

**ECO-DESIGN: IMPACTS OF BLEACHING CHEMICALS AND
VARNISHES ON THE AMOUNT OF CARBON DIOXIDE
IN THE COMBUSTION OF ORIENTAL BEECH
(*FAGUS ORIENTALIS* LIPSKY)**

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ABSTRACT

This study was carried out to determine the effects of bleaching chemicals and varnishes on the amount of carbon dioxide (CO₂) in the combustion of oriental beech (*Fagus orientalis* Lipsky). For this purpose, samples of Oriental beech prepared according to ASTM D 358 contain 18% R₁ = (NaOH + H₂O₂), R₂ = (NaOH + Ca(OH)₂ + H₂O₂), R₃ = (Na₂S₂O₅ + H₂C₂O₄), R₄ = (NaSiO₃ + H₂O₂), R₅ = (KMnO₄ + Na₂S₂O₅ + H₂O₂) solution groups, after bleaching with solution groups, water based, synthetic, polyurethane and acrylic varnish were applied according to ASTM D 3023 and combustion tests were carried out in accordance with ASTM E 160-50. Gas measurements were made with the SIGMA 74172 NSU flue gas device during the combustion process. As a result, in respect to the burning types; the highest amount of CO₂ (ppm) was found in the self-combustion (8.468 ppm) while the lowest was obtained from the flame combustion source (4.599 ppm). In respect to the types of bleaching; the highest in R₅ (7.458 ppm) and the lowest in R₃ (4.059 ppm) were found. According to the varnish types; the highest value was found in the synthetic varnish (8.261), and the lowest value was found in the acrylic varnish (4.772 ppm). According to combustion type + bleaching solution + varnish type interaction, the highest values were found for without flame combustion (II) + R₃ + Sn (18.40 ppm) and lowest for flame source combustion (I) + R₅ + Pu (0.600 ppm). Consequently, the highest values for combustion gases were found in samples of oriental beech wood samples treated with water-based varnish with R₁ solution. According to this, in terms of human health and life safety, possibility of fire in places, R₃ solution and acrylic varnish may be used in the related industries.

KEYWORDS: Combustion, carbon dioxide, bleaching, varnishing, oriental beech wood.

INTRODUCTION

Eco-design is identified in both academic and policy makers as a point of intervention in the lifecycle assessment of a product to keep in mind environmental performance (Cinar 2005). The benefit of eco-design is enhanced by rooting it firmly within theoretical design principles and establishing 'sustainability' as a functional requirement within a regulatory framework. As argued by Deutza et al. (2013), formulating such an innovative approach requires first understanding current practices of eco-design in industry. Globally, consumption of wood materials has greatly increased to high levels for the production of wood-based boards which are commonly used in the related sectors driven mostly by demands from building and furniture industries in recent years. Besides, growing environmental concerns during the last decades, coupled with public pressure and stricter regulations change the ways how people do the business across the world (Cinar and Erdogdu 2018, Cinar 2018, Cinar et al. 2018). This affects the forest and furniture industries which bring a critical question concerning environmental aspects.

From the argument drawn, for the construction of natural houses, wood is one of the healthiest building materials in contrast to composite materials. It is a natural regulator of indoor climate; it breathes and assists ventilation; it stabilizes humidity and filters and purities the air. It also does not disturb the nature (Pearson 1994). However, wood is an organic compound and consists of 50% carbon. It is one of the natural materials that play an effective role in the absorption of carbon dioxide, and in the case of combustion it releases carbon dioxide gas at a significant level. Wood material is worn out due to environmental conditions and its components are degraded by chemical and biological means. Drying against these drawbacks, impregnation and surface treatment are applied (Highley and Kicle 1990). Although it is an environmentally friendly product used in many areas such as wood, furniture, and building sector, it is very weak and needs to be protected against physical and chemical events. This is of particular importance to the environmental effects of fire and preservatives such as paints and varnishes. With the effect of the chemicals used on the wood material, the fire causes an increase in harmful gases such as carbon dioxide which adversely affects the environment.

Although wood production and wood quality are of utmost importance in forest industry, in environmental aspects, few studies have examined the impact of elevated CO₂ on wood and forest industry. CO₂ is produced by all aerobic organisms when they metabolize carbohydrates and lipids to produce energy by respiration. It is also produced during the processes of decay of organic materials, the fermentation of sugars in bread, beer winemaking and combustion of wood including with other organic materials and fossil fuels such as coal, peat, petroleum and natural gas. It is returned to water via the gills of fish and to the air via the lungs of air-breathing land animals, including humans. It is a colourless, odourless and hazardous gas that is vital to life on Earth. In addition, carbon dioxide is the most significant long-lived greenhouse gas in Earth's atmosphere. Since the Industrial Revolution anthropogenic emissions - primarily from use of fossil fuels and deforestation - have rapidly increased its concentration in the atmosphere, leading to global warming. CO₂ also causes ocean acidification because it dissolves in water to form carbonic acid. The study of Ceuleman et al (2002) demonstrates that larger stem volume production during the first years of exposure to elevated CO₂ resulted from increased ring width, early wood growth in particular and, specifically, larger tracheids. In terms of wood quality, mechanical strength was reduced after three years of CO₂ enrichment, but wood density was not significantly altered.

The physical characteristics (smell, taste, colour, pattern, etc.) of wood species are different. Wood discoloration injuries in live wood, dead knot formation, oxidation of certain chemicals

in the wood next to reasons such as illness or heartwood of the older generation or tannic wood of metals result of contact occurs with the formed bleaching (Banks and Miller 1982). In addition, colour differences may occur due to the intensity of the annual growth of the wood material (summer wood, spring wood). The colour of furniture is as important as shape, size, form and balance. It is desired that the carpet, curtains and textile used in the interior decorations are compatible with the walls, ceilings and floor coverings (Atar 1999).

Colouring or bleaching of woods are carried out for reaching to desired visual aspects. Common laundry bleach or chlorine will effectively remove stain or dye color from wood, but will not affect the wood's natural color. They cause a chemical reaction that creates bleach that will blanch the stain color and can also alter the color of the wood itself. While wood dyes usually add superficial colour to wood, the bleaching chemicals create a deep light colour and shine. Bleaching chemicals are generally reactive compounds acting on the wood material side intermesh of whitening without destroying the main colour and pattern of the woods (Wagner and Kiclighter 1986).

It has been found that boron compounds used to protect wood from biotic and abiotic pests significantly reduce burning in alder wood (Uysal 1998). The combustion properties of the oak wood turned red using $C_2O_4H_2$, NaOH, H_2O_2 , NH_3 and HCl solutions were investigated. The highest weight loss was achieved with NaOH, with the highest temperature increase and the highest amount of CO_2 with CO_4H_2 and NaOH (Ozçifci 2001). Uludag fir is a material produced by using 3 layers of impregnated phenol formaldehyde impregnated with most strength zinc chloride from the materials impregnated with $(NH_3)_2$, $Al_2(SO_4)_3$, K_2CO_3 , CaCl, $ZnCl_2$ (Uysal and Kurt 2006). Another study (Ozçifci et al. 1999) shows that boron compounds increased combustion resistance of wood and that water-repellent agents (paraffin, styrene, methyl methacrylate and impregnated with isocyanate) reduced combustion enhancing effects in a certain way. In line with the literature summary, wood is exposed to be treated with different chemicals used in impregnations, varnishes and coatings to protect against physical and biological formation and to increase its visual perception. This study carries out to determine the effects of bleaching chemicals and varnishes on the amount of carbon dioxide in the combustion of Oriental beech wood material.

MATERIAL AND METHODS

Wood

Oriental beech wood (*Fagus orientalis* Lipsky) was selected according to TS EN 1476 (1984) without any defects; rots, knots, cracks and with annual rings perpendicular to the surface and sapwood sections. The density of beech was 0.66 g.cm⁻³. The samples of beech were supplied from the region of Siteler Ankara of Turkey.

Varnishes

Four types of commercial varnishes; water-based (Wb), synthetic (Sn), polyurethane (Pu) and acrylic (Ac) were used for the experiment. The application of varnishes was carried out in accordance with the specification of the producer. Some characteristics of varnishes are given in Tab. 1 (Atar et al. 2010).

Tab. 1: Technical properties of the measured varnishes.

Type of varnish	pH value	Density (g·cm ⁻³)	Viscosity (snDIN Cup / 4mm)	Amount applied (g·m ⁻²)	Nozzle gap (mm)	Air pressure (bar)
Pu (filler)	5.94	0.98	18	125	1.8	2
Pu (finishing)	4.01	0.99	18	125	1.8	2
Sn	-	0.94	18	100	-	-
Wb (primer)*	9.17	1.014	18	100	1.3	1
Wb (filler)**	9.30	1.015	18	67	1.3	1
Wb (finishing)***	8.71	1.031	18	67	1.3	1
Ac (filler)	4.30	0.95	18	125	1.8	2
Ac (finishing)	4.60	0.97	18	125	1.8	2

ASTM D 17*, ASTM D 65**, ASTM D 45***.

Bleaching chemicals

Sodium hydroxide (NaOH), hydrogen perhydroxide (H₂O₂), sodium sulfate (Na₂S₂O₅), calcium hydroxide Ca(OH)₂, hydrochloric acid (H₂C₂O₄), sodium silicate (NaSiO₃) and potassium permanganate (KMnO₄) were used as bleaching chemicals. Some characteristics of bleaching chemicals are given in Tab. 2.

Tab. 2: Bleaching solution groups.

Bleaching chemicals	Neutralization materials
NaOH + H ₂ O ₂ (R ₁)	Distilled water Acetic acid
NaOH + Ca(OH) ₂ + H ₂ O ₂ (R ₂)	
NaSiO ₃ + H ₂ O ₂ (R ₃)	
Na ₂ S ₂ O ₅ + H ₂ C ₂ O ₄ (R ₄)	
KMnO ₄ + Na ₂ S ₂ O ₅ + H ₂ O ₂ (R ₅)	

According to the properties of bleaching chemicals, the weight (Mg) or volume (Vml) was prepared as 18% solution. The equation was used as (Atar 1999):

$$M_g = \frac{M_\zeta \cdot \% M/M}{\% S}$$

where: Mg - the desired amount of solution (g), M_ζ - preparation of the desired amount of solution (g), %M/M - percentage by weight of the desired solution, %S - impurity ratio of chemical substance (%).

For liquids; the equation was used (Atar 1999):

$$V_{ml} = \frac{V_\zeta \cdot \% V/V}{\% S \cdot d}$$

where: V_{ml} - amount of solution desired (ml), V_ζ - amount of solution desired to be prepared (ml), %V/V - percent volume of desired solution, d - the density of the solution (g·cm⁻³).

Preparation of test samples

720 test samples were prepared according to ASTM E 160-50, and were cut with 13 x 13 x 76 mm and conditioned at a temperature of (20 ± 2)°C and (65 ± 3)% relative humidity till they reached 12% humidity distribution.

Implementation of samples

Test samples were bleached with 18% solutions of NaOH + H₂O₂, NaOH + Ca(OH)₂ + H₂O₂, NaSiO₃ + H₂O₂, Na₂S₂O₅ + H₂C₂O₄, KMnO₄ + Na₂S₂O₅ + H₂O₂. The bleaching solutions were applied to the test samples with sponge, parallel to the fibers first, then perpendicular to the fibers and parallel to the fibers, (100 ± 10) ml·m⁻². The substances forming the solution were applied separately and the second solution was applied after 1-3 min to increase the effect of the first applied substance. After the bleaching process was completed, the samples were left at room temperature for 2 days and neutralized with acetic acid and sterilized water. After these processes, the samples were allowed to air-dry (12%) until the moisture reached. Prior to varnishing, the surfaces of samples were sanded with a 200 sand paper and were varnished in accordance with the provision of ASTM D 3023 (1988).

Application of varnishes

After the dusts were taken, their weights were weighted on a sensitive analytical balance with the accuracy of ± 0.01 g, varnishes were carried out. For each type of varnishes, three layers were applied. The layers for water-based varnish, acrylic and polyurethane were applied by a spray-gun, and for synthetic varnish by a brush in accordance with manufacturer's recommendation. After the application of first layer, the samples were kept in room temperature for 24 hours and surfaces of the samples were subjected to be sanded with 220 grit. Following that the second layer was applied to the surfaces and sanding was carried out with 400 grit and after 24 hours, the second layers were applied to surfaces to reach a smooth surface. Then, the top coat was applied. The varnished samples were kept for 3 weeks in conditioning chambers in (20 ± 2)°C and (65 ± 3)% relative humidity.

Combustion test

Combustion tests were carried out in accordance with the provision of ASTM E 160-50 with combustion test device. Before carrying out the combustion test, the bleached and varnished samples were conditioned at 27°C and 30% relative humidity in a conditioning room until reaching to 7% relative humidity. Fire distance from maker type outlet at the lower bound of funnel was fixed to (25 ± 1.3) cm. When the device was empty, the gas pressure was fixed to 0.5 kg·cm⁻². During the burning, temperature was set at (315 ± 8)°C in the funnel. Flame source was centered below sample pile and flame source combustion (FSC) was continued for 3 min. After extinguishing of flame source, without flame source combustion (WFSC) was carried out. In the combustion stages, measurements were made for 15, 30 and 30 sec, respectively; then, CO₂ quantities (ppm) were determined.

Data analysis

CO₂ measurements were determined in three stages; at with flame source, without flame source and cinder combustion. Multivariate analysis (MANOVA) was applied to the data in the MSTAT C statistical evaluation program, and the difference between the mean values was compared with Duncan test when the difference between the groups was significant. Thus, the order of succession of the tested factors was determined by dividing them into homogeneity groups according to the critical value of least significant difference (LSD).

RESULTS AND DISCUSSION

CO₂ amounts according to combustion, varnishing and bleaching

The average CO₂ amounts according to combustion, varnishing and bleaching substance were given in Tab. 3.

Tab. 3: CO₂ amounts according to combustion, varnishing and bleaching substance.

COMBUSTION TYPE*	X	HG
(I) Flame source combustion	4.599	B
(II) Without flame combustion	8.468	A
(III) Glowing combustion	5.414	B
BLEACHING CHEMICALS**		
(Rc) (Control)	6.440	A
(R ₁) (NaOH+H ₂ O ₂)	6.908	A
(R ₂) (NaOH+Ca(OH) ₂ +H ₂ O ₂)	5.928	A
(R ₃) (NaSiO ₃ +H ₂ O ₂)	4.059	B
(R ₄) (Na ₂ S ₂ O ₅ +H ₂ C ₂ O ₄)	6.170	A
(R ₅) (KMnO ₄ +Na ₂ S ₂ O ₅ +H ₂ O ₂)	7.458	A
VARNISH TYPE***		
(Vc) Control	7.695	A
(Wb) Water based varnish	4.828	B
(Sn) Synthetic varnish	8.261	A
(Pu) Polyurethane varnish	5.246	B
(Ac) Acrylic varnish	4.772	B

*LSD = ± 1.09, **LSD = ± 1.55, ***LSD = ± 1.42, X - arithmetic mean, HG - homogeneity group.

The amount of CO₂, in terms of combustion variety, the highest result was obtained in without flame combustion samples (8.468 ppm), the lowest result was obtained in flame source combustion samples (4.599 ppm). The bleaching chemicals yielded the highest result for R₅ (7.458 ppm) while the lowest for R₃ (4.059 ppm). For varnishes, the highest values were obtained in synthetic varnish (8.261 ppm) and the lowest result was obtained in acrylic varnishes (4.772 ppm). The amounts of CO₂ according to the interaction between combustion type + varnishes, combustion type + bleaching chemicals and bleaching chemicals + varnishes were given in Tab. 4.

Tab. 4: Average CO₂ values according to the bilateral interaction.

Process type	X	HG	Process type	X	HG	Process type	X	HG
Combustion type + Varnish type [†]								
I+Vc	6.289	B	II+Vc	10.42	A	III+Vc	6.372	B
I+Wb	4.903	BCD	II+Wb	7.431	B	III+Wb	2.150	E
I+Sn	5.933	BC	II+Sn	11.47	A	III+Sn	7.375	B
I+Pu	3.178	CDE	II+Pu	7.081	B	III+Pu	5.481	BC
I+Ac	2.692	DE	II+Ac	5.931	BC	III+Ac	5.694	BC
Combustion type + Bleaching chemicals**								
I+Rc	5.150	DEF	II+Rc	8.740	ABC	III+Rc	5.430	DEF

I+R ₁	6.251	CDE	II+R ₁	9.503	AB	III+R ₁	4.970	DEF
I+R ₂	3.327	EF	II+R ₂	7.443	BCD	III+R ₂	7.013	BCD
I+R ₃	2.330	F	II+R ₃	5.197	DEF	III+R ₃	4.650	DEF
I+R ₄	4.843	DEF	II+R ₄	8.727	ABC	III+R ₄	4.940	DEF
I+R ₅	5.693	CDE	II+R ₅	11.20	A	III+R ₅	5.483	DEF
Bleaching chemicals + Varnish type ***								
Rc	11.37	AB	R ₄ +Wb	6.317	CDEFGH	R ₂ +Pu	7.933	BCDEF
R ₁	6.501	CDEFG	R ₅ +Wb	7.956	BCDEF	R ₃ +Pu	0.000	I
R ₂	4.178	EFGH	Sn	7.439	BCDEF	R ₄ +Pu	4.600	EFGH
R ₃	6.456	CDEFGH	R ₁ +Sn	2.339	HI	R ₅ +Pu	2.528	GHI
R ₄	9.450	BC	R ₂ +Sn	10.02	BC	Ac	0.000	I
R ₅	8.211	BCDEF	R ₃ +Sn	13.84	A	R ₁ +Ac	7.978	BCDEF
Wb	8.417	BCDEF	R ₄ +Sn	6.328	CDEFGH	R ₂ +Ac	7.506	BCDEF
R ₁ +Wb	6.278	CDEFGH	R ₅ +Sn	9.600	BC	R ₃ +Ac	0.000	I
R ₂ +Wb	0.000	I	Pu	4.972	DEFGH	R ₄ +Ac	4.156	FGH
R ₃ +Wb	0.000	I	R ₁ +Pu	11.44	AB	R ₅ +Ac	8.994	BCD

LSD = ± 2.456, **LSD = ± 2.691, ***LSD = ± 3.474, X - arithmetic mean, HG - homogeneity group.

The amount of CO₂, combustion type and varnish interaction in terms of the highest without flame combustion + synthetic varnish (11.47 ppm), the lowest flame source combustion + water-based varnish (2.150) was found. The amount of CO₂, combustion type and bleaching chemicals with regard to the interaction highest without flame combustion + R₅ (11.20 ppm), the lowest values in flame source combustion + R₃ (2.33 ppm) was obtained. The amount of CO₂, varnishes and bleaching solution with regard to the interaction highest R₃ + Sn (13.84 ppm), the lowest R₁ + Sn (2.339 ppm) detected. In some cases, the gas measurement was at level 0. The results of multivariate analysis on the effect of combustion type, bleaching chemicals and varnish type on the amount of CO₂ are given in Tab. 5.

Tab.5: MANOVA of CO2 effects of combustion type, bleaching and varnish type.

Source	Degrees of freedom	Sum of squares	Mean square	F-value	P < %5 (Sig)
Factor A	2	748.657	374.329		
Factor B	4	610.489	152.622	26.7226	0.0000
AB	8	256.923	32.115	10.8954	0.0000
Factor C	5	305.587	61.117	2.2927	0.0232
AC	10	219.930	21.993	4.3631	0.0009
BC	20	2788.943	139.447	1.5700	0.1187
ABC	40	827.074	20.677	9.9549	0.0000
Error	180	2521.428	14.008	1.4761	0.0458
Total	269	8279.032			

Factor A: combustion type, Factor B: varnish type, Factor C: bleaching chemicals

The effect of combustion type, bleaching solution and varnish type on the amount of CO₂ was statistically significant (α = 0.05). Significant differences in the groups in which it is important to determine DUNCAN tests were conducted. The Duncan test results for the combustion and varnish type interaction are given in Tab. 6.

Tab.6: Duncan test results (ppm).

Process type	X	HG	Process type	X	HG
I	7.783	CDEFGHIJKLMNOP	II+R ₃ +Sn	18.40	A
I+R ₁	7.553	CDEFGHIJKLMNOPQ	II+R ₄ +Sn	9.117	BCDEFGHIJKLMNOP
I+R ₂	5.150	GHIJKLMNOPQ	II+R ₅ +Sn	14.03	ABCD
I+R ₃	3.233	JLMNOPQ	II+Pu	6.167	EFGHIJKLMNOPQ
I+R ₄	6.417	DEFGHIJKLMNOPQ	II+R ₁ +Pu	16.03	AB
I+R ₅	7.600	CDEFGHIJKLMNOPQ	II+R ₂ +Pu	9.567	BCDEFGHIJKLM
I+Wb	7.250	CDEFGHIJKLMNOPQ	II+R ₃ +Pu	0.000	Q
I+R ₁ +Wb	8.450	BCDEFGHIJKLMNO	II+R ₄ +Pu	7.900	CDEFGHIJKLMNOP
I+R ₂ +Wb	0.000	Q	II+R ₅ +Pu	2.817	KLMNOPQ
I+R ₃ +Wb	0.000	Q	II+Av	0.000	Q
I+R ₄ +Wb	7.667	CDEFGHIJKLMNOPQ	II+R ₁ +Av	9.667	BCDEFGHIJKL
I+R ₅ +Wb	6.050	EFGHIJKLMNOPQ	II+R ₂ +Av	8.900	BCDEFGHIJKLMN
I+Sn	8.400	BCDEFGHIJKLMNO	II+R ₃ +Av	0.000	Q
I+R ₁ +Sn	1.900	LMNOPQ	II+R ₄ +Av	4.050	HJKLMNOPQ
I+R ₂ +Sn	2.450	KLMNOPQ	II+R ₅ +Av	12.97	ABCDEF
I+R ₃ +Sn	8.417	BCDEFGHIJKLMNO	III	12.70	ABCDEF
I+R ₄ +Sn	6.150	EFGHIJKLMNOPQ	III+R ₁	2.783	KLMNOPQ
I+R ₅ +Sn	8.283	CDEFGHIJKLMNOP	III+R ₂	1.467	NOQ
I+Pu	2.317	KLMNOPQ	III+R ₃	8.550	BCDEFGHIJKLMNO
I+R ₁ +Pu	8.150	CDEFGHIJKLMNOP	III+R ₄	10.10	BCDEFGHIJK
I+R ₂ +Pu	4.767	HJKLMNOPQ	III+R ₅	2.633	KLMNOPQ
I+R ₃ +Pu	0.000	Q	III+Wb	5.233	FGHIJKLMNOPQ
I+R ₄ +Pu	3.233	JLMNOPQ	III+R ₁ +Wb	1.067	OPQ
I+R ₅ +Pu	0.600	PQ	III+R ₂ +Wb	0.000	Q
I+Av	0.000	Q	III+R ₃ +Wb	0.000	Q
I+R ₁ +Av	5.200	FGHIJKLMNOPQ	III+R ₄ +Wb	0.550	PQ
I+R ₂ +Av	4.267	HJKLMNOPQ	III+R ₅ +Wb	6.050	EFGHIJKLMNOPQ
I+R ₃ +Av	0.000	Q	III+Sn	2.783	KLMNOPQ
I+R ₄ +Av	0.750	OPQ	III+R ₁ +Sn	1.783	MNOPQ
I+R ₅ +Av	5.933	EFGHIJKLMNOPQ	III+R ₂ +Sn	14.78	ABC
II	13.63	ABCDE	III+R ₃ +Sn	14.70	ABC
II+R ₁	9.167	BCDEFGHIJKLMN	III+R ₄ +Sn	3.717	IJKLMNOPQ
II+R ₂	5.917	EFGHIJKLMNOPQ	III+R ₅ +Sn	6.483	DEFGHIJKLMNOPQ
II+R ₃	7.583	CDEFGHIJKLMNOPQ	III+Pu	6.433	DEFGHIJKLMNOPQ
II+R ₄	11.83	ABCDEF	III+R ₁ +Pu	10.15	BCDEFGHIJK
II+R ₅	14.40	ABC	III+R ₂ +Pu	9.467	BCDEFGHIJKLM
II+Wb	12.77	ABCDEF	III+R ₃ +Pu	0.000	Q
II+R ₁ +Wb	9.317	BCDEFGHIJKLM	III+R ₄ +Pu	2.667	KLMNOPQ
II+R ₂ +Wb	0.000	Q	III+R ₅ +Pu	4.167	HJKLMNOPQ
II+R ₃ +Wb	0.000	Q	III+Av	0.000	Q
II+R ₄ +Wb	10.73	BCDEFGHIJ	III+R ₁ +Av	9.067	BCDEFGHIJKLMN
II+R ₅ +Wb	11.77	ABCDEF	III+R ₂ +Av	9.350	BCDEFGHIJKLM
II+Sn	11.13	ABCDEF	III+R ₃ +Av	0.000	Q
II+R ₁ +Sn	3.333	IJKLMNOPQ	III+R ₄ +Av	7.667	CDEFGHIJKLMNOPQ
II+R ₂ +Sn	12.83	ABCDEF	III+R ₅ +Av	8.083	CDEFGHIJKLMNOP

HG^{*} = 6.017.

The amount of CO₂, the highest value of II + R₃ + Sn (18.40 ppm) and the lowest value of I + R₅ + Pu (0.600 ppm) were found in the triple interaction of the combustion type + bleaching chemicals + varnish type. The graph of CO₂ changes according to the process is given in Fig. 1.

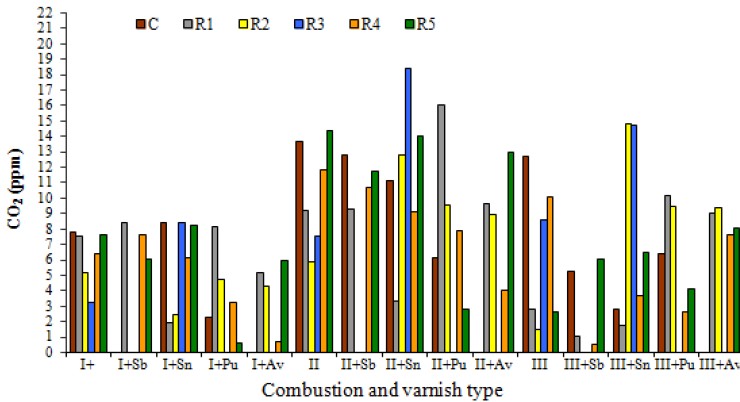


Fig. 1: CO₂ changes according to process type

CONCLUSIONS

In this study, the burning properties of wood materials varnished with water-based and synthetic varnishes were investigated after the colour whitening process with some colour-bleaching chemicals. The amount of CO₂ and without flame combustion yielded 46% higher than flame source combustion and 36% from glowing combustion. This can be due to the fact that the ignition is fully realized during the self-combustion phase. As a matter of fact, in the literature, the highest amount of CO₂ was obtained in the without flame combustion stage in cedar, spruce and chestnut woods after being impregnated with Tanalith-E and Wolmanit-CB and then combustion tests were carried out with synthetic and water based varnishes (Yasar et al. 2016a). The amount of CO₂ has shown a decreasing effect except the results of synthetic varnish. This result is supported by the study of Ozcifici (2001) and Fidan et al. (2016b). According to them, the amount of CO₂ in synthetic varnish was higher than water-based varnish. In respect to the results, it is possible to argue that the most suitable varnish is acrylic for combustion.

The amount of CO₂ was found to be different in the bleaching materials. R5 yielded the highest, while the lowest was occurred in R3. The lowest amount of CO₂ was found to be in the synthetic varnish (R3) in terms of the combustion type and the bleaching chemicals interaction. This should be taken into account in areas of high fire risk. In terms of varnish type and bleaching chemicals interaction, the amount of CO₂ was found to be the highest for synthetic varnish applications. As a matter of fact, these values were found to be in parallel with the results obtained in the literature (Yasar et al. 2016b, Uysal and Ozcifici 2000). Another argument is made by the study of Qingwen (2004), according to them, Boric acid catalyzes the dehydration and other oxygen-eliminating reactions of wood at a relatively low temperature (100–300°C). It may catalyze the isomerization of the newly formed polymeric materials to form aromatic structures. This contributes partly to the effects of boric acid for promoting charring and fire retardation of wood.

In conclusion, varnishing after the bleaching furniture or implementation of decoration at fire risk should be taken into account as an important factor in the related sectors for public and social concern in terms of human life and property safety.

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