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

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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 impregnated with boron compounds doped colophony was decreased with respect to control samples.
- Boron compounds doped colophony extend combustion 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 performance, 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.

![Graphical Abstract](image)

**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 experimental way was used with different combinations.

**Originality**

This study is unique

**Findings**

While boron compounds doped colophony is increased retention amount in impregnation process, they decrease flame sourced combustion temperature and weight loss amount 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*

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**ABSTRACT**

In this study, the combustion properties of Oriental beech wood (*Fagus orientalis* Lipsky) impregnated with boron compound (borax (Na$_2$B$_4$O$_7$10H$_2$O), boric acid (H$_3$BO$_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%. Result 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 Katılı 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$_2$B$_4$O$_7$10H$_2$O), Borik Asit (H$_3$BO$_3$)) emrenye edilen Doğu Kayımı (*Fagus orientalis* Lipsky) odunun yanma özelliklerinin belirlenmesi amaçlanmıştır. Bu amaçla Doğu Kayımı odunu deney örnekleri ASTM-E 160-50'ye uygun olarak hazırlanmış ve ASTM-D 1413 prosedürlerine uygun olarak orta süreli (24 saat) dallaştırma yöntemi ile kolofan katkılı boru bileşikleri emrenye edilmiştir. Emprenye işleminden sonra deney örneklerinin yanma özellikleri ASTM-E 160-50 prosedürlerine uygun olarak belirlenmiştir. Araştırmanın bir parçası olarak emrenye edilen numunein %6 farklı içerik ve kombinasyon, farklı kombinasyonlardaki boru bileşiklerde muamele edilen ağaç malzemenin özellikle yanma direncini ve esnaf verilmesi amacıyla amaçlanmıştır. Boru bileşiklerin tutunma performansı ve yıkanma direnci kolofan katkısı yoluya artmıştır. Araştırmanın sonucunda kolofanlı emrenye malzemesinin, emrenye maddesinin türune bağlı olarak kontrol numunelerinin yanma sırasında Alev Kaynaklı Yanma (%30’a varan oranlarda artış göstermiştir. Kolofan, yanma performansını açıktan ağaç türüne ve kullanın alanına bağlı olarak Borlu bileşikler emrenye işleme tercih edilebilir.

**Anahtar Kelimeler:** Yanma, emrenye, 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].

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 into 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, monomers and polymer systems [7].

Combustion retardant chemical materials used as impregnation material do not redound wholly incombusibl 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 pines 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 speed 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 is 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–Bandırma (Turkey) boric and acid Factory. Composition of Boric acid (H₃BO₃) is 56.30% B₂O₃; 43.70% H₂O with a molecular weight 61.83, density 1.435 g·cm⁻³ and melting point 171°C. Borax (Na₂B₄O₇·10H₂O) consists of 21.28% Na₂O, 47.80% B₂O₃, 30.92% H₂O with a molecular weight 291.35, density 1.815 g·cm⁻³, melting point 741 °C[16].

Determined ratios during preparing into this combination to increase retention capability of weighed boron compounds. Determined ratios have been calculated according to results of pilot applications, determination of dispersion ratios of rosins 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.

Table 1. Composition of impregnation materials

| Impreg. Material Codes | Composition Of Impregnation Materials |
|------------------------|---------------------------------------|
|                        | Borax (Na₂B₄O₇·10H₂O) (%) | Boric Acid (H₃BO₃) (%) | Rosin (C₉H₆O₆COOH) (%) | Distilled Water (H₂O) (%) | Ethanol (C₂H₅O) (%) |
| 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 (C₉H₆O₆COOH) is a transparent and Oriental beech rosins which are 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% rosins and 20% turpentine. As to content of rosins, it contains 90% rosins acid and 10% neutral matter. Moreover, it is softened at 70-80°C and it dissolves at 100-130 °C. 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 (CH₃CH₂OH) 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·m⁻³, boiling point is 78.5°C, freezing point is -114.5°C and dissolves in water completely. Ethanol is commonly made of plant alcohol.

Composition 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 (C₉H₆O₆COOH) 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 rosins 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 caliper with the sensitivity ±0.01mm. Air-dry densities (δ₁₂) are calculated using following formula;

\[ \delta_{12} = \frac{M_{12}}{V_{12}} \text{ g·cm}^{-3} \]

In this formula;

- \( M_{12} \) = Weight at air-dry condition (g).
- \( V_{12} \) = Volume at air-dry condition (cm³).

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 are used to be combustible tests are shown in Fig 1.

2.5. Impregnation process

Oriental Beech wood samples were impregnated with boron compound doped rosins 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 the following formula:

\[ V_n \times N = V_t \]

- \( V_n \): Volume of test samples (R:13 x T:13 x L:76 mm)
- \( N \): Number of test samples
- \( V_t \): Total volume of test samples
- \( V_n \times N \): Amount of impregnation liquid needed for each of impregnation bottles

\[ 12.844 \text{ cm}^3 \times 72 = 928.76 \text{ cm}^3 \times 0.924 \text{ L} \]

Im: 5 – 0.924 = 4.076 L

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) Preparation 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, preparation 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.

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 are 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 °C). 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

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

| Retention Performance | E1   | E2   | E3   | E4   | E5   | E6   |
|-----------------------|------|------|------|------|------|------|
| Mean (kg/m³)          | 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/m³)       | 46,199 | 46,601 | 45,835 | 49,696 | 46,215 | 47,477 |
| Maximum (kg/m³)       | 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) | Mean  | 541,694 | 520,472 | 499,805 | 510,889 | 513,972 | 512,916 | 507,055 |
|          | N     | 3    | 3    | 3    | 3    | 3    | 3    |
|          | Std.  | 28,7178 | 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) | Mean  | 570,825 | 633,2917 | 643,387 | 607,2333 | 612,6963 | 619,0263 | 620,3763 |
|          | N     | 3    | 3    | 3    | 3    | 3    | 3    |
|          | Std.  | 33,5000 | 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 | 651,2 | 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    |
|          | 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    |
|          | 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 |
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 Mengeloglu (2008). [22]. Fsc temperature values according to kind of impregnation composition are given in Fig. 3.

![Figure 3](image3.png)

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

The lowest Flc temperature values (570.82 °C) have been obtained from unimpregnated control samples when average Flc temperature values of test samples investigated. Impregnation materials coded E1 and E4 follow control samples respectively. Although 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](image4.png)

**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.

![Figure 5](image5.png)

**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.
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.

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4. CONCLUSION
Boron compounds provide economical and more healthy solution in wood processing 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 impregnation 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 impregnation materials extended combustion period of Oriental Beech test samples.

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 retardance 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].
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