Effects of Some Boron Supplemented Natural Extractives on Combustion Properties of Wood

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ABSTRACT: This study was designed to determine fire properties of Douglas fir (*Pseudotsuga menziesi* (Franco) Mirb.) wood specimens treated with boron supplemented aqueous solutions of brutia pine bark powder, acorn powder, sumach leaf powder and gall-nut powder. Boric acid and borax (BA and Bx) were used as borates which are the most common boron compounds found in many application areas in wood preservation industry, in order to get benefit their fire retardancy and this compounds "environmentally-friendly". Also some natural extractives (powder of brutia pine bark, sumach leaf, acorn, and gall-nut) were used which have toxic efficiency against insects and fungi due to their's tannin contents. A commercial treatment compound, which used as fire-retardant Tanalith-CBC (copper-borate-Chromium) was also used for comparison. Fire test method was performed flame source, without flame source and glowing stage, according to American Standard of ASTM E 160- 50. Results indicated that the lowest temperature for flame source stage, without flame source and, glowing stage were obtained for specimens treated with BA and Bx mixture (7:3; weight: weight). The mass losses of the specimens was the lowest treated with the BA and Bx mixture (57.85 %). Natural extractives didn't showed fire retardant efficacy. However, boric acid and borax had excellent fire retardant effectiveness over untreated and natural extractives which were applied as secondary treatment.

1. INTRODUCTION

Wood and wood based materials are composed mainly of carbon and hydrogen. For this reason, they are combustible (Ching-Mu and Wang, 1991). When heated, wood burns by producing flammable volatiles that may ignite. For wood flammability by oneself, the heat must be raised to 275°C. However, if there is a flame resource, it can be flammable at lower temperature (Levan and Winandy, 1990; Yalinkilic et al, 1996; Yalinkilic et al, 1997). For wood ignition, O2 flame source and flammable material are necessary. However, wood has excellent natural fire resistance as a result of remarkably thermal conductivity and, the fact that char is formed as wood burns. In order to reduce flammability and provide safety, wood is treated with fire-retardant chemicals. In other words, the combustibility of wood may be reduced with flame-retardant or fire-retardant (Mitchell, 1993; Nassbaum, 1988; Ellis, 1989; Winandy and Schmidt, 1995).

CCA (Cupper- chromium- arsenate), PCP (Pentachlorophenol) and creosote are well known, commercial available wood preservatives that have long been used. Due to environmental considerations CCA and creosote were mainly limited in use and PCP and many chloromated insecticides were also prohibited at many European countries for a long time ago due to their detrimental effect on the balance and human healthy (Bozkurt et al, 1995).

The borate chemicals offer substantial advantages for wood protection, providing fire resistance as well as efficacy against both fungi and insects, low cost, ease of handling and treatment. There is growing interest in their low mammalian toxicity and environmental acceptability (Laks and Mannig, 1995; YaUnkilic et al, 1998, Yalinkilic et al, 1997; Hafïzoglu et al, 1994).

On the other hand, due to their content of tannin, natural extractives have insecticides and fungicidal properties. Thus, they may be used for protection of wooden objects against destroying organisms (Bozkurt and Göker, 1986; Schulta and Nicholas, 2000; Temiz, 2000).

Accordingly, present research was designed to evaluate fire properties of boron compounds supplemented with some extractives in order to get more effective and long term protection.

2. MATERIALS AND METHODS

Preparation of Test Specimens

Specimens of Douglas fir *(Pseudotsuga menziesi* (Franco) Mirb.) wood were cut into 13 * 13 * 76 mm (radial by tangential by longitudinal) pieces for fire test according to ASTM D 1413-76 and ASTM E160-50. AU specimens were oven- dried at 103° ± 2° C before and after treatment.

Chemicals

Three groups of treatment chemicals were chosen to prepare their aqueous solutions (Table 1).

1. Borates: Aqueous solutions of boric acid (BA) and borax (Bx), mixed by weight (7/3; w/w) and dissolved in to the 7 % cone, distilled water.

2. Natural extractives: Powder of the Brutia pine (here is named as " bark powder),

sumach leaf, gall-nut and acorns dissolved in to the 4 % cone, distilled water.

Solutions were heated at 80 °C for 4 hour to suspense.

3. Tanalith-CBC: Commercial, widely used wood preservative comprised from Chromate, borate and arsenate, used as 4 % aqueous solutions.

Table 1. Treatment chemicals

Group No	Impregnation chemicals and concentration of solutions	PH	Density of solutions gr/ml
1	Control Tfj		
2	BA+Bx (7 %f*	7.20	1.020
3	Tanalith-CBC (4 %)	3.25	1.050
4	Acorn powder 4 (%)	4.81	1.10
,	1. Acorn powder (4%) 2. BA+Bx (7%)		
6	Gall-nut powder (4%)	4.84	1.035
7	l.Gall-nutpowder(4%) 2. BA+Bx(7%)		
8	Bark powder (4%)	4.38	1.10
n	Bark powder (4%) 2. BA+Bx (7%)		
10	Sumach leaf powder (4%)	5.47	1.085
	1 .Sumach leaf powder (4%) 2. BA+Bx (7 %)		

at25°C
** Untreated wood specimens
*** BA: Boric acid; Bx: Borax

Treatment Method

ASTM D 1413-76 standard test method was followed throughout the fire tests. Sixty min, 760 mm Hg $^{-1}$ before diffusion of treatment solutions under atmospheric pressure for 60 min.

Fire Test Method

Fire tests of Scots pine specimens was determined according to ASTM E 160-50. Specimens were conditioned at 27 ± 2 °C and 30- 35 % relative humidity to the targeted equilibrium moisture content of 7 % prior to fire test. Twenty four specimens was stowaged to make 12 layers which shaped square prism (Figure 1).

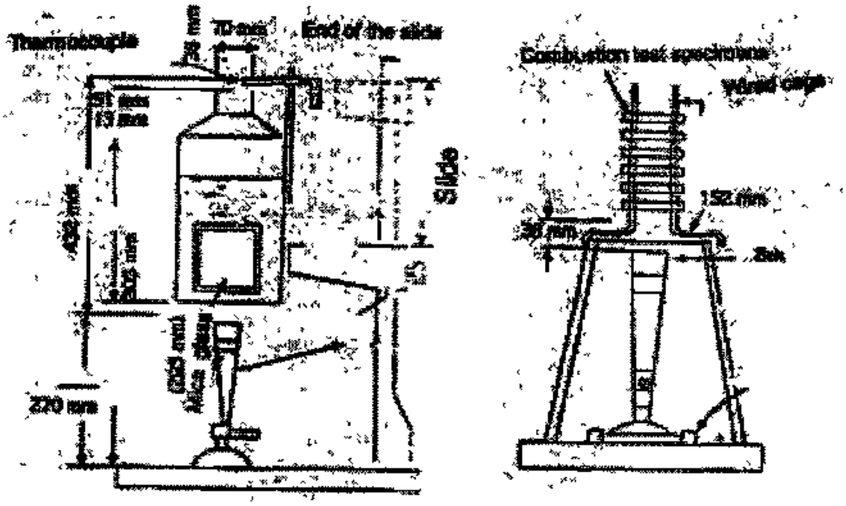

Figure 1. Combustion Test Aparatus

Heating flame was sourced to a LPG tank controlled by a sensitive bar gauged valve. Flame was balanced to the standard height before fire test samples' frame. During burning, gas pressure was adjusted to 0.5 atm., related to burning were made at three combusting stages: combustion with flame, combustion without flame and glowing.

3. RESULTS AND DISCUSSION

Mass loss

Mass losses of specimens are given Table 2. In terms of due to combustion mass losses of the treated specimens, Borates exhibit their well known fire-retardant effect at some extent. The lowest mass losses were recorded with the specimens treated with boric acid and borax mixture, after BA+Bx impregnation with the natural extractives secondary treatment of wood. With the natural extractives reduced the mass losses up to 15-20 % compared to that of the sole extractive treatments, which were yielded similar losses with those of control's. Therefore, it can be concluded at this stage that natural extractives have no fire -retardant effect that required borate supplement. Yalmkilic et al. (1998) found that Douglas fir specimens treated with BA+Bx mixture (7:3; w/w) lost around 58 % mass during combustion. Temiz (2000) also reported that *Alnus glutinosa* wood specimens treated with similar chemicals has lost about 60 % of their mass. Baysal (2003) found that *Fagus orientalis* wood specimens treated with BA+Bx mixture (7:3; w/w) lost around 68 % mass during combustion. *Temperature records at the combustion column during with and without flame source and after combustion.* Temperatures were steadily recorded at the combustion column by thermocouples at a quarter,

Table 2. The Mass losses of Douglas fir wood resulted from fire test

Group No	Treatment Chemicals	Total Retention (Mean ±SD)	Mass Losses (Mean ±SD)
1	Control	-	86.91 ±6.15
2	BA+Bx	2.20+.1.13	53.85±6.24
3	Tanalith-CBC	9.10±1.45	94.13±12.16
4	Acorn powder	6.09±2.46	94.29±7.24
5	1. Acorn powder 2. BA+Bx	1.85+1.51	78.59+13.22
6	Gall-nut powder	5.17±1.83	90.97±9.60
7	1.Gall-nut powder 2. BA+Bx	3.62±2.10	75.21±12.45
8	Bark powder	2.72+1.37	85.20±5.60
9	1. Bark powder 2. BA+Bx	2.83±1.28	77.68±10.16
10	Sumach leaf powder	2.02±0.88	90.72±7.78
11	1.Sumach leaf powder 2. BA+Bx	1.14+.1.07	77.10±11.12

Note Three replication were made for each group Small letters given as superscnpt over total retention and weight loss values represent homogenity groups(HG) obtained by statistical analysis with smilar letters reflecting statistical insignificance at the 95 % confidence level. SD : Standard deviation

Table 3. Temparature records at during flame combustion, without flame source (TFS and WTFS) and glowing stage (TGL)

Group No	Treatment chemicals	TFS (Mean±SD)	WTFS (Mean±SD)	TGL (Mean±SD)
1	Control	466 ±88	742±74	238+44
2	BA+Bx	373±56	590±108	141±33
3	Tanalith-CBC	715+146	641±124	119+24
4	Acorn powder	687±108	754±133	197±45
5	1. Acorn powder 2. BA+Bx	465±70	432±66	133±36
6	Gall-nut powders	688±107	757±95	223+43
7	1. Gall-nut powder 2. BA+Bx	557±91	581+86	141+33
8	Bark powder	596±134	610±79	208+52
9	1 Bark powder 2.BA+Bx	401±89	540±134	151±30
10	Sumach leaf Powder	766±126	804±148	199+40
11 1	1. Sumach leaf powder	519±116	466±88	119+48

30 and 30 seconds, for the combustion with and without flame source and glowing stages respectively of the experiment. Table 3 contains the recorded temperature degrees in celcius of with and without flame source (TFS and TWFS respectively) and at glowing stage (TGL).

Boric acid and borax mixture (BA+Bx) treatment and natural extractive treatment followed by supplementary borate treatments had lower heat release rate at almost all combustion stages indicating inhibitors effects of borates on combustion. The lowest heat release at the combustion stage with flame source was obtained with 310 °C for specimens treated with BA+Bx mixture. The lowest heat release of the combustion without flame source was recorded with 390 °C for specimens impregnated with BA+Bx mixture and the lowest heat release was encountered at the glowing stage with 103 °C for specimens treated with BA+Bx mixture. Therefore, BA+Bx treatment for these trials of combustion acted as reducing of heat release rate. Yielded lower temperature records that can also indicate the retardance effect of borates on combustion when combined with the natural extractives. It was seen that treated with sumach leaf powders had the highest heat release with average 788 °C. It might be due to the potential ignition effect of sumach leaf powder in combustion stage. Interestingly, Tanalith- CBC well known commercially preservative resulted in rather high heat release at with and without flame source 715 °C and 641 °C, respectively Therefore, it seems necessary to take some further precautions for this commercial preservative when used at high fire risk.

Duration of combustion without flame source and glowing

Almost all natural extractives gave the worst results in terms of duration time of combustion without flame source (Table 4). Le Van and Winandy (1990) stated that both boron compounds have different effects of flame retardancy, as Bx lengthen the time of glowing while the BA surpass smoke generation. Therefore, it seems both chemical played role as fire-retardant here in this study (Table 4). Considering the stand point of deflection stage which can be an indicator of constructional failure during combustion or time until constructional failure begins, the longest time obtained with the specimens treated with by BA+Bx treatment for the specimens treated with BA+Bx mixture. Natural extractives with secondary borate treatment exhibited better performance compare to sole natural extractives treatment.

Table 4. Duration of the without flame source (TWFS), after glowing (DGL) and to deflection (DT)

Group No	Treatment chemicals	TWFS (Sec) (Mean 1 SD)	DGL (Sec) (MeaniSD)	DT(Sec) (Mean ± SD)
1	Control	589±66	664±88	308±67
2	BA+Bx	198+ 27	367+58	985±115
3	Tanalith-CBC	690±89	585±106	348±85
4	Acorn powder	853+127	557±95	173118
5*	1. Acorn powder 1. BA+Bx	354168[c]	401±56	486169
6	Gall-nut powder	7871139	584±96	196179
7*	1. Gall-nut powder 2. BA+Bx	389±54	477±82	407157
8	Bark powder	711+113	516+84	194135
9*	1. Bark powder 2.BA+Bx	402±57	398±65	418167
10	Sumach leaf powder	814+155	586±132	85133
11*	1 .Sumach leaf powder 2. BA+Bx	395±64	4101105	311194

Note: For abbreviations refer to Table 2.

4. CONCLUSION

Some limited combustion properties of wood specimens treated with borates or natural extractives and, borate supplemented natural extractives were studied. Double treatments of wood with the natural extractives and borates were targeted to benefit their potential cumulative protection as biological resistance and fire retardancy at the same time.

Type of the natural extractives was also found having profound effect on the combustion behavior of treated wood. They were drastically increased the mass loss of wood after combustion while borates evidently reduced those losses to some considerable extent as well as reduced the temperature profiles of released heat during combustion after flame source removed and at glowing stage.

In conclusion, natural extractives as potential natural wood protective agents should be studied further by the aspect of biological resistance since environmental considerations are of primary concern at our planet worldwide. Borate as an other environmentally safe chemicals also required working on their flame retardancy and biological resistance. Their combinations with the natural extractives of wood or plants can be a gate for an increased performance of protection and immobilization of borates for a reasonable time at exterior conditions.

REFERENCES

ASTM D 1413-76. 1976. Standart test method of testing wood preservatives by laboratory solidblock cultures. Annual Book of ASTM Standart, 452-460.

ASTM E 160-50. 1975. Standart test method for combustible properties of treated wood by the crib test. 809-813.

Baysal, E. 2003. Yanmayı Geciktirici Kimyasal Maddeler ve Bitkisel Sepi Maddeleri İle Muamele Edilen Doğu Kayını (*Fagus orientalis* Lipsky) Odununun Yanma Özellikleri, Fırat Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 15(1): 123-134.

Bozkurt, Y; Y. Göker. 1986. Orman ürünlerinden faydalanma, Faculty of Forestry, İstanbul University, Issue No: 3402, p. 448.

Bozkurt, Y; Y. Göker; N. Erdin. 1995. Impregnation techhnique, Course book, Faculty of Forestry, İstanbul University, 3779/425, 429 pp.

Ching- Mu T, Y.L.Wang. 1991. Incombustibility of fire retardant-paint coated wood panels. Quart. J. Expt. Forest, NTU 5(3): 45-60.

Ellis, W. D.; R. M. Rowell 1989. Flame-retardant treatment of wood with a diisocyanate and an oligomerphosphate. Wood and Fiber Science 21(4): 367-375.

Hafizoglu, H; M.K. Yalınkılıç; U.C. Yildız; E Baysal, H. Peker; Z Demirci. 1994. Utilization of Turkey's boron reserves in wood preservation industry. Project of Turkish Science and Tech. Council (TÜBİTAK), Code: TOAG-875, p. 377.

Laks, P.E; M.J. Manning . 1995. Inorganic borates as preservative systems for wood composites. Proc. Second Pacific Kim. Bio-Based Symp, Vancouver, Canada, 236-244.

Levan, S; J.E. Winandy 1990. Effect of fire-retardant treatments on wood strength: A review. Wood and Fiber Science, 22(1): 113-131.

Mitchell, S. 1993. Fire performance of wood: Test methods and fire retardant treatments. Proceedings of the 4th annual BCC Conference on Rame Retardancy, 18-20 May, Stamford, CT Normwalk, CT: Business Commucinations Co. 1993; Inc: 36-43.

Nussbaum, R. 1988. The effect of low concentration fire retardant impregnations on wood charring rate and char yield. Journal of Fire Sciences, Vol: 6,290-306.

Schulta, T.P. D.D. Nicholas 2000. Naturally durable heartwood: evidence for purposed dual defensive function of extractives, Phytochemistry, Vol: 54, Issue: 1,47-52.

Temiz, A. 2000. Physical and mechanical properties of *Alnus glutinosa* (L.) gaetern. subsp. barbata (C .A. mey.) yalt. treated with some impregnation chemicals. M.S.c Thesis, Institue of Scientific Science, Trabzon, Turkey, p.121.

Yalınkılıç, M.K; E. Baysal, Z. Demirci 1996. Role of treatment chemicals in combustion of douglas fir wood. Proceedings of the First Trabzon International Energy and Environment Symposium, My 29-31, Karadeniz Technical University Trabzon, Turkey, 814-821.

Yalınkılıç, M.K; E. Baysal, Z. Demirci 1997. Fire resistance of calabrian pine (Pinus brutia (Ten.)) wood treated with some boron compounds and or water repellents. Turkish. J. of Agriculture and Forestry, Vol 4: 423-431.

Yalınkılıç., M.K; W. Yusu, Z. Demirci; E. Baysal, M Takahashi, S. Ishihara. 1997. Oxygen index levels and thermal analysis of wood treated with melamine formaldehyde-boron combinations. International Research Group on Wood Preservation ,28th Annual Meeting, Vancouvert, Canada, IRG/WP 9730135

Yalınkılıç, M.K; Y. Imamura, M. Takahashi, Z. Demirci 1998. Effect of boron addition to adhesive and/or surface coating on fire-retardant properties of particleboard. Wood and Fiber Science, 30(4): 348-359.

Yalınkılıç, M.K; E. Baysal, Z. Demirci 1998. Fire resistance of douglas fir (Pseudotsuga menziesii (Mirb.) Franco) wood treated with some chemicals. Pamukkale University, Journal of Engineering Sciences, Vol: 4(1-2): 613-624.

Winandy, J., E. Schmidt. 1995. Preliminary development of remedial treatments for thermally degraded fire-retardant treated wood. Forest. Prod. J. 45(2): 51-52.