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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

The Effect of Vermiculite Usage on Surface Properties of Medium Density Fibreboard

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Abstract: In this study, the effects of vermiculite, which is one of volcanic minerals, usage in medium density fibreboard (MDF) production on the surface properties of these boards were investigated. The test boards were produced using the dry method with 12% urea formaldehyde resin. Additions of 10%, 15%, 20% and 30% vermiculite were used based on the oven-dry fibre weight. Surface roughness, colour and gloss values of both surfaces of the obtained boards were determined. Based on the results, the ratio of vermiculite increased, roughness values on the surfaces increased. The roughness values in the bottom surface of the produced boards were determined to be higher than the top surface. With the use of 30% vermiculite, the average minimum surface roughness (Ra) values were found to be 8.65 µm on the upper surfaces and 15.44 µm on the lower surfaces. It has been found that total color change and gloss are improved by the increase of vermiculite usage and the colour change on the bottom surface is found higher. In short, the use of vermiculite in the production of MDF negatively affects the surface roughness and discoloration of the boards, but it has been found to positively affect the gloss.

Keywords: Colour, gloss, MDF, surface roughness, vermiculite.

Orta Yoğunluklu Lif LevhalarınYüzey Özellikleri Üzerine Vermikülit Kullanımının Etkisi

Öz: Bu çalışmada, orta yoğunlukta lif levha (MDF) üretiminde volkanik minerallerden vermikülit kullanımının yüzey özelliklerine etkisi araştırılmıştır. Deney levhaları kuru yöntemle %12 üre formaldehit tutkalı kullanılarak üretilmiştir. Tam kuru lif ağırlığına oranla %10, %15, %20 ve %30 oranlarında vermikülit kullanılmıştır. Levhaların her iki yüzeyinin yüzey pürüzlülük, renk ve parlaklık değerleri belirlenmiştir. Sonuçlara göre vermikülit oranının artmasıyla, pürüzlülük değerleri artmıştır. Levhaların alt yüzeylerindeki pürüzlülük değerlerinin üst yüzeylerinden daha yüksek olduğu belirlenmiştir. %30 vermikülit kullanımı ile ortalama minimum yüzey pürüzlülüğü (Ra) değerleri üst yüzeylerde 8,64 µm, alt yüzeylerde ise 15,44 µm olarak bulunmuştur. Toplam renk değişimi ve parlaklığın vermikülit kullanım oranının artmasıyla iyileştiği, alt yüzeylerindeki renk değişiminin daha fazla olduğu tespit edilmiştir. Kısaca, MDF üretiminde vermikülit kullanımının levhaların yüzey pürüzlülüğünü olumsuz, parlaklık ve renk değişimini ise olumlu olarak etkilediği sonucuna varılmıştır.

Anahtar sözcükler: MDF, parlaklık, renk, vermikülit, yüzey pürüzlülüğü.

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INTRODUCTION

Nowadays, board products are widely used as building materials in many areas such as construction, decoration, interior and exterior architecture, furniture production (Kim eal t., 2002; Seo et al., 2016). Medium density fibreboard (MDF) is one of wood-based panels produced by bonding wood fibres with resin under temperature and pressure and produced in high quantities (Krzysik, 2001). In recent years, MDF production has increased significantly and has a large market share in the wood composite sector (Koc & Aksu, 1999; Cabuk et al., 2013; İstek et al., 2017a). As with other wood-based boards, the disadvantages of MDF boards are poor resistance to moisture and low resistance to burning (Ustaömer et al., 2008; İstek et al., 2017b). Some measures must be taken against these disadvantages in order to make better use of wood based board products and to use these products efficiently. This is because the objective of board production is to improve the economic, aesthetic and technological properties of the material, as well as to increase the resistance against biotic and abiotic factors (Hall et al., 1982; Dix, 1997). It is reported that vermiculite can be used to increase the fire resistance of cellulose based composites in different studies (Kozlowski et al., 1999; Rider, 2015; Rider, 2016; Wang et al., 2016b; Aksogan et al., 2018).

Many methods and materials are used to improve the burning properties of wood materials. Important chemicals used as preservatives for this purpose are combustion retardants such as ammonium sulphate, ammonium chloride, dicyandiamide, borax and boric acid, and various phosphorus compounds (phosphoric acid, monoammonium phosphate and diammonium phosphates) (Ustaömer, 2008; Peker & Atılgan, 2015; İstek et al., 2012; İstek et al. 2013; İstek & Özlüsoylu, 2016; Özdemir & Tutuş, 2013).

Vermiculite is a magnesium aluminosilicate clay mineral formed by natural wear of mikan. It is a mineral obtained from volcanic magma rocks and it is expanded at high temperatures to increase volume and permeability. The bulk density value changes significantly by falling shape (Toksoy, 1997). Vermiculite has good sound and heat insulation properties and also has the ability to stick to different surfaces. When used as a fire retardant, the smoke and gases released are not toxic and do not pose a threat to the environment (Crawford et al., 1990). The expanded vermiculite has a density of between 80 kg / m^3 and 120 kg / m^3 with a heat transfer coefficient of 0.04 W / (m · K) to 0.12 W / (m · K) and a high melting point of 1240 ° C - 1430 ° C. It is also a chemically inert, stable and environmentally safe material (Suvorov & Skurikhin, 2003; Nguyen et al., 2013; Wang et al., 2016).

Surface properties are important in terms of wood-based boards, mainly medium density fibreboard (MDF) and chipboard, and board products are coated with liquid or solid coating materials to enhance their aesthetic, resistance properties and economic values (İstek et al., 2010; İstek et al., 2015; Atar, 2006; Nemli, 2003). Since the board products form the lower layer of the coating materials, surface properties such as surface roughness, bonding and quality of the final product are important. It is known that many factors are effective on the surface roughness depending on raw material and production conditions (Kılıc et al., 2009; İstek et al., 2012; Nemli et al., 2007; Dündar,et al., 2008; Özdemir 2016; Bozdogan Balcik & Özdemir, 2019).

Various studies indicated that fire-retardant materials have different effects on the physical, mechanical and surface properties of wood materials and wood-based composites (İstek & Özlüsoylu, 2016; Ustaömer, 2008; Winandy et al., 2002; Taghiyari et al., 2013; Winandy, 1998; Ayrilmis et al., 2007; Ayrilmis et al., 2005; Ayrilmis, 2007; Simsek et al., 2013; İstek et al., 2017c; İstek et al., 2017d).

The needle screening method is used in the metal and plastics industries for surface roughness. This method is more widely used in the measurement of wood composite boards and the roughness of solid wood product surfaces (Hızıroğlu, 1996; Burdurlu et al., 2005; Peters & Mergen, 1971). The use of combustion retardants affects the surface properties of the boards. In this study, the effects of vermiculite used as fire retardant on the surface properties of the boards were investigated. For this purpose, some surface properties such as roughness, colour and gloss of MDF boards produced by adding vermiculite at different ratios have been determined.

MATERIAL and METHODS

In this study oriental beech (*Fagus orientalis*) and black pine (*Pinus nigra*) wood fibres were used as raw materials. Fibres were supplied from Kastamonu Integrated Company, MDF Plant and consists of 80% beech and 20% black pine wood fibre blends. Urea formaldehyde binder (57% solid content) was used with respect to 12%. total dry fibre weight. Vermiculite was commercially available and was used in MDF production at rates of 10%, 15%, 20% and 30% relative to the total dry fibre weight in this study. The vermiculite was milled in 0.5 mm mesh before addition.

MDF Production: In the study, the total of 15 boards were produced including vermiculite in 4 different ratios (10%, 15% 20% and 30%) and control boards without vermiculite as three boards of each group. The target density of the produced boards was 800 kg/m^3 and the form sizes were 400x400x12 mm. The fibres used in the production were supplied in a ready-made form and were brought to the laboratory in plastic bags in such a way that they do not get in contact with air. After the moisture control has been carried out, it was mixed with vermiculite at the specified ratios using a rotary drum gluing machine. The prepared fibres were hand-laid out in a wooden shaping mold with dimensions of 400x400x300mm and a board mat was formed. The board mat was exposed to 180 bar pressure and the temperature of 170^{0}C and 5 minutes at a hot press (SSP180 Cemil Usta, Turkey). The MDF boards were produced using a 12 mm thick metal thickness control sticks. The colour change, gloss values and the surface roughness values of the produced boards were determined and they were compared with the control group. The colour, gloss and surface roughness measurements of the vermiculite-added boards were carried out from two different surfaces, top and bottom, depending on the position of the boards in the formation.

Colour measurements: Colour measurement of the test samples were carried out in accordance with ISO 7724 standards by Konica Minolta CD- 600 colour meter. On the board samples, the colour measurements from 3 different points were measured and their mean value were calculated for three replicates in each variation (ISO-7724, 1984). The CIELab (Commission Internationale de l'Eclairage) system consists of three variants (ISO 7724). L* refers to Light stability, a* and b* chromatographic coordinates (+a* indicates red, -a* green, +b* yellow, -b* blue). The values of *L**, *a** and *b** were measured on the samples and the colour changes were determined according to the following Formula 1.

$$\Delta E^* = (\Delta L^*2 + \Delta a^*2 + \Delta b^*2)\ ½ \qquad (1)$$

Gloss measurements: Gloss measurements were taken using a KONICA Minolta Multi gloss 268 plus. The angle of incidence of the radiation was 60±0.1°, as defined in ISO 2813.1994. Six measurements were made in each test panel.

Surface roughness: Mitutoyo Surftest SJ-301 was used for surface roughness measurements. The mean surface roughness (Ra), maximum height (Rz) and ten-point average roughness (Rq) values of the test samples were evaluated. Both of side measurements were made on the surfaces of the control and test samples according to the ISO 4287 standard. The measurements were used as a boundary wave length of 8 mm, a velocity of 0.5 mm/s and a scanning length of 12 mm. Ten measurements were made to evaluate the surface roughness of each group.

RESULTS and DISCUSSION

The results of the board groups with vermiculite added at different ratios and the results of the control group boards produced without vermiculite with respect to colour, gloss and surface roughness were discussed below.

Colour change: The colour change values in the test and control samples were calculated using the L (light intensity), a and b chromatographic coordinates (+ a * red, -a green, + b yellow and -b blue) determined according to the CIELab system. Table 1 shows the bottom surface, top surface and average values and standard deviations of L *, a *, b * values for the board groups.

According to the results, the average L * value increased as the chemical substance added increased except for the addition of 20% vermiculite. An increase in L * is an indication that the surfaces of the boards have colouring. Also, the L * values obtained at the bottom surface are higher than the values measured from the top surface. This is due to the fact that some of the vermiculite used as a dust in the forming mold collapses on the bottom surface of the mat and is found to be higher than the surface of the mat. Figure 1 shows the mean change values of L*, a* and b*.

Table 1. L*, a*, b* values of test boards.

Type of boards		Control	10% vermiculite	15% vermiculite	20% vermiculite	30% vermiculite
Bottom surface	L*	-	56.28±0.87	58.49±1.27	57.40±2.67	60.90±1.30
	a*	-	8.60±0.29	7.56±0.71	8.10±1.32	6.11±0.42
	b*	-	22.25±0.38	20.99±0.93	21.97±1.81	19.40±0.46
Top surface	L*	-	56.09±0.98	53.99±1.56	53.47±2.25	54.92±1.58
	a*	-	9.29±0.24	9.47±0.44	9.50±0.37	8.85±0.27
	b*	-	24.08±0.53	23.46±0.64	23.25±0.73	22.18±0.56
Average values	L*	52,01±2,14	56.18±0.88	56.24±0.92	55.44±0.82	57.91±1.02
	a*	9,69±0,47	8.95±0.19	8.51±0.39	8.80±0.56	7.48±0.25
	b*	23,45±0,87	23.16±0.22	22.23±0.50	22.61±1.11	20.79±0.37

The a * value decreased as the ratio of additional chemicals increased, except for the addition of 20% vermiculite for the average a * values. Reduced a * value is a sign of red colour on the board surfaces. Similarly, as the rate of added material increased, the b * value decreased. The decrease in b * indicates the increase in blue colour on the board surfaces.

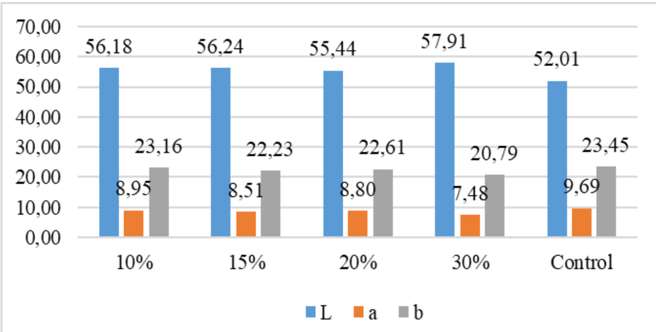

Figure 1. Average L*, a*, b* values change of board types.

Figure 2 shows the total colour change values (ΔE *).

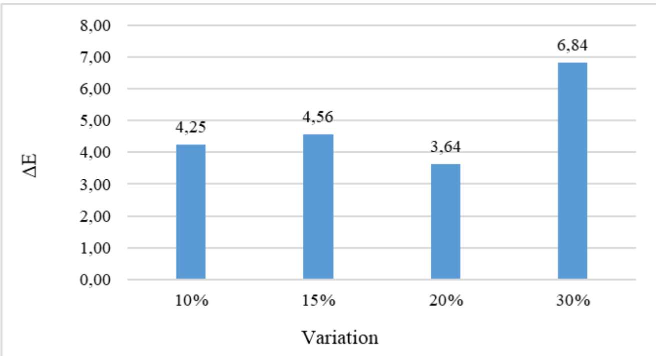

Figure 2. Total colour change of board types.

The total colour change value indicates the colour change on the surface of the board compared to the control sample. As the utilization rate of vermiculite increased in board production, total colour change values increased except for the use of 20% vermiculite. The maximum total colour change was 6.84 in the addition of 30% vermiculite while the minimum total colour change value was 3.64 in 20% vermiculite use. Ustaömer et al. (2006) found that treatment with boric acid, borax and sodium perborate tetrahydrate at 1% and 3% concentrations increased the discoloration (ΔE*) value of the fibreboard due to the increase in chemical concentration and that the highest 3% was sodium perborate tetrahydrate stated. In another study, it was reported that ΔE* values increased in direct proportion with increasing chemical concentration (Ustaömer, 2008).

Glossiness: Glossiness values of control group and groups of vermiculite added boards at different ratios are given in Table 2. It has been understood that the use of vermiculite as compared to the control sample increases the gloss value of the boards but this increase is not linear. The highest gloss value was achieved as 2.33 with 15% vermiculite use, while the lowest gloss was achieved with control as 2.09.

Table 2. Gloss value of test boards.

Type of boards	Bottom surface	Top surface	Average values
Control	-	-	2.09±0.03
10% vermiculite	2.18±0.13	2.38±0.05	2.28±0.06
15% vermiculite	2.38±0.17	2.28±0.05	2.33±0.06
20% vermiculite	2.25±0.17	2.20±0.12	2.23±0.06
30% vermiculite	2.15±0.10	2.08±0.05	2.11±0.05

Surface roughness: The surface roughness test results of the boards produced in the study are given in Table 3.

Table 3. Surface roughness of test boards

Type of boards		Control	10% vermiculite	15% vermiculite	20% vermiculite	30% vermiculite
Bottom surface	Ra	-	8.69±1.42	9.39±1.08	11.76±1.63	15.44±3.92
	Rq	-	9.97±1.72	12.03±1.30	15.12±2.19	20.51±4.97
	Rz	-	72.42±6.31	77.63±10.71	95.83±15.35	124.92±14
Top surface	Ra	-	8.63±1.06	8.71±1.37	8.84±1.04	8.65±1.40
	Rq	-	11.25±1.26	11.14±1.78	11.35±1.42	11.14±1.87
	Rz	-	65.15±8.28	69.25±12.47	70.80±10.91	73.29±12.20
Average values	Ra	8.06±1.58	8.66±1.24	8.94±0.80	10.09±0.86	10.97±1.34
	Rq	10.27±2.05	10.61±1.49	11.40±0.88	12.97±1.39	14.48±1.81
	Rz	60.43±6.01	68.78±7.30	72.83±6.98	75.33±7.08	89.30±6.13

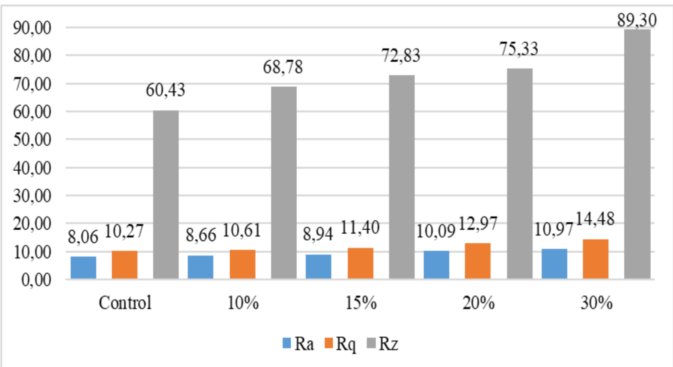

Figure 3. Change of Ra, Rq and Rz values of the board groups.

It was determined that vermiculite addition increased the surface roughness (Ra, Rz and Rq) properties and reduced the smoothness of the surfaces when compared to the control group of surface roughness properties. Moreover, the higher roughness values on the bottom surfaces were caused by the accumulation of more vermiculite on the bottom surface of the board compared to the pavement pattern during the formation of the board. Figure 3 shows the change of Ra, Rq and Rz values of the board groups.

As shown in Fig. 3, the lowest Ra value was 8.06 µm in control and the highest Ra was 10.97 µm in 30% vermiculite added boards. It has been concluded that vermiculite used in powder form did not disperse homogeneously in the board and adversely affected bonding between fibres and glue, preventing smooth surface formation during hot pressing. This has led to an increase in surface roughness values with increasing vermiculite use. This appears to be more pronounced on the bottom surfaces where vermiculite is distributed unevenly. It is thought that the grain size of the vermiculite used additionally may be effective on the surface roughness. Ustaömer et al. (2008) reported that surface roughness values of MDF boards produced were increased due to chemical types and concentration increase of 3%, 5% boric acid, borax, sodium perborate tetrahydrate, zinc borate and boric acid+borax mixtures of fire retardant treatment. In addition, different studies have reported that the morphological properties of the used fibre raw materials and the production parameters effect surface roughness (Nemli, et al., 2007; Dündar, et al., 2008; Özdemir, 2016).

CONCLUSION

In this study, colour, glossiness and surface roughness values of MDF produced by vermiculite addition at different ratios were determined. As a result of the study, L * value increased with increasing vermiculite use rate, but a * and b * values decreased. This is an indication of the increase in white colour (+L*) and blue colour (-b*) and decrease in red colour (+a*) on the boards. Total colour change was increased with increasing vermiculite usage rate except 20% vermiculite usage. When the glossiness values were examined, it was determined that vermiculite usage increased the glossiness compared to the control sample. The surface roughness values (Ra, Rq and Rz) increased as vermiculite usage increased and the surfaces became rougher.

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