MAKÜFEBED

ISSN Online: 1309-2243
http://dergipark.org.tr/makufebed
https://doi.org/10.29048/makufebed.722095

Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi 11(2): 142-149 (2020)
The Journal of Graduate School of Natural and Applied Sciences of Mehmet Akif Ersoy University 11(2): 142-149 (2020)

Araştırma Makalesi / Research Paper

Mineral Based Boards made from Lignocellulosic Wastes: 1st Part - Physical And Mechanical Properties

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Geliş Tarihi (Received): 17.04.2020, Kabul Tarihi (Accepted): 23.05.2020
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ABSTRACT

Lignocellulosic waste of eggplant and tomato stalks has used with minerals of olivine and dolomit at various proportions to produce experimental particleboards that have subject to some physical and mechanical tests. In this regards, Thickness Swelling in water (TS, %), Water Absorption (WA, %), Internal Bond (IB), Bending Strength (MOR), Modulus of Elasticity (MOE) and color properties (CIE,L,a,b) of the boards were examined. It has observed that type and content of minerals effects TS and WA of test panels. Besides the internal bond strength values of the test boards that were generally higher than 0.28 N/mm^2, it was found that the bending resistance properties of the boards produced with tomato stalk/dolomite mixture show higher MOR values in similar manufacturing conditions than those produced with olivine. However, boards prepeared from tomato/eggplant stalks proportions with dolomite/olivine mixture sho lower MOE values than the standard value in all production conditions.

Keywords: Lignocellulosic waste, mechanical properties, particleboard, physical properties

Lignoselülozik Atıklardan Üretilen Mineral Esaslı Levhalar: 1. Bölüm - Fiziksel ve Mekanik Özellikler

ÖZ

Lignoselülozik atık olarak değerlendirilen patlıcan ve domates sapları ile olivin ve dolomit minerallerinin belli oranlarda karışımı ile yonga levha üretimi olanakları bazı fiziksel ve mekanik testlerle araştırılmıştır. Bu bağlamda levhaların kalınlık artım oranı (%), su emme miktarı (%), yüzeye dik çekme direnci, eğilme direnci (MOR), elastikiyet modülü (MOE) ve renk özellikleri (CIE, L, a, b) üzerine araştırma yapılmıştır. Minerallerin türü ve içeriğinin test örneklerinin kalınlık artım ve su alma miktarlarını etkilediği gözlemlenmiştir. Test levhalarının yüzeye dik çekme direnç değerlerinin genellikle standart değer olan 0.28 N/mm^2 daha yüksek olduğu, ayrıca domates sapı/dolomit karışımı ile üretilen levhaların eğilme direnci özelliklerinin, benzer imalat koşullarında olivinle üretilenlere göre daha yüksek MOR değerleri gösterdiği bulunmuştur. Bununla birlikte, domates/patlıcan sapları ile dolomit/olivin karışımından oluşan levhaların tüm üretim koşullarında standart değerden daha düşük MOE değerleri gösterdiği anlaşılmıştır.

Anahtar Kelimeler: Lignoselülozik atık, mekanik özellikler, yonga levha, fiziksel özellikler

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INTRODUCTION

Woody parts of some annual plants have become important source for producing particle boards (Younguist et al., 1994). Numerous studies has already conducted for many non-wood sources in order to explaine their properties and suitable to bio-composite manufacturing. Some of the examples could be given as; kenaf plant (Muehl et al., 1999), wheat and rice stalks (Mantanis et al., 2000), sugar cane residues (Wu, 2001) , vine pruning residues (Ntalos and Grigoriou 2002), Kiwi (Actinidia sinensis planch.), pruning wastes (Nemli et al., 2003), sunflower stalk/wood mixture (Bektaş et al., 2005), cotton carpels (Alma et al., 2005), some vegetable waste stalks (tomato, pepper, eggplant) (Karakuş 2007), fruit pruning's (apple, apricot, cherry) wastes (Arslan et al., 2008), were investigated and the possibilities of board production were reported with some important results . It has predicted that economicaly unsound parts of some plants that have obtained after agricultural process such as; agave, hazelnut, peanut shells, cotton seeds, sunflower stalks, sugar cane residues could be useful in forest products industry as wood substitute material (Atchison, 1993; Rowell, 1997; Young, 1997).

However the usage of inorganic materials such as olivine or dolomite, in the production of bio-based composite boards are limited. These materials are usually utilized in large quantities in iron-steel processing, ceramic manufacturing, paint additives, fertilizer for plants, glass producing and construction industry (Peiwei et al., 2008). Although these mineral sources could be available in nature in large quantity, only limited experiments conducted and found to be some positive results within board properties (Peiwei et al., 2008).

It was reported that the addition of dolomite as filler to the structure of HDF boards that produced from beech-pine fibers, clearly effects some physical and mechanical properties that water absorption, thickness swelling, MOR, MOE and surface roughness lowered in some level while the fire resistance properties increased (Özdemir, 2016; Özdemir et al., 2016).

There is very limited research conducted on olivine and dolomite effects on particleboards properties. However, in this study, a basic approach was used to understand the effects of two similar minerals (olivine and dolomite) on experimental particleboards made from two different waste of bio materials (tomato and eggplant) with certain proportions.

MATERIALS AND METHODS

Eggplant and tomato stalks (as waste material) were used for particleboard production obtained from the greenhouses of Antalya province, Turkey. These are collected and separated from soils and other substances after the main production in greenhouses. The minerals of olivine and dolomite materials were collected from Isparta-Aksu mining sites in Turkey. The urea-formaldyhde adhesive was supplied from a commercially operate a particle board plant.

The eggplant and tomato stalks were turn to particles (1-3 cm) with labaratory type hammer mill then dried in the oven at 105 (± 3^{o}C) temperatures until they reached 2-3% moisture content. The 65% urea-formaldehyde glue and 20% ammonium chloride hardener were used in the production of the boards. The glue was applied 10% and hardener was 1% in the test boards by weight based on oven dry material. Metal mold plates with the dimensions of 40 x 40 cm and 10 mm was used to prepare the board paste. Then it were pressed for 8 minutes under 2.5N / mm^2 at 170-180 ºC with laboratory type electrically heated press. Boards were kept between metal plates after the end of pressing process and then climatized. The experimental panels were conditioned at 23ºC and 65% relative humidity and samples were cut to determine the IB (Internal Bond), MOE and MOR (Modulus of Elasticity and Rupture), TS (Thickness Swelling after two and 24 hours immersion in water) and The Water Absorption (WA, %), in accordance with TS EN 310 (1999), TS EN 319 (1999) and TS EN 317 (1999) standards, respectively. The experimental boards were prepared with given codes in this study was summarized in Table 1.

Table 1. Code numbers and mixture proportions (gr) of materials (**0-5:** Tomato stalks (%), **a-f:** Eggplant stalks(%), **X:** Dolomit, **Y:** Olivine)

Board Code	Dolomite (%)	Tomato Stalks (%)	Board Code	Olivin (%)	Tomato Stalks (%)
X_0	0	100	Y_0	0	100
X_1	10	90	Y_1	10	90
X_2	20	80	Y_2	20	80
X_3	30	70	Y_3	30	70
X_4	40	60	Y_4	40	60
X_5	50	50	Y_5	50	50
Board Code	**Dolomite (%)**	**Eggplant Stalks (%)**	**Board Code**	**Olivin (%)**	**Eggplant Stalks (%)**
X_a	0	100	Y_a	0	100
X_b	10	90	Y_b	10	90
X_c	20	80	Y_c	20	80
X_d	30	70	Y_d	30	70
X_e	40	60	Y_e	40	60
X_f	50	50	Y_f	50	50

Measuraments were conducted in Isparta University of Applied Sciences, Forest Product Engineering Research and Application Laboratory.

The color characteristics were measured by X-Rite SP-68 spectrophotometer. The experimental boards were kept in external atmospheric conditions for 60 days and according to CIE L * a * b * (1976) standard, differences (Delta values) were calculated as surface color values.

An ANOVA general linear model procedure was employed for data to interpret interaction of the panels manufactured. Duncan test was used to make comparison among board types for each property tested if the ANOVA found significant.

RESULTS AND DISCUSSIONS

The water absorption (WA) properties of boards in water (2.0 and 24 hours) are shown in Table 2. It is clearly seen that more less similar results were observed for water absorption properties of the experiemntal boards made from tomato and eggplant stalk with dolomite and olivine as mineral filler in mixture. However, the lowest amount of water absorption were observed on X_4 type board (40% dolomite/60% tomato stalk mixture board) as 62.70%. It is important to note that increasing mineral content have been found to improve the water absorption properties in some levels, but especially the boards produced with dolomite rather than olivine at similar manufacturing conditions.

It was shown from statistical data that F value of dolomite-tomato mixture type boards was found 9.114 (P = 0.009) on water absorption properties. Likewise F value of dolomite-eggplant mixture type boards was observed as 8.054 (P=0.012). According to these results, significant difference was found between board mixing rates (X_{0-5}/X_{a-f}) and water intake properties. The similar F value results were seen in olivine-eggplant (Y_{a-f}) mixture as 23.913 (P=0.001). But olivine-tomato type boards were found statistically insignificant.

Table 3 shows the thickness swelling (TS) values of boards in water. It can be realized that the thickness swelling values of the boards were found higher than the standard value of 12.5% in all conditions. However the lowest TS value 12.80% was observed with Y_f that produced from 50% eggplant stalk and 50% mineral olivine. Moreover the highest TS value of 50.59% was found in X_a type board which produced only by eggplant stalks.

It seems that presence of both dolomite and olivine as mineral filler have negative effect on TS properties. Therefore, it seems that mineral increment can not block the penetration into the board, resulting in higher TS properties.

F value of dolomite-tomato mixture type boards was found 38,034 (P=0,000) for TS properties. Similarly, F value of olivine-tomato mixture and olivine-eggplant type boards were found as 6,526 (P=0,020), 14,353 (P=0,003) respectively. According to these results, significant difference was seen between board mixing rates (X_{a-f}/Y_{0-5}/Y_{a-f}) and thickness swelling properties. However dolomite-tomato type boards were found statistically insignificant.

Table 2. The water absorption(%) values of boards

Board Code	WA (2h)	WA (24 h)	F value	Board Code	WA (2h)	WA (24 h)	F value
X_0	59.92	90.00 (bc)		Y_0	59.92	90.00(a)	
X_1	77.36	98.99 (c)		Y_1	65.15	90.19(a)	
X_2	63.25	79.93 (ab)	**9.114****	Y_2	63.08	83.88(a)	**2.111$^{(ns)}$**
X_3	48.41	62.73 (a)		Y_3	57.31	78.10(a)	
X_4	48.99	62.70 (a)		Y_4	67.94	87.46(a)	
X_5	48.83	63.79 (a)		Y_5	57.35	78.47(a)	
X_a	76.36	110.30 (b)		Y_a	76.36	110.30(c)	
X_b	67.81	105.05 (b)		Y_b	81.34	112.69(c)	
X_c	61.28	88.34 (ab)	**8.054***	Y_c	72.58	95.25(b)	**23.913****
X_d	37.46	66.55 (a)		Y_d	56.63	74.41(a)	
X_e	75.87	106.12 (b)		Y_e	72.90	98.42(b)	
X_f	50.22	77.07 (a)		Y_f	69.08	92.87(b)	

Note: (***) means 99.9% confidence level, (ns) is statistically insignificant, (a, b, c, d, e) means homogeneous groups.

Table 3. The thickness swelling (%) properties of boards in water

Board Code	TS (2h)	TS (24 h)	F Value	Board Code	TS (2h)	TS (24 h)	F Value
X_0	25.69	37.90(a)		Y_0	25.69	37.90(b)	
X_1	25.83	32.00(a)		Y_1	25.86	34.86(b)	
X_2	24.20	30.49(a)	**2.377 $^{(ns)}$**	Y_2	21.70	28.87(b)	**6.526***
X_3	22.64	27.48(a)		Y_3	27.09	37.30(b)	
X_4	18.95	23.85(a)		Y_4	10.85	14.97(a)	
X_5	20.84	26.51(a)		Y_5	21.69	28.48(b)	
X_a	26.18	50.59(c)		Y_a	36.39	50.59(bc)	
X_b	19.37	36.60(c)		Y_b	26.18	38.82(c)	
X_c	25.65	39.61(c)	**38.034*****	Y_c	27.91	33.92(b)	**14.353****
X_d	10.21	23.23(b)		Y_d	20.25	26.23(ab)	
X_e	11.48	14.86(a)		Y_e	12.12	15.81(a)	
X_f	10.53	14.71(a)		Y_f	10.78	12.80(a)	

Note: (***) means 99.9% confidence level, (ns) is statistically insignificant, (a, b, c, d, e) means homogeneous groups.

Table 4 shows the comparative internal bond (IB), modulus of rupture (MOR) and modulus of elasticity (MOE) values of boards produced from tomato stalk /eggplant stalk / dolomite and olivine mixture.

It was realized that the highest internal bond (IB) value was observed in the 30%dolomite,70% tomato stalk mixture (X_3) as 0.81 N/mm^2 and the lowest IB in 100% eggplant stalk mixture (X_a) as 0.22 N/mm^2.

Figure 1 shows that approximately all boards have higher internal bond (IB) strength value than the standard value of 0.28 N/mm^2. It was seen that mineral fillers especially dolomit rather than olivine could positive effect to IB properties. This is very interesting results considering IB strength developments in composite network. It could be hypothesed that the mineral fillers may not absorb the adhesive as others that effects further adhesive available for lignocellulosic. However, tomato and eggplant stalks's porosity is higher than minerals that could be possible to better alignment in network structure and absorp sysnthetic adhesive properly.

According to the ANOVA analysis results for IB bond properties of boards, significant differences with 99.9% confidence level were found between (X_{0-5}/Y_{0-5}/Y_{a-f}) type board mixing rates and modulus of rupture (MOR). Likewise, 99% confidence level was observed on eggplant-dolomite mixture type boards. Moreover modulus of elasticity (MOE) results were found statistically significant in Y_{a-f} (99.9%), X_{a-f}/Y_{0-5} (99%) but X_{0-5} type samples were found statistically insignificant.

Table 4. The mechanical strength properties of experimental boards (MOE, MOR, and IB)

Board Code	IB (MPa)	F value	MOR (MPa)	F value	MOE (MPa)	F value
X_0	0.35(a)	**7.862*** **	8.46(c)	**7.216*** **	1367.9(a)	**0.889(ns)**
X_1	0.73(cd)		8.51(c)		835.3(a)	
X_2	0.58(bc)		6.69(bc)		693.5(a)	
X_3	0.81(d)		6.21(bc)		694.7(a)	
X_4	0.80(cd)		4.88(ab)		689.9(a)	
X_5	0.53(ab)		3.23(a)		1056.1(a)	
X_a	0.22(a)	**5.046** **	3.38(a)	**4.998** **	486.34(a)	**5.542** **
X_b	0.29(ab)		5.95(bcd)		660.14(ab)	
X_c	0.30(ab)		6.67(cd)		1212.36(c)	
X_d	0.40(c)		7.02(d)		915.66(bc)	
X_e	0.34(ab)		4.10(ab)		655.43(ab)	
X_f	0.38(bc)		4.81(abc)		1242.69(c)	
Y_0	0.35(a)	**3.131***	8.46(d)	**10.458*** **	1367.9(d)	**4.946** **
Y_1	0.74(b)		7.44(cd)		1075.8(bc)	
Y_2	0.67(b)		5.85(bc)		1119.7(bc)	
Y_3	0.68(ab)		3.83(ab)		830.2(ab)	
Y_4	0.64(ab)		2.84(a)		647.3(ab)	
Y_5	0.54(ab)		2.49(a)		508.9(a)	
Y_a	0.22(a)	**4.596** **	3.38(ab)	**8.350*** **	486.34(a)	**7.829*** **
Y_b	0.29(ab)		4.81(bc)		728.4(a)	
Y_c	0.37(bc)		7.76(d)		1139.6(b)	
Y_d	0.43(c)		6.64(cd)		1037.1(b)	
Y_e	0.24(ab)		5.06(bc)		641.8(a)	
Y_f	0.35(ab)		2.71(a)		534.8(a)	

Note: (***) means 99.9% confidence level, (ns) is statistically insignificant, (a, b, c, d, e) means homogeneous groups.

Figure 2 shows bending strength (MOR) and modulus of elasticity(MOE) values of boards manufactured from various proportions of tomato/eggplant stalks with mineral fillers. It could be seen that the addition of both dolomite and olivine substances in the board affected these values are negatively.

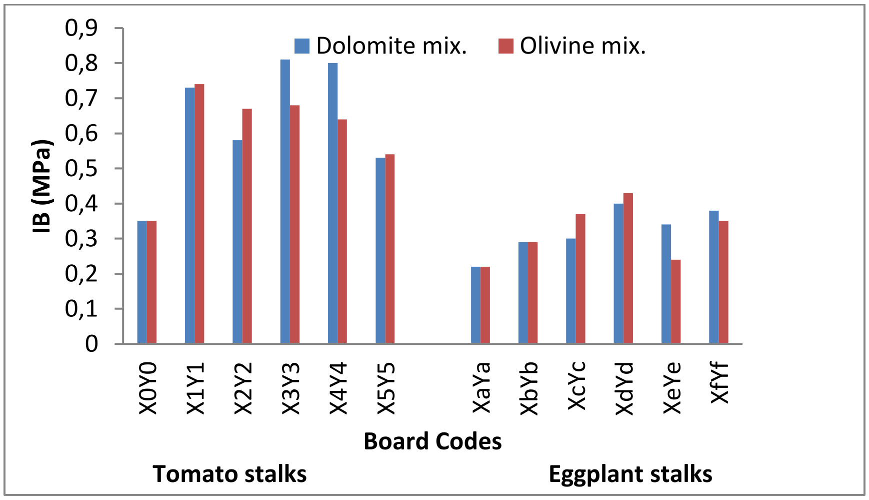

Figure 1. The internal bond (IB) properties of boards

It was observed that the highest modulus of rupture was found 8.51 N/mm^2 in the 90% tomato/10% dolomite (X_1) board and the lowest in the 50% olivine/50% tomato stalks (Y_5) board with 2.49 N / mm^2. It has been found that dolomite based boards have usually higher MOR values than those produced with olivine under the same production conditions. It can be seen that increasing mineral proportion effects on lowering MOR values in general.

However, it was shown that the modulus of elasticity (MOE) values of all boards were found lower than the standard value of 1600 N/mm^2. Moreover, the lowest MOE value was calculated in 100% eggplant stalk board sample as 486.34 N / mm^2 and the highest value was in 100% tomato stalk board sample as 1367.9 N/mm^2.

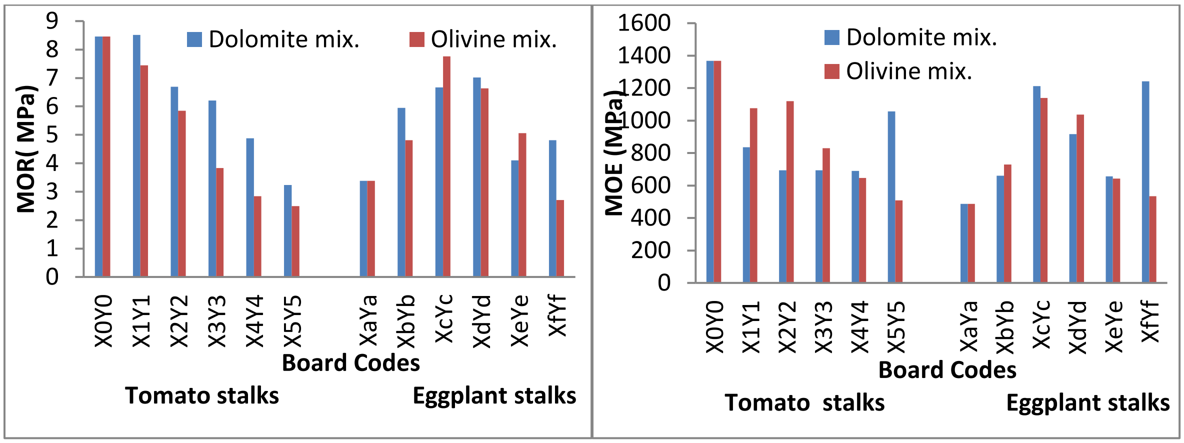

Figure 2. Modulus of rupture (MOR) and modulus of elasticity(MOE) properties of boards

The bending strength and elasticity of bio composite materials are sensitive to bonding potential as well as the relative bonded area, which originates from the surface properties of fillers and particles in matrices that other properties (lignocellulosic particle dimensions) remain intact. Although in certain manufacturing conditions, boards show higher IB strength properties than standard values, that show considerably lower MOR and MOE properties than standard values. It is clear that mineral fillers could effects fibre flexibility and bonding potential of particles in matrice structure.

Test boards were kept for 60 days under external atmospheric conditions for evaluating weathering performances and then the differences of surface color values were determined. Color changing (∆) are shown in Figure 3**.** Although it is an easy and useful method to determine the basic color values of the materials, the explanation of each color parameter (CIE L *, a *, b *) is quite complicated. However, examination of the total color difference (∆E) value is important in terms of providing information about the way of change.

It was measured that the maximum color differences were observed in X_0 (100% tomato) type board as 12.81% and X_a (100% eggplant) type board as 13.67% . However, the lowest changing was observed in X_c type board as ∆**E** =1.15 and Y_5 type board as ∆**E**=2.30 respectively. It could understood from Figure 3 that mineral in higher proportions in mixtures in all types was decreased the color changings.

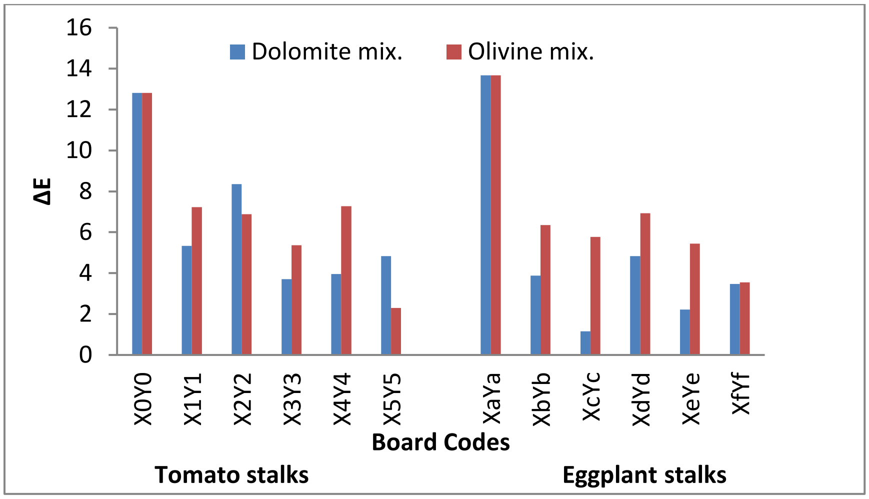

Figure 3. Color characteristics of the boards

CONCLUSIONS

In this study, the usability of mineral substances which are dolomite and olivine minerals with tomato and eggplant stalks as greenhouse waste in the board structure was investigated. It was understood that tomato and eggplant stalks as lignocellulosic waste materials could use in the production of composite boards with mineral mixture in some proportions.

However, addition of the hydrophobic mineral substances to mixture improved thickeness swelling and water absorbtion properties in water. But, in some cases dolomite and olivine minerals contribute negative effects such as bending strength and modulus of elasticity. Therefore, the mechanical properties of boards are not between acceptable level for composite panels such as construction panels, however it can use some places where is not strength neccesity such as; insulation applications, outdoor panels or sidings.

It is important that large particle size of the mineral substances and the heterogeneous distribution in the board composition negatively affected the mechanical properties. Hence, the application of mineral materials should improve efficiently then required levels can be achieved.

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