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THE USE OF BORAX PENTAHYDRATE OF INORGANIC FILLER IN MEDIUM DENSITY FIBERBOARD PRODUCTION

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ABSTRACT

The aim of the study was the use of the inorganic borax pentahydrate mineral in medium density fiberboard production instead of biomass fiber and to specify the performance which physical, mechanical, combustion of produced boards. Chips used in manufacture were subjected to cooking for 4,5 minutes in Asplund defibrator at the vapor pressure of 7,6 kg/cm^2 pressure and 190 ºC temperature. 1,6 % paraffin according to based on oven-dried wood fibers was added to cooked chips before the fiber processing in segments of defibrillator section. 1 % ammonium sulphate according to based on oven-dried wood fibers were added to fiber in the bowline. Borax pentahydrate was prepared in a separate tank in order to use the production of medium density fiberboard medium density fiberboard. Borax pentahydrate inorganic mineral was mixed with urea-formaldehyde resin. Urea-formaldehyde glue was prepared as three different solutions including the borax pentahydrate as 3 % (20 kg), 6 % (40 kg) and 9 % (60 kg) respectively. Borax pentahydrate mixed fibers were dried to 12 % moisture. Mat was formed before prepress. Daily multi-press was manufactured 188 °C temperature and 32 kg/cm^2 pressure and 270 second pressing time. Manufactured boards size were 2100x4900x18 (mm). According to this work result, 3 % and 6 % rate borax pentahydrate added medium density fiberboard boards were measured more good physical and mechanical test results compare to control boards. 9 % borax pentahydrate added medium density fiberboard boards were shown incredibly superior performance at fire resistance.

Keywords: Borax pentahydrate, color properties, combustion temperature, fibers, mechanical properties, medium density fiberboard, physical properties

INTRODUCTION

The amount of production increases day by day in the boron and boron derivatives forest products plate production sector. Boron and boron derivatives are used effectively in the production of composite plates due to their resistance to fire. Scientific studies on the effective use of boron derivatives chemicals in the production of forest products are carried out all over the world.

Borates have several important advantages in addition to its preservative features such as imparting flame retardant, providing sufficient protection against wood destroying organisms, having low mammalian toxicity and low volatility. Moreover, they are colorless and odorless. Baysal *et al.* (2005) have examined a comparative study on stability and decay resistance of some environmentally friendly fire retardant baron compounds in his study. Hafızoglu *et al.* (1994) have investigated various fire retardants to be used with MDF panels. The effects of fire retardants over the fire performance of MDF and plywood were determined and the results showed that the fire performance of MDF and plywood increased nearly 6,4 % and 1,6 % respectively.

Istek *et al.* (2013) investigated the effect of fire retardants on the combustion performance of medium-density fiberboards that were coated with mixtures of water, binder, calcite, and various fire-retardant coatings. Jiang *et al.* (2011) have researched the influence of three boron flame retardants on thermal curing behavior of urea formaldehyde resin. Kurt *et al.* (2012) have studied the effects of many boron compounds (boric acid, borax, ammonium *etc.*) used as fire retardants in wood. According to LeVan *et al.* (1990), the inorganic salts such as di-ammonium phosphate, mono ammonium phosphate, zinc chloride, ammonium sulphate, borax, and boric acid are the most common fire-retardant chemicals used for wood.

Ozcıfcı *et al.* (2007) have studied the fire properties of laminated veneer lumber (LVL) prepared from beech (*Fagus orientalis* L.) veneers treated with some fire retardants. According to their study, the lowest temperature and mass loss are obtained for specimens treated with di-ammonium phosphate and boric acid–borax mixture. Taghiyari and Nouri (2015) have investigated the influence of nano-wollastonite (5, 10, 15, and 20 g/kg dry weight basis of wood fibers) on physical and mechanical properties of MDF. According to the results, nano-wollastonite material contents of 10 % and 15 % are optimal. Taghiyari *et al*. (2016) have produced MDF from wollastonite fibers, camel-thorn, and wood fibers. According to studies, wollastonite fibers with the further addition of camel-thorn fibers improved most of the physical and mechanical properties of MDFs.

Tondi *et al.* (2014) have studied the comparison of di-sodium octaborate tetrahydrate-based and tannin-boron-based formulations as fire retardant for wood structures. When the ratio of fire retardants in wood panels is increased, it is found that their fire performances are improved even more (Tsunoda 2001). Such improvement is a significant outcome in wood industry. Usta *et al.* (2012) have examined the effect of some boron compounds for the physical and the mechanical properties of medium density fiberboard (MDF) panels in terms of the fire-retardant properties such as melamine urea-formaldehyde (MUF) resins having different melamine contents (10 %, 15 %, and 20 %).

Valcheva *et al.* (2015) have studied the effect of thickness of medium density fiberboard produced of hardwood tree species on their selected physical and mechanical properties. Yang *et al*.(2014) have examined the effect of typical boron compounds on the thermal degradation and combustion properties of *Phyllostachys pubescen.* Yu *et al.* (2017) have studied the combustibility of boron-containing fire retardant treated bamboo filament. Zahedsheijani *et al.* (2011) have studied the potential use of Na+ montmorillonite (Na+MMT) nanoclay in MDF production. According to the test results, the air permeability of MDF boards are decreased. The mass diffusivity of board is not affected.

The production of MDF was about 4,910 million m^3/year in 2018 in Turkey. However, this figure was about 99,443 million cubic meters/year in the world (accessed, 24 January 2020). Some researchers have performed various studies to reduce the amount of raw materials in the MDF industry. These studies were about the usage possibilities of the borax pentahydrate minerals rather than lignocellulosic raw materials.

The inorganic borax pentahydrate mineral which has the mixing ratio of 0 %, 3 %, 6 %, 9 % respectively are produced for boards in the MDF production process. In this study, the experimental investigations are performed in order to realize the physical, mechanical, color and combustion properties of the produced boards having borax pentahydrate mineral according to the reference board. According to MDF boards combustion tests, Borax Pentahydrate inorganic mineral can be used for the fire as a resistive material in the production of MDF.

MATERIAL AND METHODS

Materials

Wood species used in MDF production are beech (*Fagus orientalis* L.), Oak (*Quercus robur* L) and Pine (*Pinus sylvester* L). These species were brought from Duzce Province forestry, West Black Sea Region and Bolu Province, respectively.

Borax pentahydrate

Borax pentahydrate is produced in Eskişehir ETİ mine (Etibor-48). Borax pentahydrate chemical formula $Na_2B_40_7.5H_20$ density is as follows: 1,880 gr/cm^3 with high abrasiveness. In the basic structure, the rombohedral crystal is a boron compound also knownas tinkhanite. It could be rapidly crystallized in aqueous solutions above 60,8°C. Turkey is one of the world's richest countries in terms of boron reserves. Borax pentahydrate is in a lot of reserves in Bigadic, Emet, Kestelek, Kırka areas (accessed 22 June 2019)].

Borax pentahydrate was prepared as ratio 40 % solution in a separate tank. Than later, 40 % borax pentahydrate solution was mixed to urea-formaldehyde resin with blender as homogenous. Mixed (BP+UF) were added fibers in the blowline.

Chemicals

The chemicals used in this study were urea-formaldehyde, liquid paraffin, and ammonium sulphate. These chemicals were brought from Polisan Company in Gebze, Mercan Chemistry in Denizli and from another company in Gebze, respectively.

Urea formaldehyde resin used in the production of MDF has the following technical specifications; solid 65 %, formaldehyde/urea molar ratio: 1,25, density (at 20°C g/cm^3):1,227, viscosity (20°C cps) 185 seconds, gel time (100°C) (20 % $(NH4)_2SO_4$): 25-40 second, pH: 7,5 to 8,5 free formaldehyde content 0,5 % max, methylol groups 12-15 %, average shelf life is 45 days.

Hardener; the ammonium sulphate was supplied from a private company from Izmit (Turkey), the catalyst was 20 % ammonium sulphate $(NH4)_2SO_4$ solution (density of 0,95 g/cm^3 and pH 6,5).

Paraffin (wax); the paraffin was dirty white and liquid form, it had a solid content of 60 %, the pH was 9, viscosity was 13 second, and the density was 0,96 g/cm^3. The liquid paraffin was supplied from Mercan Chemistry in Denizli (Turkey).

Methods

Provided that the other production conditions are the same, the test boards that are produced by changing the ratio of the borax pentahydrate mixture are the general-purpose boards. Divapan Integrated Wood Company produce these products. The method is shown in Figure 1.

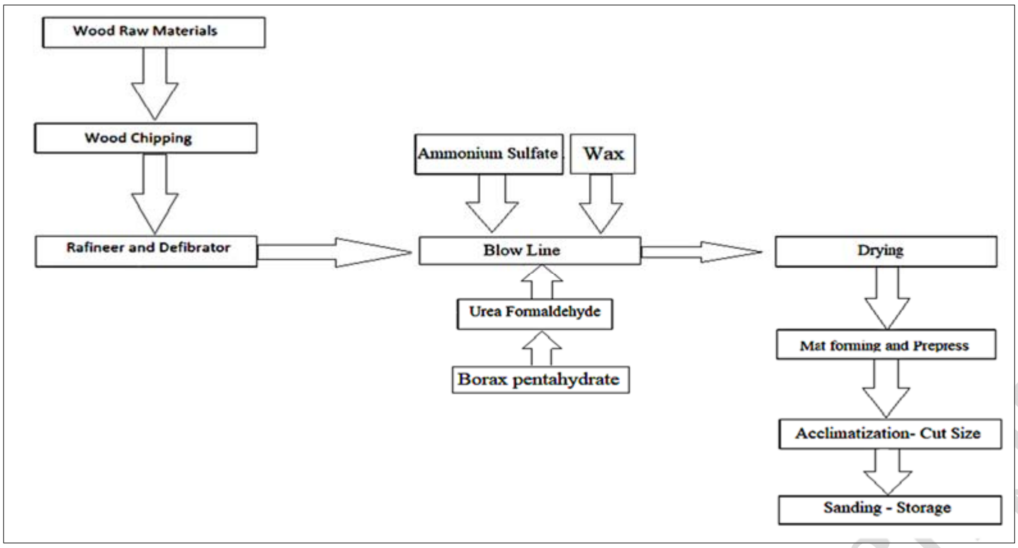

Figure 1: Product process flow sheet.

It mixes the resins and other chemicals in the glue unit. The borax pentahydrate inorganic mineral solution is prepared in the solution preparing tank. Then these chemicals, which are prepared in the tank are mixed and then the mixture is sent to the blowline. This process and applications are the main topic of this study. These applications are shown in Fig. 2.

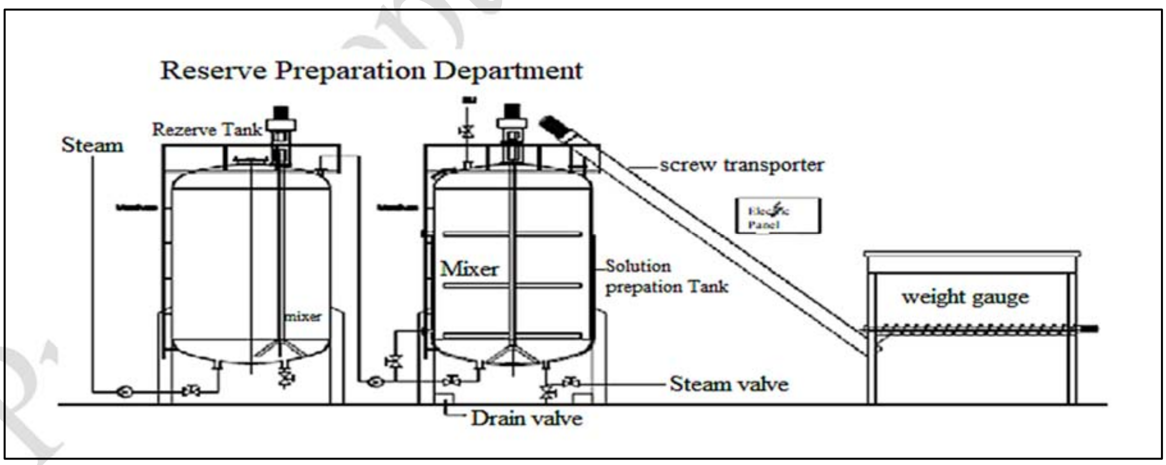

Figure 2: Preparation of the resin, inorganic borax pentahydrate solution and other chemicals.

Product parameters

Production parameters are shown in Table 1. The addition of inorganic borax pentahydrate solution and other chemicals to lignocellulosic biomass are presented. The symbols in Table 1 correspond that R defines the consumed wood fibers for 1 m^3 board, B defines the consumed borax pentahydrate minerals for 1 m^3 board, x and y subscripts define the percentage (%) of the mixture.

Table 1: Board content.

Groups	Product	Biomass	Resin	Hardener	Paraffin	Inorganic additive	Industrial fibres	Ratio
$R_{100}B_0$	MDF[a]	L[b]	UF[c]	AS[d]	Wax	-	100 %	0
$R_{97}B_3$	MDF[a]	L[b]	UF[c]	AS[d]	Wax	BPH[e]	97 %	3 %
$R_{94}B_6$	MDF[a]	L[b]	UF[c]	AS[d]	Wax	BPH[e]	94 %	6 %
$R_{91}B_9$	MDF[a]	L[b]	UF[c]	AS[d]	Wax	BPH[e]	91 %	9 %

[a]Medium density fiberboard. [b]Lignocellulosic. [c]Urea formaldehyde. [d]Ammonium sulphate. [e]Borax pentahydrate.

Fiber analysis

Wood fiber contains 70 % hardwoods and 30 % softwood fibers in this study. These fibers are sieved by means of an Imal Ultrasonic Analysis machine. The fiber analysis diagram is shown in Fig. 3.

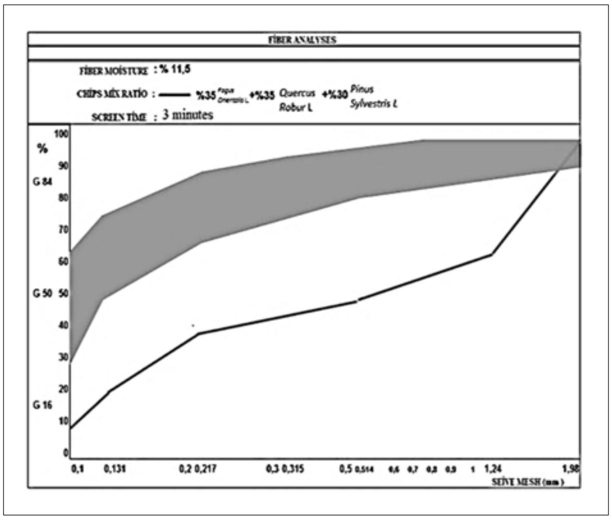

Figure 3: Analysis of the fiber.

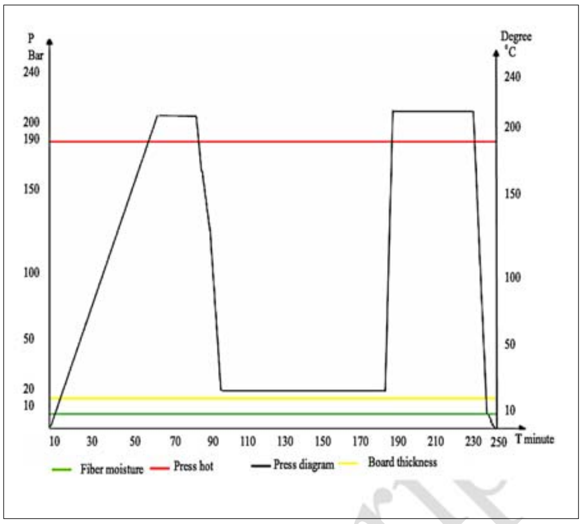

Figure 4: Hot press diagrams.

The hot press diagram in Fig. 4. was applied in the production of MDF boards.

Boards Manufacturing

Firstly, the hardwood and softwood species were obtained from the Western Black Sea forests, and then these species were chopped and stored one by one in silos according to the production parameters. Chips used in production were applied to cooking for 4,5 minutes at vapor pressure of 7,6 kg/cm² pressure and 190ºC temperature in Asplund defibrillator. Chips cooked in asplund defibrillator were made into fibers in segmnents. The solid ratio of the urea-formaldehyde was reduced to 50 % solid level in the production process. The color of the ammonium sulphate crystal grains was off white. It was prepared for hardener with the 20 % solution, and then it was injected from a single point to blow line. The color of liquid paraffin was cream and the fat content is up to 2 %. The penetration of the liquid paraffin was 32, and then it was stored in the reserve tank as the liquid state. It was mixed the liquid paraffin with a maximum ratio up to 1,5 % to dry fiber. The mixture having the above-mentioned properties was made of fibers in Asplund defibrator. The hardener, borax pentahydrate solution and urea-formaldehyde were injected from blow line to the biomass fiber. These applications were shown in Fig. 1.

Fibers included the borax pentahydrate and the chemical were dried at the drier line up to 12 %. Dried fibers were placed on the mat in the mechanical station. These applications were shown in Fig. 5. The mat was produced by pressing in the multiday hot press. The pressing parameters were 190°C, 32kg/cm^2 and 275 second. The dimensions of the panel were 2100x4900x18 mm. After the production of the panels, they were kept in pre-storage on 5 days. The panels were acclimatized in storage area. These applications were shown in Fig. 6. Then the level of moisture was adjusted to 7,5 %. After this process, the top and bottom surfaces of panels were sanded with 40-80-120 degrees sandpaper.

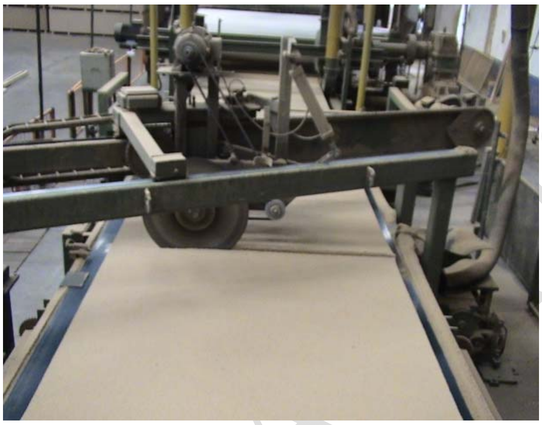

Figure 5: MDF production process. **Figure 6:** Borax pentahydrate additive MDF products.

Physical test method

Physical properties were tested according to TS-EN 622-5 (2008) and the density of panels was tested according to TS-EN 323 (1999). Water absorption test and the thickness swelling test of the specimens were made according to TS-EN 317 (2008). The sheet surface toluene TS was made according to the EN 382-1 (1999). Sample thickness and length of specimens were measured by using a digital micrometer and compass with 0,01 mm gradients. The surface color parameter test of the fiberboard was used by elrephospectrophotometer according to ASTM D 2244-07e1.

Color properties

Color measurements were measured by using the tristimulus photoelectric colorimeter Elrepho Spectrophotometer, with a measuring head of 50 mm in diameter according to ASTM D 2244-07e1 standards. The Elrepho spectrophotometer was measured the color of any material in a three-dimensional color area (Fig. 7). This system which is called CIE L*a*b* operates according to the CIE Standard. The part of the coordinate system interested in this study is the first quadrant which corresponds positive values of a* and b*. The color parameters L*, a*, and b* were determined by the CIEL*a*b* method on the surface fiberboards. Their variations concerning the treatment (ΔL*, Δa*, Δb*) was calculated. The color sphere as the circle of the cross-section at L* = 50 was defined. The color difference, ΔE total color difference is the distance between two color points in the color sphere. To the right: Cross section at L* = 50 showing the axis from green to red (a*) and from blue to yellow (b*), the coordinates chroma (C*) and hue [h = arctan (b*/ a*)] is the hues of color: 0 or 360 is red, 90 is yellow, 180 is green and 270 is blue. L* is the lightness; 100 = white and 0 = black. C* is the chroma or saturation; 0 represents only greyish colors and 60. These three measured coordinates represented by L*, a* and b* were transformed to L*, C* and h coordinates and ΔE total color difference values were found (Akgul *et al.* 2013).

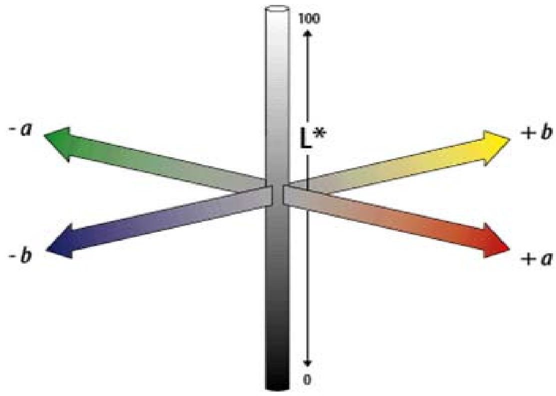

Figure 7: CIELAB the coordinate system shows the color changes in three coordinates which are represented as L*, a* and b* it gives the total color difference equation as.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

The average color values, standard deviations, and 5 % significance level based on distribution are calculated by assuming a normal distribution. The lower value of the ΔE total color difference shows that the color isnot changed or the change of color can be ignored (Akgul *et al.* 2013).

Mechanical test method

Cutting and sizing according to TS EN 325 (2008), TS EN 326-1 (1999) standard were performed to specify the properties of MDF plates with inorganic borax pentahydrate. These tests were; bending strength TS EN 310 (2008), modulus of elasticity TS EN 310 (2008), internal bond TS EN 319 (2008). Screw holding ability perpendicular to the plane of panel TS EN 310 (2011), A universal tester (Imal Mobiltemp shc 22, model ib 400) was used to assess mechanical properties. Janka hardness was measured according to ASTM D-1037-78. (1994) standards.

Combustion test method

We prepared MDF specimens from MDF for the combustion test. The combustion test of borax pentahydrate MDF specimens was determined according to ASTM-E 160-50 (1975).

These applications are shown in Fig. 8. Its conditioned specimens were at 27 ºC ± 2 °C and 30–35 % relative humidity to the targeted equilibrium moisture content of 7 % before the combustion test samples. Twenty-four specimens were stored to make 12 layers forming a square prism (Fig. 9).

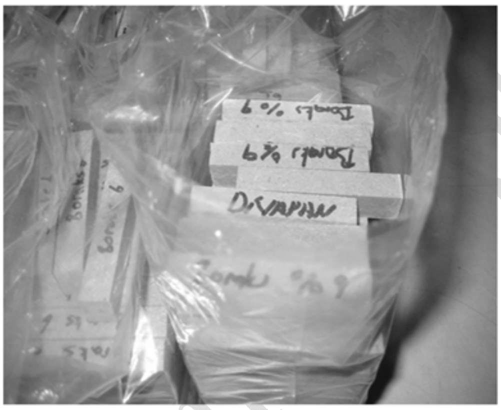

Figure 8: Combustion test apparatus. **Figure 9:** Combustion test samples.

It derived the fire of the heating flame from an LPG tank controlled by a sensitive pascal gauged valve. The flame to the standard height was balanced before the combustion test samples frame. The combustion test method was performed subsequently with the flame stage (FS) and without a flame stage (WFS). The glowing stage (GS) was performed according to ASTM-E 160-50 (1975). We recorded temperatures at the combustion column by using thermocouples at 15 and 30-time intervals for combustion with a flame stage and without a flame stage, and a glowing stage, respectively. We calculated the mass loss of the test specimens from the following equation.

$$\text{mass loss} = \frac{(\text{wbf} - \text{waf})}{\text{wbf}} \text{x}100 \qquad (2)$$

Where wbf was the weight (g) of a wood specimen before the combustion test, and waf was the weight (g) of a wood specimen after the combustion test. The 936 pieces boards which have additive borax pentahydrate were combusted according to ASTM E 160-50 standards. The applied tests were FIC (flame-induced combustion), FIC lux (flame-induced combustion lux), SC (self-combustion), SC lux (self-combustion lux), SC time (self-combustion time), ESC (ember situation combustion), ESC lux (ember situation combustion lux), ESC time, mass loss, IST (initial starting temperature), IST time (initial starting temperature-time), IST lux, FC (full Combustion), FC time, (full Combustion time), FC lux (full combustion lux).

Statistical Analysis

The data concernings physical tests, colour feature tests, mechanical tests and combustion test results were explained ± standard deviation and were analyzed using an analysis of variance (ANOVA) method for a entirely completely randomized design. Differences were considered statistically substantial at $p<0,05$. As a result of these tests, SPSS 17 (ANOVA) Duncan results are evaluated by statistical programs.

RESULTS AND DISCUSSION

Physical properties of fiberboard

The results of ANOVA and Duncan show that the separation test for density, the toluene surface, the thickness swelling (TS, 2-24 hours) and water absorption (WA, 2-24 hours) percent of the fiberboards made from borax pentahydrate additive fiber and control fiberboards in Table 2. Each test with 20 different samples was measured in this study.

The results of the density test

Density and mechanical properties of medium fiberboards statistical tests with Duncan's tests are made in the 95 % confidence interval analysis. The results are shown in Table 2. No differences were found between densities for borax pentahydrate added panels ($R_{100}B_0$, $R_{97}B_3$, $R_{94}B_6$, $R_{91}B_9$) according to this statistical analysis. The results of MDF densities were in the range of $650\ kg/m^3<MDF<850\ kg/m^3$ according to TS EN 622-5 standards. The density of medium fiberboards affect the used lignocellulosic raw materials, density, moisture content, the width of the heartwood, the width of sapwood, fiber structure and fiber dimensions, the annual ring width, types of cells and quantity. The mat moisture of the draft of the creation form unit, density, fiber distribution and press parameters affect the density during production.

Table 2: The results of ANOVA and Duncan mean separation test for density, the toluene surface of the board, the thickness swelling (TS) and water absorption (WA) percent of the fiberboards are made from borax pentahydrate additive fiberboards and control fiberboard.

Boards Borax pentahydrate		Avg.[x]	Std. Deviation	Board Borax pentahydrate		Avg.[x]	Std. Deviation
Density (kg/m³)	$R_{100}B_0$	715[a]	10	WA 24 hours (%)	$R_{100}B_0$	41, 68[a]	2,87
	$R_{97}B_3$	715[a]	10		$R_{97}B_3$	41,904[a]	4,82
	$R_{94}B_6$	714[a]	10		$R_{94}B_6$	52,832[b]	4,25
	$R_{91}B_9$	712[a]	10		$R_{91}B_9$	78, 400[c]	11,17
BST (cm)	$R_{100}B_0$	34, 350[a]	1,09	TS 2 hours (%)	$R_{100}B_0$	3,817[a]	0,40
	$R_{97}B_3$	30, 300[b]	1,59		$R_{97}B_3$	6,029[b]	0,41
	$R_{94}B_6$	34, 100[a]	1,41		$R_{94}B_6$	7,023[c]	0,63
	$R_{91}B_9$	33, 00[c]	1,97		$R_{91}B_9$	8,480[d]	1,16
WA 2 hours (%)	$R_{100}B_0$	21,297[a]	2,01	TS 24 hours (%)	$R_{100}B_0$	10,556[a]	0,29
	$R_{97}B_3$	24,868[b]	3,44		$R_{97}B_3$	12,375[b]	0,75
	$R_{94}B_6$	35, 757[c]	3,53		$R_{94}B_6$	14,141[c]	0,49
	$R_{91}B_9$	36, 836[c]	5,21		$R_{91}B_9$	17,332[d]	1,38

[x]The average value of the samples, standard deviation, 95 % (p<0,05) the confidence interval for the average ANOVA. a, b, c, d values with the same letter are not different (Duncan's test). TS (Thickness swell); WA (Water absorption), BTS (board surface toluene)

The ratio between the densities for the lowest fiberboard with the average fiberboard is always expected to be between 850 kg/m^3 to 950 kg/m^3. The efficiency of process parameters and the applied hot press diagram in MDF production affect the optimum homogenous density of the fiberboard. If the ratio between the densities for the lowest fiberboard with the average fiberboard near to one number, then this ratio represents that the density of the fiberboard is at the optimum homogeneity. Physical and surface properties of fiberboards statistical tests (ANOVA) with Duncan's test are made in the 95 % confidence interval analysis. The results were shown in Table 2. No differences were found between densities for borax pentahydrate added panels ($R_{100}B_0$, $R_{97}B_3$, $R_{94}B_6$, $R_{91}B_9$) according to this statistical analysis result. TS EN 323 standards are applied in this test. The results of MDF densities were in the range of 650 kg/m³<MDF<850 kg/m³ according to TS EN 622-5 standards. The density of fiberboards affect the used lignocellulosic raw materials, density, moisture content, the width of the heartwood, the width of sapwood, fiber structure and fiber dimensions, the annual ring width, types of cells and quantity. The mat moisture of the draft of the creation form unit, density, fiber distribution and press parameters were affected the density during production. The ratio between the densities for the lowest fiberboard with the average fiberboard was always desired between 850 to 950 kg/m³. The efficiency of process parameters and the applied hot press diagram in MDF production was affected the optimum homogenous density of the fiberboard.

The result of the swell in water for 2 hours test

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of TS-2 hours. The brief results were presented inTable 2. The ratio for this test was 58,26 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of TS-2 hours were increased for $R_{97}B_3$. Similarly, the ratio was 84,25 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of TS-2 hours were increased for $R_{94}B_6$. The ratio was 122,57 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of TS-2 hours were increased for $R_{91}B_9$. Since there was the anisotropic swelling of the secondary wall fibers in the cell wall and these fibers in board lie with different directions and angels, the swelling of the board was the smallest. Hydrophobic materials and water-resistant resin have increased the resistance of the board against such swelling effect. The percentage of swelling of MDF depends on the density of the board, the chemical structure of inorganic borax pentahydrate, the geometrical shape of the borax pentahydrate and the amount of the borax pentahydrate. The quantity of the surface of the board, the density profile of the board, the adhesion strength between the fibers, the lengthof fibers, the shortness of the fibers have depended on the type and the amount of the paraffin added to MDF.

The result of the swell in water for 24 hours

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), $R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of TS-24 hours. The brief results were shown in Table 2. The ratio for this test was 17,23 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of TS-24 hours increased for $R_{97}B_3$.Similarly, the ratio was 33,90 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of TS-24h increased for $R_{94}B_6$. The ratio was 64,10 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of TS-24h increased for $R_{91}B_9$. TS EN 317 standards were applied in this test. Softwood fibers have longer than the hardwood fibers. For softwood fibers, the felting ratio, the elasticity ratio and the F factor have higher than the hardwood fibers. For hardwood fibers, the rigid coefficient, the muhlsteph ratio, the runkel ratio and the bulk density value have higher than that of softwood fibers. As the contact angle increase, the adhesion ability increases for softwood fiber according to hardwood fiber. Thus, the entrance of the water and moisture between fibers was more difficult than that of softwood fiber according to hardwood fiber. As the amount of hydrophobic material in fiberboard product increase, the swelling in thickness decreased. However, there was a negative effect on the adhesion of fibers.

The results of the water absorption for the 2 hours

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), ($R_{94}B_6$, R_{91}, B_9) according to the percentage of WA-2h. The results were presented in Table 2. The ratio for this test was 16,81 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of WA-2h increased for $R_{97}B_3$.Similarly, the ratio was 67,96 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of WA-2h increased for $R_{94}B_6$. The ratio was 73,03 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of WA-2h increased for $R_{91}B_9$.

The results of the water absorption for 24 hours test

There was a significant difference between ($R_{100}B_0$, $R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of WA-24h. of the brief results were presented in Table 2. The ratio for this test was 0,527 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of WA-24 hour increased for $R_{97}B_3$.Similarly, the ratio was 26,75 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of WA-24h increased for $R_{94}B_6$ and the ratio was 88,08 % for $R_{91}B_9$ according to $R_{100}B_0$. TS EN 317 standards were applied in this test. Therefore, the percentage of WA-24h increased for $R_{91}B_9$. As the amount of inorganic borax pentahydrate was increased in MDF production, the absorption of the water in fiberboards increases as well.

The results of toluene on the surface of the board

There was a significant difference between ($R_{100}B_0$, $R_{94}B_6$), ($R_{97}B_3$) and ($R_{91}B_9$)and according to the percentage of toluene on the surface of the board test. The ratio for this test decreased 13,36 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of BST decreased for $R_{97}B_3$.Similarly, the ratio decreased by 0,73 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of BST decreased for $R_{94}B_6$. The ratio was 4,09 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of BST decreased for $R_{91}B_9$. TS EN 382-1 standards were applied in this test. The factors affecting the surface quality of the MDF board have affected such as; the amount of the inorganic borax pentahydrate filler, the geometry of the inorganic borax pentahydrate filler, the chemical structure, amount of lignin type of cellulosic raw material, density, fiber structure, fiber dimensions, the ratio of fiber moisture, the amount of the resin, hardener and paraffin.

The factors affecting the surface quality during the production of MDF board have affected such as; mat fiber moisture, pulverized sprayed water amount of the top and bottom of the mat, pre-press pressure, hot-pressing parameters and hot press. The applied temperature press and time diagrams during the hot press of the board have especially important. Sanding of MDF, the sanding paper properties, sanding method and sandpaper have affected the smoothness of the board surface.

Color properties

ASTM D 2244-07el standards were applied in this test. The surface color analysis of fiberboards was measured using Eq. (1). The results were presented in Table 3. The results of ANOVA and Duncan mean separation test for ΔL black-white color change, Δa red-green color change, Δb yellow-blue color change, ΔE total color difference per cent of the fiberboards made from borax pentahydrate additive fiber and control fiberboards are shown in Table 3. Each test with 20 different samples was measured in this study.

Table 3: The results of ANOVA and Duncan mean separation test for ΔL black-white color change, Δa red-green color change, Δb yellow-blue color change, ΔE total color difference per cent of the fiberboards made from borax pentahydrate additive fiber and control fiberboards.

Board Borax pentahydrate		Avg.*	Std. Deviation	Board Borax pentahydrate		Avg.*	Std. Deviation
ΔL	$R_{100}B_0$	60,13[a]	0,91	Δb	$R_{100}B_0$	17,46[a]	0,56
	$R_{97}B_3$	58,96[b]	0,50		$R_{97}B_3$	16,89[b]	0,28

	$R_{94}B_6$	57,84[c]	0,24		$R_{94}B_6$	16,01[c]	0,16
	$R_{91}B_9$	56,02[d]	0,44		$R_{91}B_9$	15,48[d]	0,32
Δa	$R_{100}B_0$	5,62[a]	0,06	ΔE	$R_{100}B_0$	62,87[a]	0,98
	$R_{97}B_3$	5,51[b]	0,06		$R_{97}B_3$	61,58[b]	0,53
	$R_{94}B_6$	5,42[c]	0,06		$R_{94}B_6$	60,26[c]	0,27
	$R_{91}B_9$	5,19[d]	0,06		$R_{91}B_9$	58,35[d]	0,50

[x]The average value of the samples, Standard Deviation, 95% ($p<0,05$). The confidence interval for the average ANOVA. and, b, c, d values with the same letter are not different (Duncan's test). ΔE[x] total color difference; ΔL[y] black-white color change; Δa[z]red-green color change; Δb[t]yellow-blue color change.

The variation of Δ*L*

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) in terms of variation. Brief results of Table 3 were explained. This variation decreased by 1,98 % for 422 $R_{97}B_3$ according to $R_{100}B_0$. Similarly, the variation decreased by 3,95 % for $R_{94}B_6$ according to 423 $R_{100}B_0$. Therefore, the variation decreased for $R_{94}B_6$. The variation decreased 7,33 % for $R_{91}B_9$ 424 according to $R_{100}B_0$. Therefore, the variation decreased for $R_{91}B_9$.

The variation of Δ*a*

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), ($R_{91}B_9$), ($R_{94}B_6$) and the variations of them. Brief results of Table 3 were explained. This variation decreased by 1,19 % 430 for $R_{97}B_3$ according to $R_{100}B_0$. Similarly, the variation decreased by 3,69 % for $R_{94}B_6$ 431 accordingto $R_{100}B_0$. Therefore, the variation decreased for $R_{94}B_6$. The variation decreased 432 8,28 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the variation decreased for $R_{91}B_9$.

The variation of Δ*b*

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$) and ($R_{94}B_6$), ($R_{91}B_9$) in terms of variation. Brief results of Table 3 were explained. This variation increased by 3,37 % for $R_{97}B_3$ according to $R_{100}B_0$. Similarly, the variation decreased by 9,05 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the variation decreased for $R_{94}B_6$. The variation decreased 12,79 % for 440 $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the variation decreased for $R_{91}B_9$.

The variation of Δ*E*

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$) and ($R_{94}B_6$), ($R_{91}B_9$) in terms of variation. The results of Table 3 were explained. This variation decreased by 2,09 % for 446 $R_{97}B_3$ according to $R_{100}B_0$. Similarly, the variation decreased by 4,33 % for $R_{94}B_6$ according to 447 $R_{100}B_0$. Therefore, the variation decreased for $R_{94}B_6$. The variation decreased 7,74 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the variation decreased for $R_{91}B_9$. As the amount of inorganic borax pentahydrate increase in MDF production, the value decreased.

Mechanical properties

The results of ANOVA and Duncan displays the separation test for bending strength, modulus of elasticity, internal bond, surface screw holding ability, Janka hardness measure vertically to the plate surface of the fiberboards made from borax pentahydrate additive fiber and control fiberboards and are shown in Table 4.

The results of the bending strength test (MOR)

There was a significant difference between ($R_{100}B_0$, $R_{97}B_3$), ($R_{94}B_6$, $R_{91}B_9$) according to the percentage of the bending strength test. Brief results of Table 4 were explained. The ratio for this test was 0,68 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of bending strength decreased for $R_{97}B_3$. Similarly, the ratio was 26,81 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of bending strength decreased for $R_{94}B_6$. The ratio was 32,12 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of bending strength decreased for $R_{91}B_9$.

The mechanical properties of the MDF were significant in terms of bending strength. MDF is required to be resistant to the places of use. It was made the bending strength according to the relevant standard. All measurement results of the test boards were measured according to TS EN 622-5 (2008) standard value. Fiber length was the most important factor affecting bending strength. The fiber length and the fibers contact degree are increased with each other's fibers. Thus, a more effective adhesion area is formed. It is boosted the bending strength of the board. The softwood fiber length have between 6-7 mm. The hardwood fiber length have between 5 and 2 mm. The hardwood fiber wall thickness has thick and the lumen has narrow. This negatively is affected fiber-to-fiber bonding and compression. The fiber wall of softwood has got thin, lumen wide and ellipse. Therefore, it has affected the fiber-fiber bonding and compression factors positively. The blond ratio of MDF to fiber-fiber has increased the tensile strength.

Factors affecting surface quality and bending strength (MOR) of MDF are affected which are the lignocellulosic raw material, the density of the raw material, fiber structures, fiber sizes, fiber moisture content, type of glue, amount of glue, other chemical material, mat moisture content, refiner fibrillation degree, amount of pulverizing water spray of up and down of mat, prepress pressure, hot press type, hot press factors, hot press specific values, hot press temperature, hot press pressure and hot press time.

Table 4: The results of ANOVA and Duncan mean separation test for density and mechanical properties of the borax pentahydrate additive fiberboards and control fiberboard.

Board	Borax pentahydrate	Avg.[x]	Std. Deviation	Board	Borax pentahydrate	Avg.[x]	Std. Deviation
Modulus of elasticity (MOE) (MPa)	$R_{100}B_0$	3482,915^{a}	218,22	Surface screw holding ability (N)	$R_{100}B_0$	10,073^{a}	0,30
	$R_{97}B_3$	3447,622^{a}	168,99		$R_{97}B_3$	12,585^{b}	0,42
	$R_{94}B_6$	2779,268^{b}	164,49		$R_{94}B_6$	9,757^{a}	0,81
	$R_{91}B_9$	2594,864^{c}	127,31		$R_{91}B_9$	7,441^{c}	0,67
Bending strength (MOR) (MPa)	$R_{100}B_0$	36,894^{a}	2,44	Janka hardness (MPa)	$R_{100}B_0$	81,05^{a}	1,23
	$R_{97}B_3$	36,647^{a}	1,55		$R_{97}B_3$	79,60^{b}	2,23
	$R_{94}B_6$	29,090^{b}	1,46		$R_{94}B_6$	77,20^{c}	1,15
	$R_{91}B_9$	27,921^{c}	1,58		$R_{91}B_9$	78,50^{d}	2,04
Internal bond (IB) (MPa)	$R_{100}B_0$	0,586^{a}	0,03				
	$R_{97}B_3$	0,579^{a}	0,06				
	$R_{94}B_6$	0,538^{b}	0,08				
	$R_{91}B_9$	0,246^{c}	0,05				

[X]: The average value of the samples. *95 % confidence interval for the average ANOVA. a, b, c, d values with the same letter are not different (Duncan's test).

During hot pressing, draft (mat) moisture has an important factor. Mat humidity has included 12 %. At this humidity value, the top and bottom surfaces of the boards have plasticized during the hot press. It has transfered the press heat to the center of the board. The resin has become as a cure and the sheet has become stable. The most important factor in wood has the cellulose chain.

The results of the internal bond test (IB)

There was a significant difference between ($R_{100}B_0$, $R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of internal bond (IB) test. The results of Table 4 were explained. The ratio for this test was 1,03 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of the internal bond decreased for $R_{97}B_3$. Similarly, the ratio was 8,92 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of the internal bond decreased for $R_{94}B_6$. The ratio was 138,20 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of the internal bond decreased for $R_{91}B_9$. The IB strength of the board decreased as the amount of inorganic minerals increases. The mechanical properties for the 9 % inorganic mineral added to board were the lowest because borax pentahydrate inorganic filler minerals reduced fibers between contact and adhesion strength. The increase in the density of MDF positively affected the internal bond of the board. It was achieved optimum efficiency in the press diagram. MDF production was applied the press diagram at Fig. 4. During pressing; temperature, pressure and time diagrams were applied.

The results of the modulus of elasticity test (MOE)

There was a significant difference between ($R_{100}B_0$, $R_{97}B_3$), ($R_{94}B_6$), ($R_{91}B_9$) according to the percentage of the modulus of elasticity test. The brief results of Table 4 were explained. The ratio for this test was 1,02 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of modulus of elasticity decreased for $R_{97}B_3$. Similarly, the ratio was 25,32 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of modulus of elasticity decreased for $R_{94}B_6$. The ratio was 34,22 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of modulus of elasticity decreased for $R_{91}B_9$. In MDF production, the fiber length increased the modulus of elasticity of the board. The important factors affecting the modulus of elasticity were the chemical, anatomical structure of wood, density, amount of extractive substance, extractive content, pH, humidity of the mat fiber, press temperature, press pressure and timing diagram, respectively. The more contact and sticking surface between the fibers, the greater the elasticity modulus occurred. As the contact surface between the fibers and the area of adhesion decreases, the elastic modulus of the board decreased. Akgul *et al* (2012) have measured the elasticity modulus of the board produced burned pine woods between 2567-2733 (Mpa).

The results of the surface screw holding ability test (N)

There was a significant difference between ($R_{100}B_0$, $R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of the surface screw holding ability test. The results were explained in Table 4. The ratio for this test was 25,02 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of the surface screw holding ability decreased for $R_{97}B_3$.Similarly, the ratio was 3,23 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of the surface screw holding ability decreased for $R_{94}B_6$. The ratio was 37,37 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of the surface screw holding ability decreased for $R_{91}B_9$. Screw holding resistance was the most important for mechanical properties. It is related to the surface screw holding strength of the board to the strength of the between fiber adhesive. The screw holding test results are standardized in TS EN 622-5 (2008). As the amount of inorganic borax pentahydrate increases in MDF, the surface screw holding ability decreased. Akgul *et al.* (2008) have tested the surface screw holding strength of MDF produced from *Rhododendron ponticum*. Wood fibers between 121,07-125,42 kp. Yorur *et al.* (2020) have explained that the highest direct screw withdrawal resistance the test blocks with polyurethane and the lowest direct screw withdrawal resistance the test blocks without a pilot hole drilled in both materials. According to the results, medium density fiberboard was best measured direct screw withdrawal resistance than particleboards.

The results of janka hardness test

There was a significant difference between ($R_{100}B_0$), ($R_{97}B_3$), ($R_{94}B_6$) and ($R_{91}B_9$) according to the percentage of Jank hardness test. The results were explained in Table 4. The ratio for this test decreased 1,82 % for $R_{97}B_3$ according to $R_{100}B_0$. Therefore, the percentage of Janka hardness decreased for $R_{97}B_3$. Similarly, the ratio decreased by 4,99 % for $R_{94}B_6$ according to $R_{100}B_0$. Therefore, the percentage of Janka hardness decreased for $R_{94}B_6$. The ratio was 3,25 % for $R_{91}B_9$ according to $R_{100}B_0$. Therefore, the percentage of Janka hardness decreased for $R_{91}B_9$. The high surface hardness of MDF is affected the Janka strength and resistance properties of the board positively. The surface hardness of the MDF board was the decisive factor for quality control surface Janka strength of MDF board, the density of the board surface and the strength of the between fibers adhesive. Akgul *et al*. (2008) have tested the surface Janka strength of MDF board from *Rhododendron ponticum*. Wood fibers between 73,08-79,83 MPa. The increase in the top and bottom density of the MDF board positively affected the surface strength of the board. Akgul *et al* (2012) have measured the Janka strength of the board produced burned pine woods between 72,40-77,90 (Mpa).

The Combustion experiment results of MDF boards

Table 5 are showed FIC, FIC lux, SC, SC lux, ESC, ESC lux ESC time and mass loss experiments result according to ANOVA Duncan for MDF board which have additive borax pentahydrate. The temperature measured as $R_{100}B_0$ (560,21 ºC), $R_{97}B_3$ (491,91 ºC), $R_{94}B_6$ (434,04 ºC), $R_{91}B_9$ (428,91 ºC) in the FIC experiment for the produced boards. The results of Table 5 and Table 6 are explained. When the FIC temperature of 560,21ºC for $R_{100}B_0$ boards with the additive inorganic mineral was compared, it was increased the panel resistance 491,91 ºC for $R_{97}B_3$ of FIC temperature as the amount of the additive inorganic mineral. It was measured the 434,04 ºC for $R_{94}B_6$ highest FIC temperature in the control board as 560,21 °C in control board. The FIC temperature 428,91 ºC for $R_{91}B_9$ board decreased as the amount of the additive inorganic mineral in MDF increases. Therefore, the 428,91 ºC heat is absorbed in MDF, which is produced with borax pentahydrate mineral, and $R_{91}B_9$ MDF board 428,91 ºC has resistive properties against combustion.

Table 5: The statistical results for FIC, FIC lux, SC, SC lux, ESC, ESC lux ESC time and mass loss experiments of MDF board which have additive borax pentahydrate according to ANOVA Duncan.

Board Borax pentahydrate			Avg. [x]	Std. Deviation	Board Borax pentahydrate		Avg.[x]	Std. Deviation
FIC	Temperature (ºC)	$R_{100}B_0$	560,21[a]	17,98	FIC (lux)	$R_{100}B_0$	309,00[a]	2,83
		$R_{97}B_3$	491,91[b]	5,07		$R_{97}B_3$	251,04[b]	9,72
		$R_{94}B_6$	434,04[c]	2,89		$R_{94}B_6$	241,62[b]	7,36
		$R_{91}B_9$	428,91[c]	18,15		$R_{91}B_9$	239,04[b]	2,53
SC	Temperature (ºC)	$R_{100}B_0$	662,57[a]	6,64	SC (lux)	$R_{100}B_0$	302,42[a]	24,86
		$R_{97}B_3$	634,89[ab]	8,50		$R_{97}B_3$	281,75[a]	3,89
		$R_{94}B_6$	559,93[b]	42,61		$R_{94}B_6$	285,68[a]	0,88
		$R_{91}B_9$	450,47[c]	37,96		$R_{91}B_9$	271,04[a]	20,39
ESC	Temperature (ºC)	$R_{100}B_0$	652,57[a]	18,99	ESC(lux)	$R_{100}B_0$	302,57[a]	19,19
		$R_{97}B_3$	400,58[b]	1,29		$R_{97}B_3$	281,16[a]	8,25
		$R_{94}B_6$	353,75[b]	33,59		$R_{94}B_6$	226,12[b]	23,16
		$R_{91}B_9$	237,50[c]	24,75		$R_{91}B_9$	250,00[ab]	21,21
ESC	Time (minute)	$R_{100}B_0$	64,33[a]	0,95	Mass loss %	$R_{100}B_0$	96,35[a]	0,07
		$R_{97}B_3$	68,25[b]	1,06		$R_{97}B_3$	95,75[a]	0,21
		$R_{94}B_6$	71,50[c]	0,00		$R_{94}B_6$	94,45[b]	0,64
		$R_{91}B_9$	58,50[d]	0,71		$R_{91}B_9$	91,15[c]	0,21

x: averagevalue of samples, * 95 % confidenceintervalforaverage ANOVA a,b,c,d values with the same letter are different (Duncan's test).

Table 6 are showed FIC temperature, FIC lux, SC temperature, SC lux, IST temperature, IST time, IST lux, FC temperature, FC time, FC lux, IST time and mass loss experiments result according to ANOVA Duncan for MDF board having additive borax pentahydrate. SC temperatures were measured as 662,57 ºC for $R_{100}B_0$, 634,89 ºC for $R_{97}B_3$, 559,93 ºC for $R_{94}B_6$, 450,47 ºC for $R_{91}B_9$ in the SC temperature experiment. The value of temperature 450,47 ºC decreased and this reduction was responsible for the chemical properties of the borax pentahydrate mineral. ESC temperatures were measured as 65,57 ºC for $R_{100}B_0$, 400,58 ºC for $R_{97}B_3$, 353,75 ºC for $R_{94}B_6$, and 237,50 ºC for $R_{91}B_9$ in the ESC temperature experiment. ESC temperature decreased as the ratio of inorganic mineral usage increases. ESC Time results were 64,33 minute for $R_{100}B_0$, 68,25 minute for $R_{97}B_3$, 71,50 minute for $R_{94}B_6$, 58,75 minute for $R_{91}B_9$. The $R_{91}B_9$ boards have lowest test results.

Table 6: Combustion experiment of additive borax pentahydrate MDF boards.

	FIC Average.		SC Average.		ESC Average.		IST Average			FC Average			IST	Mass loss
Board	Temp^x (ºC)	(Lux)	Temp^x (ºC)	(Lux)	Temp^x (ºC)	(Lux)	Temp^x (ºC)	Time (minute)	(Lux)	Temp^x (ºC)	Time (Minute)	Lux)	Minute	(%)
$R_{100}B_0$	560,1	309	662,58	302,42	652,57	302,57	654	150,0	321,0	614,0	540,0	1,0	64,3	6,40
$R_{97}B_3$	491,92	251,04	634,89	281,75	400,58	281,17	603,5	315,0	286,0	348,0	765,0.	81,5	71,5	5,70
$R_{94}B6$	434,04	241,63	559,93	285,68	353,75	226,13	575,5	240,0	287,5	320,0	540,0	28,0	67,0	4,50
$R_{91}B_9$	428,92	239,04	450,47	271,04	237,5	250,0	365,0	260,5	260,5	237,5	465,0	50,0	58,75	1,10

x: average value of temperature

FIC lux was measured as 309,00 lux for $R_{100}B_0$, 25,.04 lux for $R_{97}B_3$, 241,62 lux for $R_{94}B_6$, 239,04 lux for $R_{91}B_9$ in FIC lux experiment. FIC light density decreased and released dark fog as the amount of inorganic borax pentahydrate materials increases in the additive MDF. SC lux was measured as 302,42 lux for $R_{100}B_0$, 281,75 lux for $R_{97}B_3$, 285,68 lux for $R_{94}B_6$, 271,04 lux for $R_{91}B_9$ in SC lux experiment. ESC lux experiment was tested 302,57 lux for $R_{100}B_0$, 281,16 lux $R_{97}B_3$, 226,12 lux $R_{94}B_6$, 250,00 lux $R_{91}B_9$. As the amount of borax pentahydrate minerals increases, the dark fog density of ESC decreased. The mass loss of tests of boards was measured using Eq. (2). The mass loss experiment was measured 96,35 % for $R_{100}B_0$, 95,75 % for $R_{97}B_3$, 94,45 % for $R_{94}B_6$, 91,15 % for $R_{91}B_9$. As the amount of borax pentahydrate minerals increases in MDF measured resistance to fire increased. According to combustion results, ash amount was more increased

CONCLUSIONS

As the amount of inorganic borax pentahydrate increases in MDF production, both the percentage of TS-2h, WA-2h and the percentage of TS-24h, WA-24h increased.
The pH and chemical structure of the borax pentahydrate mineral is suitable for the production of the MDF board.

As the amount of inorganic borax pentahydrate increases in MDF production physical and mechanical properties decreased. The geometrical structure of borax pentahydrate inorganic filler minerals reduced between fibers contact and adhesion strength.

As the amount of inorganic borax pentahydrate increases in MDF, the surface total color difference of the board acceptable limits decreased in terms of the result of color parameters according to the control board. However The total color difference and whiteness (black-white color change) over the surface board increased.

The combustion experiments were revealed positive results according to FIC, SC, ESC, FIC lux, SC lux, ESC lux, IST and mass loss. According to test results, The resistance to combustion increased as the amount of the inorganic additive minerals increases.

It is suggested that borax pentahydrate per cent 3 % use instead of biomass fiber in MDF production. It is suggested that borax pentahydrate per cent 9% use against combustion in MDF manufacture.

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