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Effect of impregnation with boron compound doped rosin to the combustion resistance of oriental beech wood (*fagus orientalis* lipsky)

Kolofan katkılı borlu bileşiklerle emprenyenin doğu kayını (fagus orientalis lipsky) odununun yanma direncine etkisi

***Yazar(lar) (Author(s))**: Taner AŞÇI[1], Hakan KESKİN[2]*

ORCID[1]: 0000-0001-5452-2670

ORCID[2]: 0000-0001-8753-0554

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Effect of Impregnation With Boron Compound Doped Rosin to the Combustion Resistance of Oriental Beech Wood (*Fagus Orientalis* Lipsky)

Highlights

- *Flame sourced combustion temperature of Oriental beech wood imoregnated with boron compounds doped colophony was decreased with respect to control samples.*
- *Boron compounds doped colophony extend combuston period of impregnated Oriental Beech wood materials*
- *Boron compounds doped colophony decrease weight loss amount after combustion process of Oriental Beech wood materials.*
- *In terms of combustion perfromance, colophony is preferable in impregnation process with boron compounds depending on usage area and kind of wood.*

Graphical Abstract

Boron compounds doped colophony decrease flame sourced combustion temperature.

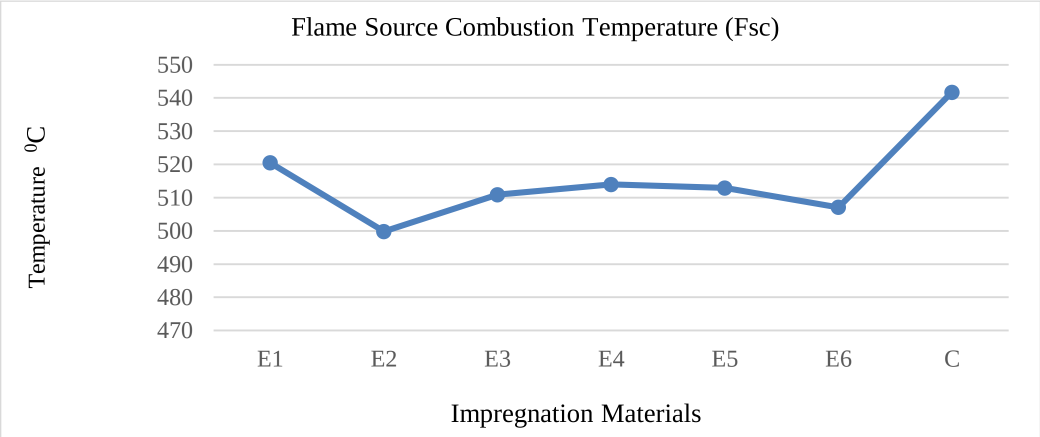

Figure. Fsc temperature values of Oriental beech test samples

Aim

Aim of the study is to determine the impact of impregnation with boron compounds doped colophony on combustion properties of oriental beech wood.

Design & Methodology

In this study experiemental way was used with different combinations.

Originality

This study is unique

Findings

While boron compounds doped colophony is increased retention amount in imprenation process, they decrease flame sourced compustion temperature and weight loss amonut in Oriental Beech wood.

Conclusion

Impact of colophony which was used to increase retention performance in impregnation process with boron compounds, on combustion properties of oriental beech wood samples is disposed to decrease flame sourced combustion temperature. Furthermore, weight loss amount of samples are lower than control samples depending on composition.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Effect of Impregnation with Boron Compound Doped Rosin to the Combustion Resistance of Oriental Beech Wood (*Fagus orientalis* Lipsky)

Araştırma Makalesi/Research Article

Taner AŞÇI[1*], Hakan KESKİN[2]

[1]Fen Bilimleri Enstitüsü, Gazi Üniversitesi, Türkiye

[2]Teknoloji Fakültesi, Ağaçişleri Endüstri Müh. Bölümü, Gazi Üniversitesi, Türkiye

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ABSTRACT

In this study, investigation of the combustion properties of Oriental beech wood (*Fagus orientalis* Lipsky) impregnated with boron compound (borax ($Na_2B_4O_710H_2O$), boric acid (H_3BO_3) doped rosin ($C_{19}H_{29}COOH$) was aimed. For this purpose, Oriental beech wood samples were prepared according to ASTM E 160-50 and impregnated with boron compound doped rosin by the method of medium-term dipping (24 hours) according to ASTM D 1413 and producers' definition. Combustion properties of samples after impregnated process were determined according to ASTM E 160-50. As a part of the research, 6 different combination and contents of impregnation materials have been used in order to especially investigate resistance against combustion of wood material treated with boron compounds in different concentrations. As a result of the study, retention performance and leaching resistance of boron compounds can be increased through rosin addition. Consequently, impregnation materials with rosin decreased the flame sourced combustion (Fsc) temperatures depending on kind of impregnation material, extended combustion period and decreased weight loss ratio of the test samples in comparison to the control samples. On the contrary, weight loss ratios were affected negatively in Oriental beech test samples up to 3% when compared with samples which were impregnated with borax. Meanwhile, combustion periods increased in test samples up to 30%. Rosin, in terms of its combustion performance, can be preferred in impregnation with boron compounds depending on kind of wood and using area.

Keywords: Combustion, impregnation, rosin, boron compounds.

Kolofan Katkılı Borlu Bileşiklerle Emprenyenin Doğu Kayını (*Fagus orientalis* Lipsky) Odununun Yanma Direncine Etkisi

ÖZ

Bu çalışmada kolofan *($C_{19}H_{29}COOH$)* katkılı borlu bileşiklerle (Boraks *($Na_2B_4O_710H_2O$)*, Borik Asit *(H_3BO_3)*) emrenye edilen Doğu Kayını *(Fagus orientalis Lipsky)* odununun yanma özelliklerinin belirlenmesi amaçlanmıştır. Bu amaçla Doğu Kayını odunu deney örnekleri ASTM-E 160-50'ye uygun olarak hazırlanmış ve ASTM-D 1413 prosedürlerine uygun olarak orta süreli (24 saat) daldırma yöntemi ile kolofan katkılı borlu bileşklerle emrenye edilmiştir. Emprenye işleminden sonra deney örneklerinin yanma özellikleri ASTM-E 160-50 prosedürlerine uygun olarak belirlenmiştir. Araştırmanın bir parçası olarak emprenye maddesinin 6 farklı içerik ve kombinasyonu, farklı kombinasyonlardaki borlu bileşiklerle muamele edilen ağaç malzemenin özellikle yanma direncinin tespit edilmesi amacıyla kullanılmıştır. Borlu bileşiklerin tutunma performansı ve yıkanma direnci kolofan katkısı yoluyla arttırılabilir. Araştırmanın sonucunda kolofanlı emprenye malzemesinin, emprenye maddesinin türüne bağlı olarak kontrol numuneleri ile karşılaştırıldığında Alev Kaynaklı Yanma (AKY) sıcaklığını düşürdüğü, yanma süresini uzattığı ve ağırlık kaybı oranlarını düşürdüğü tespit edilmiştir. Buna karşın sadece Boraks ile emprenye edilen kontrol numunelerine göre Doğu Kayını numunelerinde ağırlık kaybı oranları %3'e kadar negatif yönde etkilenmiştir. Bununla birlikte deney örneklerinde yanma süreleri %30'a varan oranlarda artmıştır. Kolofan, yanma performansı açısından, ağaç türüne ve kullanım alanına bağlı olarak Borlu bileşiklerle emprenye işleminde tercih edilebilir.

Anahtar Kelimeler: Yanma, emprenye, kolofan, borlu bileşikler.

1. INTRODUCTION

Impregnation can be identified as process of embedding of chemical material into gaps of wood structure in order to protect of wood material against fungus, insects, thermites, sea creatures beside dimensional changings and fire [1]. Within this context, organic and inorganic boron compounds appeared as one of mostly preferable protective material on the matter of protection of massive and wood based composite materials [2].

**Sorumlu Yazar (Corresponding Author)*
e-posta : tdekors@hotmail.com

Wood protection efficacy of borates against biological agents, flame retardancy, and suitability to the environment is well known. Since borates can be applied to timber as water based solutions, they are preferred economically as well. Even though they are highly mobile in wood, boron compounds are widely used in timber preservation. Borates migrate in liquid and increase the hygroscopicity of wood in damp conditions [3]. Boron compounds gained importance due to its high impacts against to the biological pesticides, diffusion abilities to wood materials, cheap and easy-obtainable features, low toxic impact on mammals and increase combustion resistance of wood materials. However, usage area of these minerals has been restricted to interior applications because of its low leaching resistance against water in atmosphere conditions [4].

Formulations range from being a primarily boron-based formulation to a formulation that contains some amount of boron. The overall efficacy of such compounds may rely more on the other compounds than the borate itself. The advantages of boron preservatives may not be retained as it will result in a change in the mechanism of action and mammalian toxicity [5].

In Europe and many other parts of the world, CCA formulations are now being replaced in the lower use classes by preservatives free of arsenic and chromium due to the concerns related to the toxicity of these components. Borate-based preservatives should be taken into account as an effective and safe-to-handle alternative [6]. To increase the use of boron compounds as environmentally wood preservatives, several fixation systems have been developed to limit or decrease boron leaching. Some attempts have relied on limiting the water penetration of treated wood using water repellents, monomer and polymer systems [7].

Combustion retardant chemical materials used as impregnation material do not redound wholly incombustible feature to the wood material. However, it can make flammability difficult and retard spread out of flame after combustion started [8].When impacts of impregnation and upper surface protection materials which are used to protect wood raw materials against interior and exterior ambient (biotic, abiotic: fire etc.) on combustion properties of wood are researched, varnishes applied after impregnation process have no impact on combustion properties of test samples [9].

Lowest mass lost for both of Brazil wood and South Pine samples treated with a mixture of 5% of boric acid and borax solutions with water has been determines between 68.72% and 72.37%, however, borax solution ratio of 5% is the best efficient treatment to extend fire period of wood [10].

Combustion resistance of Scots pine and Oriental beech treated with various chemicals shows diversity according to the type of impregnation technique. From this point of view, dipping method has more low resistance against fire than vacuum-pressure method [11]. As a result of statistical analysis of obtained data from fire experiments made by using Oriental beech and Scots pine samples impregnated with boron compounds, borax and boric acid mixture used as impregnation material provides better results on coniferous woods [12].

It should be taken into account that wood materials impregnated and treated with varnish cause to increase fire temperature and gases as a result of fire in fire risky zones. Wood materials to be used in fire risky zones should not be treated with varnish after impregnation. Its suggested that borax as impregnation material and water based varnish as wood varnish should be used [13].

Some acetone-carried consolidants for waterlogged archaeological wood were tested in order to evaluate treatments able to save time and energy. To evaluate the processes, retention of impregnating products were measured; The results highlighted that natural and modified rosin treatments gave the most satisfactory results both in the maintenance of shape. This fact was related to the high retention values of those products that occluded most of the porosity including the microporosity of cell walls [14].

In this study, determination of impacts of rosin on combustion resistance of Oriental Beech wood impregnated with boron compounds doped rosin is aimed. Boron compounds are used as healthy and domestic impregnation material but it dissolves in water. Due to this reason, it cannot be used in industry heavily. Within this context, starting from the idea of retention amount of boron compounds can be raised by adding rosin into impregnation liquid, impregnation material produced in the laboratory has been applied into wood material by using dipping method. After weight stabilization, combustion tests of wood samples have been carried out in laboratory.

2.MATERIAL and METHOD

2.1.Wood Materials

Oriental beech wood was chosen randomly from timber merchants of Ankara, Turkey. Special emphasis is given for the selection of the wood material. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect and fungi damages) wood materials were selected according to TS 2476 (TSE 1976) [15].

2.2. Impregnation Material

Boric acid (BA) and Borax (BX) are obtained from Etibank–Bandırna (Turkey) boric and acid Factory. Composition of Boric acid (H_3BO_3) is 56.30% $B_2O_3$43.70% H_2O with a molecular weight 61.83, density 1.435 g·cm^{-3} and melting point 171ºC. Borax ($Na_2B_4O_710H_2O$) consists of 21.28% Na_2O, 47.80% B_2O_3, 30.92% H_2O with a molecular weight 291.35, density 1.815 g·cm^{-3}, melting point 741 ºC [16].

Table 1. Composition of impregnation materials

Impreg. Material Codes	Composıtıon Of Impregnatıon Materıals				
	Borax ($Na_2B_4O_7 \cdot 10H_2O$) (%)	Boric Acid (H_3BO_3) (%)	Rosin ($C_{19}H_{29}COOH$) (%)	Distilled water (H_2O) (%)	Ethanol (C_2H_6O) (%)
E1	-	3	10	17	70
E2	3	-	10	17	70
E3	1.5	1.5	10	17	70
E4	3		-	97	-
E5		3	-	97	-
E6	1.5	1.5	-	97	-
C	Control Samples un-impregnated				

Rosin ($C_{19}H_{29}COOH$) is a transparent and Oriental beech rosin which is made via distilling tall oil. It dissolves in ether, alcohol, chloride hydrocarbon and other hydrocarbons. Rosin obtained from pine trees via natural way contains 80% rosin and 20% turpentine. As to content of rosin, it contains 90% rosin acids an 10% neutral matter. Moreover, it is softened at 70-80 ºC and it dissolves at 100-130 ºC. Rosin has no negative impact on human health. It is called as Rosin in USA. Rosin is identified as water repellent and combustion resistant in industry [17]. Rosin was obtained from *WSSFC – Wuzhou Sun Shine Forestry and Chemicals* from China.

Ethanol (CH_3CH_2OH) which has been used as solvent in development of impregnation material obtained from industry with the purity ratio of 96%. Its density is 789 $kg \cdot m^{-3}$, boiling point is 78.5 ºC, freezing point is -114.5 ºC and dissolves in water completely. Ethanol is colourless and made of plant alcohol.

Compositions of the new generation impregnation materials developed in laboratory are shown in Table 1.

Six different combination and contents of impregnation materials have been used to especially investigate resistance against combustion of wood material treated with boron compounds in different concentrations.

Rosin ($C_{19}H_{29}COOH$) that is natural resin and used widely in paint and adhesive industries has been added into this combination to increase retention capability of boron compounds. Determined ratios during preparing different concentrations of impregnation material have been calculated according to results of pilot applications, determination of dispersion ratios of rosin into ethanol and soluble amount of boron compounds into water. 70% of total weight of impregnation material is ethanol and 10% is rosin. These ratios provide clean and brilliant impregnation liquid without sludge. Furthermore, 3% of boron compounds in this impregnation material completely dissolves into the liquid. No sludge is seen.

2.3. Determination of density

Weights of impregnated samples are weighed through analytical balances with sensitivity of ±0.01g and volumes are calculated after measure of dimensions through digital calliper with the sensitivity ±0.01mm. Air-dry densities (δ_{12}) are calculated using following formula;

$$\delta_{12} = \frac{M_{12}}{V_{12}} g \cdot cm^{-3}$$

In this formula;
M_{12} = Weight at air-dry condition (g),
V_{12} =Volume at air-dry condition (cm^{-3}).

2.4 Preparation of test samples

Oriental beech test samples obtained from industrial companies have been shaped according to the ASTM E 160-50 (ASTM 1975) [18] principles using special equipment in Gazi University Technology Faculty Department of Wood Products Industrial Engineering Laboratories. After this process, best samples have been reserved as test samples. Shapes and dimensions of test samples to be used to combustion tests are shown in Fig.1.

2.5. Impregnation process

Orıental Beech wood samples were impregnated with boron compound doped rosin by the method of medium-term dipping (24 hours) at room temperature according to ASTM D 1413-99 (ASTM 2005) [19] and producers' definition. Test samples at 10% moisture content were kept for 24 hours in 5 litres volume bottles coded with number of related impregnation material. Prepared test samples were put into these bottles sensitively and filled up prepared impregnation materials. It was not allowed to air gaps in the covered bottles to provide full contact of impregnation material to the test samples during impregnation process. Also, the bottles tightly closed were shaken at periodic intervals in order to increase the impregnation impact of the impregnated material. After impregnation process, test samples put on a table vertically and leave to dry until its weights were stable. Moreover, the impregnation liquids were kept in coded bottles.

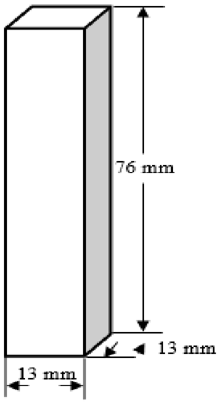

Figure 1. Dimensions of samples (R:13 x T:13 x L:76 mm)

Amount of impregnation material is calculated according to following formula;

Vn x N = Vt ⟶ 12.844 cm^{-3} x 72 = 924,76 cm^{-3}
1 cm^{-3} = 0.001 Liter ⟶ 924,76 cm^{-3} = 0.924 L
Volume of impregnation bottle = 5 L
Im: 5 – 0.924 = 4.076 L
Vn: Volume of test samples (R:13 x T:13 x L:76 mm)
N: Number of test samples
Vt: Total volume of test samples
Im: Amount of impregnation liquid needed for each of impregnation bottle

2.6. Combustion Test Method

ASTM E 160-50 principles were followed during fire tests. Test and control samples were kept in climate room at the temperature 27±2 °C and relative moisture content 30±5 % until reaching 7 % of moisture content before fire process. Moisture content of a part of control samples was kept at 30 %. In this test 24 test samples were aligned as rectangle prismed and burned. 3 different tests were made for each of composition of impregnation liquid and 72 test samples were used for each of them. Totally 504 samples were burned to determine min, max and average combustion temperatures. During this process, gas pressure was kept at 0.5 kg·cm^{-2} stable.

Measurements was realized at two levels in both method, flame resourced and without flame resourced [20].

Figure 2. a) Preperation of test samples b) Combustion in test equipment c) Ash after combustion process

Combustion process was realized using special test equipment prepared according to ASTM E 160-50 standard principles. Ash after fire process was kept to the aim of determination of combustion conditions of test samples. Investigation of ash samples from the points of weight and shape was resource for determination of impregnation conditions and impact of impregnation material. Combustion test equipment, preperation of test samples and ash details are shown in Figure 2.

2.6. Data analyses

Analysing of data gained from test samples was carried out using SPSS 22. ANOVA analysis was applied for Flame Sourced Combustion (Fsc), Flameless Combustion (Flc) data, weight loss and combustion period within the context fire test. Moreover, Duncan test was applied among groups at the end of analysis in case of differences are seen in order to test homogeneity of the groups.

Table 2. Retention performance of oriental beech samples impregnated with boron compounds doped rosin in combustion test

		E1	**E2**	**E3**	**E4**	**E5**	**E6**
Retention Perfomance	Mean (kg/m^3)	47,099	47,202	48,086	56,228	57,504	58,978
	N	3	3	3	3	3	3
	Std. Deviation	1,009	0,664	2,255	6,740	10,385	18,000
	Minimum (kg/m^3)	46,199	46,601	45,835	49,696	46,215	47,477
	Maximum (kg/m^3)	48,190	47,915	50,345	63,159	63,159	79,723

Table 3. Combustion properties of Oriental beech wood samples impregnated with boron compounds doped rosin

		C	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
Fsc (C^0)	Mean	541,6943	520,4723	499,8057	510,889	513,9723	512,9167	507,0553
	N	3	3	3	3	3	3	3
	Std.	28,71784	23,29634	0,555144	7,500523	23,25984	10,12638	7,202711
	Min.	524,083	504,25	499,333	502,583	487,167	501,417	498,833
	Max.	574,833	547,167	500,417	517,167	528,833	520,5	512,25
Flc (C^0)	Mean	570,8253	633,2917	643,387	607,2333	612,6963	619,0263	620,3763
	N	3	3	3	3	3	3	3
	Std.	33,5003	10,78941	14,31218	6,939981	14,25615	13,86495	7,990218
	Min.	532,143	623,75	627,143	602,5	596,375	603,222	611,429
	Max.	590,333	645	654,143	615,2	622,714	629,143	626,8
Weight loss (%)	Mean	88,2933	88,1633	89,72	86,1	83,2833	90,4233	90,4033
	N	3	3	3	3	3	3	3
	Std.	0,47648	0,54903	0,30806	1,69106	2,21109	1,04577	0,25502
	Min.	87,92	87,58	89,49	84,73	80,89	89,6	90,15
	Max.	88,83	88,67	90,07	87,99	85,25	91,6	90,66
Combustion Period (min)	Mean	23,33	20,33	31,67	31	20	45,67	25,33
	N	3	3	3	3	3	3	3
	Std.	4,726	1,528	4,041	1	3	4,041	3,215
	Min.	18	19	28	30	17	41	23
	Max.	27	22	36	32	23	48	29

3. RESULTS AND DISCUSSION

3.1. Retention Performance

Retention performance of developed impregnation material was investigated within the context minimum, maximum, average retention amounts and standard deviation. Retention amounts of impregnation material are shown in Table 2.

Retention amounts show that the highest amount in terms of average retention amount values were measured from test samples impregnated with E6 coded impregnation material and test samples impregnated with E5 and E4 coded impregnation materials follow respectively. This case can be explained with negative impact of rosin on retention performance of borax in oriental beech samples. In other words less penetration amount of impregnation materials to the wood material is investigated.

Retention performance of rosin added impregnation materials are lower than composition of impregnation liquids which contain different percentages of boron compounds. This case can be explained with incompatibility of rosin with kind of wood and its low retention features that decrease penetration performance of impregnation material during impregnation process which is dipping method.

3.2. Combustion properties

Combustion resistance of materials is classified according to its usage area. While using of wood material as heat resource, good combustion performance is determined through indicators such as long combustion period, low ash amounts, high heat and light spread out, etc.

In industrial materials, this issue shows direct opposition. Best combustion resistance of wood material to be used in industry means long combustion period, high ash amount, low heat and light emission. In this study, longer combustion period, lower weight loss amount, flame source combustion (Fsc) and Flameless combustion (Flc) temperatures of test samples according to control samples indicate better combustion resistance. In other words, samples that fire in long period and sustain lower weight loss, have better combustion resistance. In this section, data obtained from Oriental beech test samples used in combustion test are investigated separately.

Values of Fsc and Flc temperatures, maximum, minimum and average temperature values, mass loss amount and combustion period of test samples according to the impregnation compositions are given in Table 3.

According to the data, in terms of average values, lowest Fsc temperature is obtained from Oriental beech test samples impregnated with E2 coded impregnation material (499.80 ºC). While the highest Fsc temperature is investigated in impregnation free control samples, using boron compounds and rosin addition can decrease Fsc temperature values in Oriental beech test samples as a result of experiment. The lowest heat release at the combustion stage with a flame source was obtained at 323 °C for specimens impregnated with the BA + Bx mixture reported by Baysal et al. (2003) [21]. Additionally, BA/ BX treatment has increased the fire resistance of laminated veneer lumbers (LVL). The findings support the beneficial effects of incorporation of BA/BX on fire retardance of LVL as reported by Kurt and Mengeloğlu (2008). [22]. Fsc temperature values according to kind of impregnation composition are given in Fig. 3.

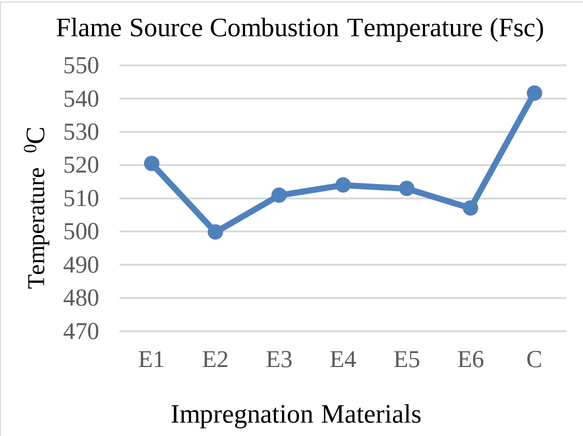

Figure 3. Fsc temperature values of Oriental beech test samples according to impregnation compositions

The lowest Flc temperature values (570.82 ºC) have been obtained from unimpregnated control samples when average Flc temperature values of test samples investigated. Impregnation materials coded E3 and E4 follow control samples respectively. Altough lowest Flc temperature values were obtained from control samples that are unimpregnated, according to Borax-Boric acid composition used as fire retardant and/or inhibitor impregnation material provides better performance in Oriental beech wood which is coniferous wood (Uysal and Kurt 2005). E3 shows almost similar performance in comparison to E4 when lowest Flc temperatures compared. Flc temperature values of Oriental Beech test samples are shown in Fig 4.

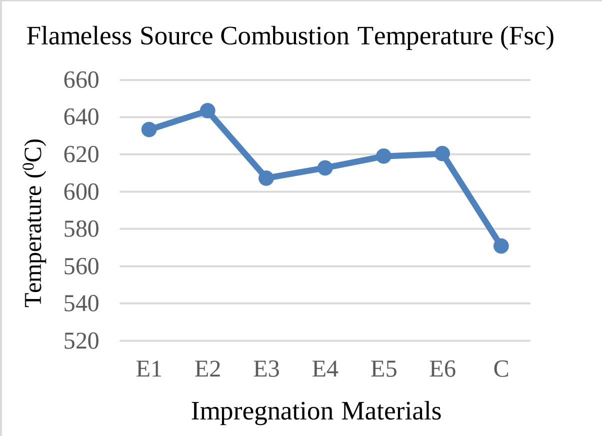

Figure 4. Flc temperature values of Oriental beech test samples according to impregnation compositions

Weight loss and combustion period are another factor on the issue determination of combustion resistance of test samples after impregnation process. Weight loss ratios of test samples according to impregnation compositions are given in Fig. 5.

Depending on the data, the highest weight loss ratios are investigated on test samples which are impregnated with E5 and E6. Lowest weight loss ratio is determined in test samples impregnated with only Borax. It means Borax has combustion preventive feature according to the data. E3 follows E4 as second lowest weight loss ratio for Oriental beech test samples. As a result of weight loss ratio values, impregnated test speciments with only Borax have the highest performance against combustion. On the other hand test samples impregnated with E3 that contains Borax, Boric Acid and rosin have another positive performance in line with literature. Materials made of boric acid, borax and chitosan at different compositions have been used in wood composite plastic production. As a result of combustion tests, additives in this produced composites were developed combustion resistance of the material. Beside of this, this additives were increased amount of ash after combustion process according to Wu and Xu (2014). [23]

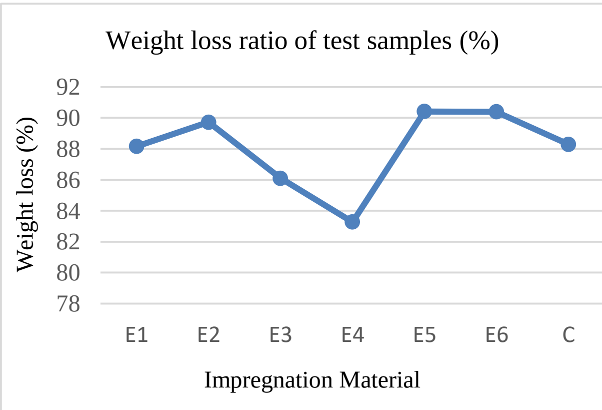

Figure 5. Weight loss (%) of Oriental beech test samples according to impregnation compositions

As to investigation of combustion period of test samples, the higher combustion periods were investigated on impregnated test samples in comparison to control samples except impregnation materials coded E1 and E4, while best performance was determined in test samples impregnated with E5 that contains only Boric Acid. Combustion periods of Oriental beech test samples according to the impregnation material compositions were given in Fig. 6.

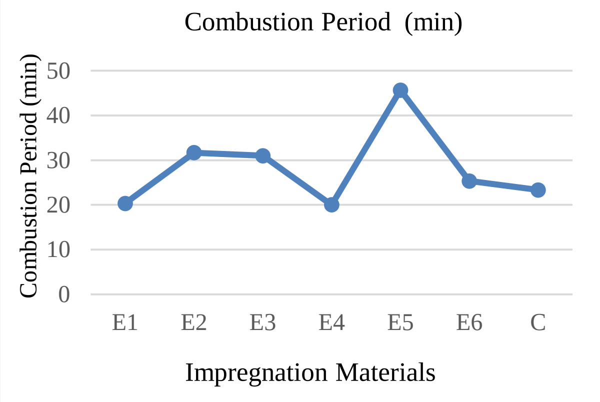

Figure 6. Combustion Period values of beech test samples according to impregnation compositions

In general impregnation materials extend combustion period according to the Fig.6. This case indicates impact of Borax and Boric Acid on combustion performance of test samples treated with boron compounds**.** Fei et al (2019) reported that combination treatment with boron compounds could substantially improve the flame retardance of the modified wood, making them especially useful for application in public settings. [24]

Fire reterdance characteristic is expected from Boron compounds. In general, boron based fire retardants increase combustion resistance of polymer matrix. This case is mostly related to heat capacity of matters in the matrix. When material exposes to high temperature, boron based fire retardants create a thin label and provide prevention of heat transfer as reported by Altuntaş, Karaoğul and Alma (2017) [25].

4. CONCLUSION

Boron compounds provide economical and more healthy solution in wood protecting against fungi and insects. The main problem related with boron compounds used as impregnation material is leaching from wood. This issue answered through using a natural rosin. As a result of its water repellent characteristics, rosin decreases leaching and has positive impact on impregnation performance.

On the other hand, in this study, it has been found that the rosin negatively impacts retention performance of impregnation liquid in Oriental Beech wood when compared with impregantion material that contains only boron compounds.

Combustion feature of wood is a negative factor in furniture sector, so fire retardance characteristic is expected from impregnation materials. Rosin additive that used with Boron compounds in impregnation material in this research, dramatically decreased the flame sourced combustion (Fsc) temperatures according to the results. Moreover Rosin added impregmation materials extended combustion period of Oriental Beech test samples.

Weight loss ratio is another significant factor in order to determine combustion resistance of impregnation materials. As a result of this study Rosin added Boron compounds can impact on positive way of weight loss ratios when compared with Boron compound based impregnation materials without Rosin. On the contrary, weight loss ratios were affected negatively in Oriental beech test samples up to 3% when compared with samples which were impregnated with borax. Meanwhile, combustion periods can be reduced in test samples impregnated with Rosin added impregnation materials up to 30%.

Rosin, in terms of its combustion performance, can be preferred in impregnation with boron compounds of Oriental Beech wood depending on using area. Furthermore new impregnation materials combinations should be studied in order to develop combustion resistance of wood material.

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods they used in this study do not require ethics committee permission and / or legal-specific permission.

AUTHORS' CONTRIBUTIONS

Taner AŞÇI: Performed the experiments defined in the study, analyse the results and wrote the manuscript.

Hakan KESKİN: Provided consultancy, check all data and helped writing manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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