS 5724, 1988). The mean retention values for the impregnating material used on sessile oak are displayed in Table 3.

Table 3. Retention Values for the Impregnating Material

Impregnating material	Retention (kg cm^{-3})
Wolmanit-CB	2.48 b
Tanalith-E	1.26 a

Weight loss

The results of the analysis of variance on the effect of environment, type of impregnating material and the type of varnish on the weight loss are presented in Table 4. The mean values and the results of the LSD test are given in Table 5; a figure associated with these results is provided in Figure 1. The 2-way interaction effects and the 3-way interaction effects are presented in Tables 6 and 7, respectively.

Table 4. Results of the Analysis of Variance on the Differences in Weight Loss

Factor	*Degrees of Freedom*	*Sum of Squares*	*Mean of Squares*	*F Value*	*P α≤0,05*
Weather (W)	1	125.431	125.431	180.6694	0.0000
Impregnating agent (I)	2	62.627	31.314	45.1035	0.0000
Varnish type (V)	2	50.086	25.043	36.0715	0.0000
WI	2	50.283	25.141	36.2131	0.0000
WV	2	71.255	35.627	51.3172	0.0000
IV	4	92.685	23.171	33.3756	0.0000
WIV	4	12.110	3.027	4.3606	0.0056
Error	36	24.993	0.694		
Total	53	489.470			

All interactions between the environment, type of impregnating material and the type of varnish parameters were determined as significant (P≤0.05) by the multiple variance analysis of the weight loss of sessile oak wood. Weight loss ratios were determined to be higher for the outdoor group (86.0%) and lower for the indoor group (83.0%) in regards to environmental conditions, the highest for the wolmanit-CB impregnated materials (85.6%) and the lowest for the control group (83.0%) in regards to impregnation strategy, and the highest for the use of water-based varnish (85.7%) and the lowest for the control group (83.4%) in regards to varnish application. The environmental conditions, the type of impregnating material and varnish that were employed were determined to be effective on the weight loss ratio.

These results indicated that the highest ratio of weight loss with respect to environment + impregnating material type occurred in the outdoor + wolmanit-CB (86.3%) group and the lowest ratio was determined for the indoor groups (80.2%); the highest with respect to the environment + varnish type category was observed for the outdoor + synthetic varnish group (86.0%), and the lowest ratio was determined for the indoor groups (80.5%); the highest with respect to the impregnating material + varnish type category was observed for wolmanit-CB + water-based varnish group (86.8%) and the lowest ratio was determined for the untreated group (79.5%). Outdoor conditions, the type of impregnating material and the type of varnish were all found to affect the WL.

Table 5. Mean Weight Loss Ratios (%) with Respect to Differences in the Environment, Impregnating Material and the Type of Varnish

Factor		X_{ort}	*GH*
Weather	Out-group (W)	86.0	A*
	In-group (I)	83.0	B
LSD:± 0.4548			
Impregnating agent	Wolmanit-CB (Wcb)	85.6	A
	Tanalith-E (T)	84.9	B
	W_I	83.0	C
LSD:± 0.5570			
Varnish Type	Synthetic (St)	84.4	B
	Water-based (Wb)	85.7	A
	W_v	83.4	C
LSD:± 0.5570			

*X_{ort}: Arithmetic mean, W_I: Without impregnate, W_v: Without varnish, * Amount of the highest*

Table 6. Homogeneity Groups of the Weight Loss Ratios Formed by the 2-Way Interaction Effects of The Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	X_{ort}	*GH**
Weather + Impregnated	W+Wcb	86.3	A
	W+T	85.9	A
	W	85.9	A
	I+Wcb	84.9	B
	I+T	83.8	C
	I	80.2	D
Weather + Varnished	W+St	86.0	A
	W+Wb	85.8	A
	W	85.9	AB
	I+St	82.8	B
	I+Wb	85.6	A
	I	80.5	C
Impregnated+ Varnished	Wcb+St	84.3	DE
	Wcb+Wb	86.8	A*
	Wcb	85.8	AB
	T+St	85.1	BCD
	T+Wb	84.7	CDE
	T	84.8	BCDE
	St	83.9	E
	Wb	85.7	BC
	Control (Co)	79.5	F

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:0.7877, **$LSD_{0,5}$:0.9647*

Table 7. Homogeneity Groups of the Weight Loss Ratios Formed by The 3-Way Interaction Effects of The Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	*X_{ort}*	*GH**
Weather + Impregnated+ Varnished	W+Wcb+St	85.0	BCDE
	W+Wcb+Wb	86.6	A
	W+Wcb	87.2	A
	W+T+St	86.0	ABC
	W+T+Wb	84,5	CDE
	W+T	87.2	A
	W+St	87.1	A
	W+Wb	86.3	AB
	W	84.4	DE
	I+Wcb+St	83.5	EF
	I+Wcb+Wb	86.9	A
	I+Wcb	84.4	DE
	I+T+St	84.2	DE
	I+T+Wb	84.9	BCDE
	I+T	82.4	F
	I+St	80.8	G
	I+Wb	85.1	BCD
	I	74.6	H

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:1.364*

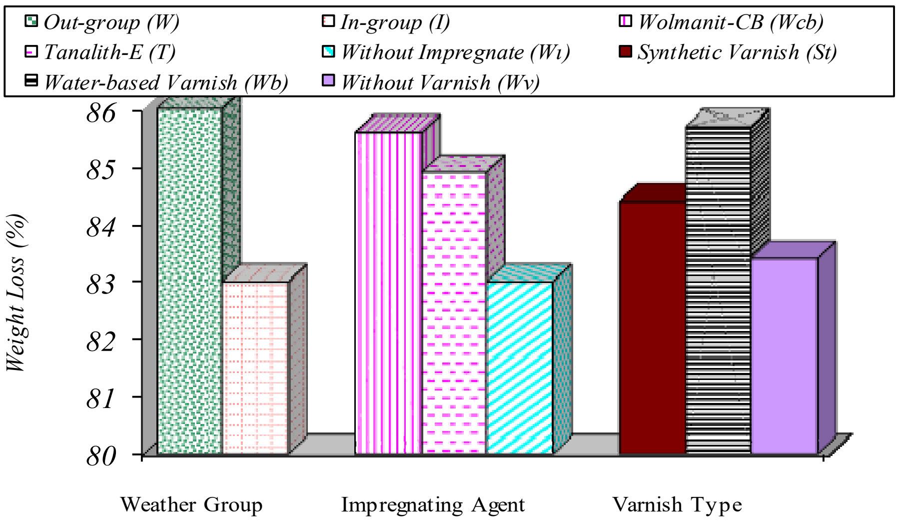

Figure1. Mean Ratios (%) of The Effect of the Environment, Impregnating Agent and the Type of Varnish Variables on Weight Loss

The highest ratio of weight loss was determined for the outdoor + wolmanit-CB (87.2%) group and the lowest ratio was determined for the indoor sample group (74.6%) with respect to the 3-way interaction between the environment + impregnating material + type of varnish category.

Temperature of combustion

Temperature of combustion in the presence of a heat source

The results of the analysis of variance on the effect of environment, type of impregnating material and the type of varnish on the temperature of combustion of sessile oak wood in the presence of a heat source are presented in Table 8. The mean values and the results of the LSD test are given in Table 9 and the figure associated with these results is provided in Figure 2. The 2-way interaction effects and the 3-way interaction effects are presented in Tables 10 and 11, respectively.

All interactions between the environment, type of impregnating material and the type of varnish parameters were determined as significant (P≤0.05) by the multiple variance analysis of the temperature of combustion of sessile oak wood in the presence of a heat source.

Table 8. Results of the Analysis of Variance on the Differences in Changes in Temperature as a Result Of Combustion with a Heat Source

Factor	*Degrees of Freedom*	*Sum of Squares*	*Mean of Squares*	*F Value*	*P α≤0,05*
Weather (W)	1	5978.723	5978.723	99.6362	0.0000
Impregnating agent (I)	2	2596.440	1298.220	21.6350	0.0000
Varnish Type (V)	2	9279.856	4639.928	77.3250	0.0000
WI	2	4998.269	2499.135	41.6484	0,0000
WV	2	2072.441	1036.221	17.2687	0,0000
IV	4	2235.013	558.753	9.3117	0,0000
WIV	4	7837.962	1959.491	32.6552	0,0000
Error	36	2160.200	60.006		
Total	53	37158.905			

The temperature of combustion in the presence of a heat source was higher for the indoor group (491.6°C) and lower for the outdoor group (470.5°C) with respect to environmental conditions, the highest when tanalith-E was used as the impregnating material (487.7°C) and the lowest when wolmanit-CB was used as the impregnating material (471.5°C) with respect to impregnation, and the highest for the employment of water-based varnish (496.3°C) and the lowest for the control group (464.3°C) with respect to varnish application.

The highest temperature of combustion in the presence of a heat source was observed for the indoor + tanalith-E group (507.1°C) and the lowest for the outdoor + tanalith-E group (468.3°C) with respect to environment + impregnating material category. The highest temperature was observed for the indoor + water-based varnish (502.4°C) and the lowest temperature for the outdoor groups (458.1°C) with respect to the environment + varnish type category. The highest temperature was observed for tanalith-E + water-based varnish (513.2°C) and the lowest temperature for the wolmanit-CB groups (453.2°C) with respect to the impregnating material + varnish type category.

Table 9. Mean Temperatures During Combustion in the Presence of a Heat Source (°C) with respect to Differences in the Environment, Impregnating Material and the Type of Varnish

Factor		X_{ort}	*GH*
Weather	Out-group (W)	470.5	B
	In-group (I)	491.6	A
LSD:± 4,229			
Impregnating agent	Wolmanit-CB(Wcb)	471.5	B
	Tanalith-E (T)	487.7	A
	W_I	483.9	A
LSD:± 5,179			
Varnish Type	Synthetic (St)	482.6	B
	Water-based (Wb)	496.3	A*
	Wv	464.3	C
LSD:± 5,179			

*X_{ort}: Arithmetic mean, W_I: Without impregnate, Wv: Without varnish, * Amount of the highest*

Table 10. Homogeneity Groups of the Mean Temperatures During Combustion in the presence of a Heat Source (°C) Formed by the 2-way Interaction Effects of the Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	X_{ort}	*GH**
Weather + Impregnated	W+Wcb	474.3	C
	W+T	468.3	C
	W	468.9	C

	I+Wcb	468.7	C
	I+T	507.1	A
	I	498.9	B
Weather + Varnished	W+St	463.3	CD
	W+Wb	490.1	B
	W	458.1	D
	I+St	501.9	A
	I+Wb	502.4	A
	I	470.4	C
Impregnated + Varnished	Wcb+St	482.9	C
	Wcb+Wb	478.4	CD
	Wcb	453.2	E
	T+St	479.9	C
	T+Wb	513.2	A
	T	470.1	D
	St	485.1	C
	Wb	497.1	B
	Control (Co)	469.5	D

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:7.324**$LSD_{0,5}$:8.970*

Table 11. Homogeneity Groups of the Mean Temperatures During Combustion in the Presence of a Heat Source (^{O}C) Formed by the 3-Way Interaction Effects of the Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	*X_{ort}*	*GH**
Weather + Impregnated + Varnished	W+Wcb+St	457.3	GH
	W+Wcb+Wb	486.7	DE
	W+Wcb	479.0	EF
	W+T+St	469.3	FGH
	W+T+Wb	496.3	BCD
	W+T	439.3	I
	W+St	463.3	GH
	W+Wb	487.3	CDE
	W	456.0	H
	I+Wcb+St	508.4	B
	I+Wcb+Wb	470.1	FG
	I+Wcb	427.4	I
	I+T+St	490.4	CDE
	I+T+Wb	530.1	A
	I+T	5009	BC
	I+St	506.9	B
	I+Wb	5069	B
	I	482.9	DEF

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:12.69*

The highest temperature of combustion in the presence of a heat source was determined for the indoor + tanalith-E + water-based varnish group (530.1°C) and the lowest temperature was determined for the indoor + wolmanit-CB group (427.4°C).

Temperature of combustion in absence of a heat source

The results of the analysis of variance of the effect of environment, type of impregnating material and the type of varnish on the temperature of combustion in absence of a heat source are presented in Table 12. The mean values and the results of the LSD test are given in Table 13 and the figure associated with these results is provided in Figure 2. The 2-way interaction effects and the 3-way interaction effects are presented in Tables 14 and 15, respectively.

All interactions between the environment, type of impregnating material and the type of varnish parameters were determined as significant ($P \leq 0.05$) by the multiple variance analysis of the temperature of combustion of sessile oak wood in absence of a heat source except for the 1-way interaction of the type of varnish parameter.

Table 12. Results of the Analysis of Variance on The Differences in Changes in Temperature as a result of Combustion in Absence of a Heat Source

Factor	*Degrees of Freedom*	*Sum of Squares*	*Mean of Squares*	*F Value*	*P α≤0,05*
Weather (W)	1	23935.959	23935.959	265.6310	0.0000
Impregnating agent (I)	2	4995.741	2497.671	27.7203	0.0000
Varnish Type (V)	2	133.713	66.856	0.7419	Ns
WI	2	6714.608	3357.804	37.2579	0.0000
WV	2	6157.802	3078.901	34.1683	0.0053
IV	4	9611.686	2402.921	26.6666	0.0049
WIV	4	15810.395	3952.699	43.8642	0.0000
Error	36	3243.953	90.110		
Total	53	70603.857			

Ns: İnsignificant

The temperature of combustion in absence of a heat source was higher for the indoor group (597.4ºC) and lower for the outdoor group (555.3ºC) with respect to environmental conditions, the highest for tanalith-E impregnated material (583.5ºC) and the lowest for the wolmanit-CB impregnated material (562.8ºC) with respect to impregnation material, and the highest for the employment of water-based varnish (578.6ºC) and the lowest for the control group (575.0ºC) with respect to varnish.

The highest temperature of combustion in absence of a heat source was observed for the indoor + tanalith-E group (614.9ºC) and the lowest for the outdoor + tanalith-E group (552.1ºC) with respect to environment + impregnating material category. The highest temperature was observed for the indoor + synthetic varnish group (606.6ºC) and the lowest for the outdoor + synthetic varnish group (544.4ºC) with respect to the environment + varnish type category. The highest temperature was observed for tanalith-E + water-based varnish (606.1ºC) and the lowest for the wolmanit-CB + water-based varnish group (542.8ºC) with respect to the impregnating material + varnish type category.

Table 13. Mean Temperatures During Combustion in Absence of a Heat Source (ºC) with respect to Differences in the Environment, Impregnating Material and the Type Of Varnish

Factor		*X_{ort}*	*GH*
Weather	Out-group (W)	555.3	B
	In-group (I)	597.4	A*
LSD:± 5.182			
Impregnating agent	Wolmanit-CB(Wcb)	562.8	B
	Tanalith-E (T)	583.5	A
	W_I	5829	A
LSD:± 6.347			
Varnish type	Synthetic (St)	575.5	A
	Water-based (Wb)	578.6	A
	Wv	575.0	A
LSD:± 6.347			

*X_{ort}: Arithmetic mean, W_I: Without impregnate, Wv: Without varnish, * Amount of the highest*

Table 14. Homogeneity Groups tf The Mean Temperatures During Combustion in Absence of a Heat Source (ºC) Formed by the 2-Way Interaction Effects of the Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	*X_{ort}*	*GH**
Weather + İmprengnated	W+Wcb	557.2	C
	W+T	552.1	C
	W	556.7	C
	I+Wcb	568.4	B
	I+T	614.9	A
	I	609.1	A
Weather + Varnished	W+St	544.4	D
	W+Wb	572.3	C
	W	549.2	D

	I+St	606.6	A
	I+Wb	584.9	B
	I	600.9	A
İmprengnated+Varnished	Wcb+St	482.9	C
	Wcb+Wb	581.8	B
	Wcb	542.8	E
	T+St	563.8	D
	T+Wb	567.1	CD
	T	606.1	A
	St	577.3	BC
	Wb	577.7	BC
	Control (Co)	587.0	B

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:8.975, **$LSD_{0,5}$:10.99*

Table 15. Homogeneity Groups of the Mean Temperatures During Combustion in Absence of a Heat Source (^{O}C) Formed by the 3-Way Interaction Effects of the Environment, Impregnating Material and the Type of Varnish

Interaction	*Factor*	*X_{ort}*	*GH**
Weather + İmprengnated + Varnished	W+Wcb+St	544.0	GH
	W+Wcb+Wb	568.7	EF
	W+Wcb	559.0	FG
	W+T+St	551.3	GH
	W+T+Wb	588.0	CD
	W+T	517.0	I
	W+St	538.0	H
	W+Wb	560.3	FG
	W	571.7	DEF
	I+Wcb+St	619.6	B
	I+Wcb+Wb	516.9	I
	I+Wcb	568.6	EF
	I+T+St	582.9	CDE
	I+T+Wb	624.1	AB
	I+T	637.4	A
	I+St	617.4	B
	I+Wb	613.6	B
	I	596.4	C

*X_{ort}: Arithmetic mean, HG: Groups of Homogeneity, *$LSD_{0,5}$:15.55*

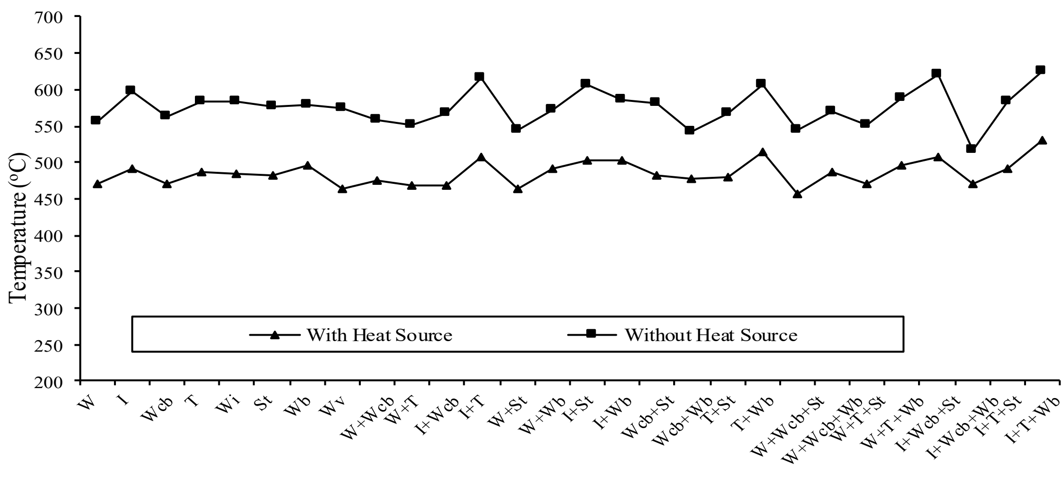

Figure 2. Variation in The Temperature of Sessile Oak Wood With Heat Source and Without Heat Source

The highest temperature of combustion in absence of a heat source was determined for the indoor + tanalith-E group (637.4ºC) and the lowest temperature was determined for the indoor + wolmanit-CB + water-based varnish group (516.9ºC).

CONCLUSION AND DISCUSSION

The extent of retention was determined to be higher following wolmanit-CB impregnation and lower following tanalith-E impregnation.

With respect to the environment, weight loss was higher for the outdoor samples than for the indoor samples. With respect to impregnation, the highest weight loss occurred in wolmanit-CB impregnated samples and the lowest in the control group. With respect to varnish, the highest weight loss occurred in samples treated with water-based varnish and the lowest in the control group. Environment, the type of impregnating material and varnish employed were all found to have an effect on weight loss.

The highest weight loss was observed for the outdoor + wolmanit-CB group and the lowest loss was determined for the indoor groups with respect to environment + impregnating material category; the highest loss was observed for the outdoor + synthetic varnish group and the lowest loss was determined for the indoor groups with respect to the environment + varnish type category; the highest loss was observed for wolmanit-CB + water-based varnish group and the lowest loss was determined for the untreated group) with respect to the impregnating material + varnish type category. Outdoor conditions and the type of impregnating material and varnish that were employed were all found to influence the weight loss ratio.

The highest weight loss ratio was determined for the outdoor + wolmanit-CB group and the lowest ratio was determined for the indoor sample group with respect to the 3-way interaction between the environment + impregnating material + type of varnish category.

The temperature of combustion in the presence of a heat source was determined to be higher for the indoor group and lower for the outdoor group with respect to environmental conditions, the highest for tanalith-E and the lowest for the wolmanit-CB with respect to impregnating material, and the highest for the employment of water-based varnish and the lowest for the control group with respect to varnish application.

The highest temperature of combustion in the presence of a heat source was observed for the indoor + tanalith-E group and the lowest for the outdoor + tanalith-E group with respect to environment + impregnating material category, the highest temperature for the indoor + water-based varnish and the lowest for the outdoor groups with respect to the environment + varnish type category, and the highest temperature for tanalith-E + water-based varnish and the lowest for the wolmanit-CB groups with respect to the impregnating material + varnish type category.

The highest temperature of combustion in the presence of a heat source was determined for the indoor + tanalith-E + water-based varnish group and the lowest temperature was determined for the indoor + wolmanit-CB group with respect to the 3-way interaction between the environment + impregnating material + type of varnish category.

The temperature of combustion in absence of a heat source was higher for the indoor group and lower for the outdoor group, the highest for the employment of tanalith-E as the impregnating material and the lowest for that of wolmanit-CB, and the highest for the application of water-based varnish and the lowest for the no-varnish control group.

The highest temperature of combustion in absence of a heat source was observed for the indoor + tanalith-E group and the lowest for the outdoor + tanalith-E group with respect to environment + impregnating material category. The highest temperature was observed for the indoor + synthetic varnish group and the lowest for the outdoor + synthetic varnish group with respect to the environment + varnish type category. Finally, the highest temperature was observed for tanalith-E + water-based varnish and the lowest for the wolmanit-CB + water-based varnish group with respect to the impregnating material + varnish type category.

The highest temperature of combustion in absence of a heat source was determined for the indoor + tanalith-E group and the lowest temperature was determined for the indoor + wolmanit-CB + water-based varnish group.

The temperature values determined for combustion in the presence or in absence of a heat source followed similar trends. Wolmanit-CB lowered the temperature of combustion whereas tanalith-E elevated them. The employed varnish types increased the temperature of combustion.

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