

INVESTIGATION OF SOME PROPERTIES OF MEDIUM DENSITY FIBERBOARD (MDF) PRODUCED WITH ADDITION OF SAWDUST OF FRUIT TREES

Derya USTAÖMER

Karadeniz Technical University, Faculty of Forestry, Forest Industry Engineering
Address: 61080, Trabzon, Türkiye
E-mail: uderya@ktu.edu.tr

Elif TOPALOĞLU*

Giresun University, Giresun Vocational School, Department of Architecture and Urban Planning
Address: 28049, Giresun, Türkiye
E-mail: elif.topaloglu@giresun.edu.tr

Nurgül AY

Karadeniz Technical University, Faculty of Forestry, Forest Industry Engineering
Address: 61080, Trabzon, Türkiye
E-mail: nay@ktu.edu.tr

Abstract:

Wood waste, which constitutes an important component of solid waste, is produced by the wood industry, and especially in the processing one. The wood industry includes tree bark, sawdust, planer shavings, sander dust etc. produces unwanted products and/or wastes. This study investigated the usability of sawdust of fruit trees in the production of Medium Density Fiberboard (MDF) and some technological properties of the produced MDF panels. Sawdust of fruit trees was mixed to beech fibers at the ratio of 10, 20 and 30% by weight. The mats were manually formed using 13% urea formaldehyde and pressed at a temperature of 185 °C for 8 min in a computer control press. The MDF panel samples of water absorption (WA), thickness swelling (TS), surface hardness, surface roughness, MOR and MOE were investigated. It was determined that the values of WA and TS decreased with increasing the ratio of sawdust. Modulus of rupture (MOR), modulus of elasticity (MOE), surface hardness, surface roughness parameters (R_a , R_q and R_z) values of panel samples increased with increasing the ratio of sawdust from panels. Based on these results, it is advisable that wood sawdust fruit-trees can be used as an alternative raw material source in MDF production.

Key words: MDF; sawdust; MOR; MOE; roughness; hardness; swelling; water absorption; wood waste.

INTRODUCTION

With increasing global environmental awareness, the field of wood waste management has become an important issue in recent years. Global warming, significant environmental degradation and deforestation have prompted efforts to find sustainable ways on reducing wood waste. Reducing the amount of raw wood used, slowing down the rate of deforestation, and protecting the area of old-growth forests are all possible with sustainable wood waste management (Olszewski *et al.* 2023).

Wood is a natural resource, having definite chemical and physical properties that can be utilized in a variety of applications such as packaging, furniture, construction, and energy. Upon reaching the end of its life, wood-based waste is recognized as a valuable material, as it has the potential for both energy recovery and recycling process (Faraca *et al.* 2019). The sustainable management of wasted forest biomass is made possible by the utilization of alternative raw materials. Less valuable wood waste resulting from the processing of wood such as wood chips, wood pulp, sawdust and shavings also reduces the panel production costs (Pędzik *et al.* 2022a). Nguyen *et al.* (2023) stated that most of the studies carried out in the waste wood type sector is related to wood-based panels.

As it is known, a lot of wood-based waste is generated during the use of wood raw materials in various industries. Therefore, these natural wastes need to be evaluated more rationally, not only as fuel but also as alternative raw material sources. Thus, while contributing to the environment, alternative solutions can be produced for decreasing raw material resources.

Türkiye's suitable climatic conditions allow many fruit trees to grow in the country (Gül and Akpınar 2006, Topaloğlu *et al.* 2019). According to TÜİK (2023), especially apple, pear, olive, loquat and persimmon are among the fruit trees grown in the country. *Diospyros lotus* L., which is in the *Ebenaceae* family, can grow up to 10-15 m tall and sheds its leaves in winter (Merev 2003). Edible fruits, leaves and timber of some species of the *Diospyros* genus are of commercial importance (Rauf *et al.* 2017). It is also stated that some

*Corresponding author

species are used in the production of high-quality furniture, carving, and musical instruments due to their high density and hard wood (Noda *et al.* 2002, Kiaei and Bakhshi 2014). *Olea europaea* L. (olive), belonging to the *Oleaceae* family, is a woody plant in the form of evergreen shrubs and trees (Merev 2003), growing in the Mediterranean basin (Mansour-Gueddes *et al.* 2018). Olives are of great commercial importance in Türkiye and play an important role in the agricultural and processing sectors of olive-producing countries (Tous and Ferguson 1996). In addition to that, olive wood has been used for high-end turned objects, carving, indoor furniture, veneer, flooring, and tool handles or high-end knife because it is adaptable and strong properties. Biomass as a source of energy is the first and primary use for olive tree wood (Aliaño-González *et al.* 2022). *Eriobotrya japonica* (Thunb.) Lindl., within the *Rosaceae* family, subtropical regions of China, Japan, India and the Mediterranean areas. It is a small evergreen tree that grows in these regions. It is grown for both its fruit and ornamental tree (Tous and Ferguson 1996, Lin *et al.* 1999). As known, although fruit tree woods are not commonly utilized in the wood-based panel industry, these woods can be considered as species that possess potential for utilization in various usage areas.

Numerous studies have been conducted on the utilization of various wood wastes and forest residues in the production of wood-based panels (Nemli and Aydın 2007, Akgül and Tozluoğlu 2008, Ayırmis *et al.* 2009, Bardak *et al.* 2010, Lykidis *et al.* 2014, Yel *et al.* 2014, Lykidis *et al.* 2016, Ustaömer *et al.* 2017, Savov *et al.* 2019, Taş and Sarı 2022, Pędzik *et al.* 2022a, Pędzik *et al.* 2022b). When the relevant literature is examined, it is understood that there are not much researches on the use of sawdust of end-of-life fruit trees grown in Türkiye as alternative raw materials in MDF production. Therefore, it would be beneficial to conduct further research on the benefits and feasibility of using wood waste of fruit-trees.

OBJECTIVE

The objective of the study was to evaluate the selected properties such as water absorption (WA), thickness swelling (TS), modulus of rupture (MOR), modulus of elasticity (MOE), surface roughness parameters (R_a , R_q , R_z) and surface hardness of medium density fiberboard, produced from commercial beech fiber and sawdust of *Diospyros lotus* L., *Olea europaea* L. and *Eriobotrya japonica* Lindl. wood of fruit trees. In addition, other aim is to investigate the usability of sawdust from the stem wood of these three fruit-trees as wood waste in the production of MDF.

METHOD

In the present study, the stem wood of three fruit-trees, that is growing in the Eastern Black Sea region of Türkiye and commercial beech fibers were used. These fruit trees are date plum (DP), olive (O) and loquat (L) trees. Before manufacturing process, the sawdust obtained from the stem wood were converted into small-sized fibers. Beech fibers and sawdust were dried until they reached 2% moisture content. Then, the ratio of 10%, 20% and 30% sawdust by weight was mixed with 13% urea formaldehyde into the beech fibers and mats were manually formed. The mats were pressed in a press for 8 minutes and at a press temperature of 185°C. Three panels were produced for each group. The DP panel groups are observable in Fig. 1. Before preparing the test samples, the produced panels were conditioned at a temperature of 20°C and 65% relative air humidity conditions for 24 hours, until test samples reached a constant weight. Table 1 lists the panel groups and panel type contents.



Fig. 1.

Sample panels- A (DP-1), B (DP-2), C (DP-3) and D (Control).

Table 1

MDF Panel groups		
	Panel groups	Contents
Date Plum	DP-1	90% fiber + 10% sawdust
	DP-2	80% fiber + 20% sawdust
	DP-3	70% fiber + 30% sawdust
Olive	O-1	90% fiber + 10% sawdust
	O-2	80% fiber + 20% sawdust
	O-3	70% fiber + 30% sawdust
Loquat	L-1	90% fiber + 10% sawdust
	L-2	80% fiber + 20% sawdust
	L-3	70% fiber + 30% sawdust
Control	C	100% fiber (without sawdust)

Water Absorption and Thickness Swelling

Water absorption (WA) and thickness swelling (TS) of panel samples were determined according to TS EN 317 (1999) standard. Test samples with dimensions of 50mm (length) × 50mm (width) × 10mm (thickness) were placed in a flat beaker filled with distilled water. Measurements were performed after 2 hours and 24 hours of immersion of water. The relations of these tests were (Eq. 1):

$$WA = \frac{m_f - m_i}{m_i} \cdot 100 [\%] \quad TS = \frac{t_f - t_i}{t_i} \cdot 100 [\%] \quad (1)$$

where: m_f -final mass, in g; m_i -initial mass, in g and t_f -final thickness, in mm; t_i -initial thickness, in mm

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

The modulus of rupture (MOR) and modulus of elasticity (MOE) experiments of test samples were performed with a Zwick/Rowell Z010 Universal testing machine in three point bending mode according to TS EN 310 (1999) standard. The relationships for determining MOR and MOE were (Eq.2):

$$MOR = \frac{3}{2} \cdot \frac{F_{max} \cdot L}{b \cdot t^2} \left[\frac{N}{mm^2} \right] \quad MOE = \frac{F \cdot L^3}{4 \cdot b \cdot t^3 \cdot f} \left[\frac{N}{mm^2} \right] \quad (2)$$

where: F_{max} -the maximum load applied during the test, in N; L-the span length between the supports, in mm; b-the width of the sample, in mm; t-the thickness of the sample, in mm; F-the load difference in elasticity, in N; f-the deflection of the sample under the maximum load, in mm

Surface Roughness

Surface roughness parameters of panel samples were determined by using Mitutoya Surftest SJ-210 instrument. The surface roughness parameters (R_a , R_q and R_z) were measured to evaluate surface roughness of the samples according to ISO 21920-2 (2021) standard. The explanations of these parameters are as follows: R_a (average surface roughness), R_q (root mean square roughness) and R_z (ten-point mean roughness). Ten measurements were performed on each test sample.

Surface Hardness

Shore Durometer is used to measure surface hardness values of test samples. Shore D hardness test method according to ASTM D2240 (2021). Ten measurements were made on each test sample, and average hardness value was calculated using ten measurements.

RESULTS AND DISCUSSION

Water Absorption and Thickness Swelling

The average values of the water absorption and thickness swelling for 2h and 24h of panel groups are presented in Fig. 2. and Fig. 3. The error bars in the graphs show the standard deviation values. From the data in Fig. 2, it is apparent that the WA values for 2h and 24h of MDF panel samples depend on panel type and ratio of sawdust of *Diospyros lotus* L., *Olea europaea* L. and *Eriobotrya japonica* Lindl. fruit woods. As shown in Fig. 2, WA (2h) values of DP, O and L panel groups ranged between 42.10-60.62%, 59.71-68.22% and 58.85-62.47%, respectively. The greatest WA (2h) value was found in control samples (72.77%). WA (24h) values of DP, O and L panel groups ranged between 57.25-74.07%, 72.62-82.78% and 68.71-82.65%, respectively. The control samples had the greatest value (90.43%). As the proportion of fruit tree sawdust in

the mixture increased, the water absorption ratios of MDF panels for 2h and 24h decreased proportionally (Fig. 2).

The WA values of groups DP, O, L were found smaller than the WA value of control panel. In general, it is possible to say that the water resistance of MDF panels improves as the proportion of fruit wood sawdust in the mixture increases. Comparing the all groups, the smallest obtained values were 42.10% and 57.25% in DP-3 panel group for 2h and 24h, respectively. Another finding that stands out from the results is the group with sawdust of *Diospyros lotus* L. resulted in the lowest WA values comparing the values of all panel groups. Among all three fruit panel groups the greatest WA values for 2h and 24h were found in O-1 panel group. This may be related to fiber characteristics of olive wood. However, in our previous study (Topaloğlu *et al.* 2019), the wood fiber wall thickness of olive tree was found to be greater than those of date plum and loquat. Additionally, Harmaen *et al.* (2012) and Awang *et al.* (2023) stated that the water absorption of the boards depends on the structure of the wood cells.

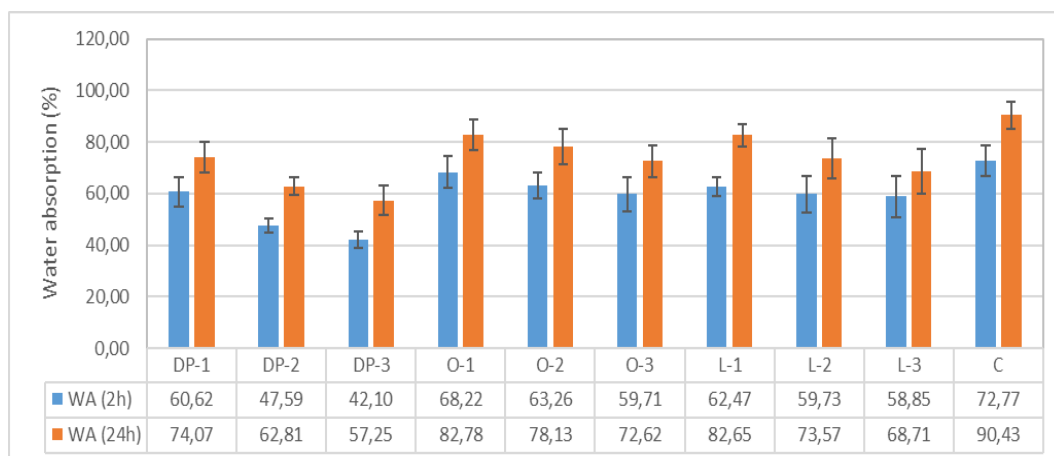


Fig. 2.
WA values for 2 and 24 hours of MDF samples.

As shown in Fig. 3, TS (2h) values of DP, O and L panel groups ranged between 6.15-8.26%, 7.92-9.73% and 8.50-9.71%, respectively. The greatest TS (2h) value was found in control samples (13.19%). TS (24h) values of DP, O and L panel groups ranged between 12.60-12.97%, 12.89-14.65% and 14.09-14.74%, respectively. The control samples had the greatest value (16.03%). It was observed that the results of TS values of MDF panels were similar to those of WA values. As the proportion of fruit tree sawdust in the mixture increased, there was a decrease in TS values of all panel groups, and this decreasing trend was especially more evident in DP group for 2h. Similar to this result, Ustaömer *et al.* (2017) found that the WA and TS ratios for 2h and 24h of fiberboard produced from ash wood sawdust decreased as the sawdust ratio increased. On the contrary, Savov *et al.* (2019) determined that as the sawdust ratio of the wood-based panels produced using coniferous sawdust increased from 0% to 50%, the WA and TS values of the panels also increased, and also concluded that the increase in WA could be explained by the decrease in the active area of contact between fibers.

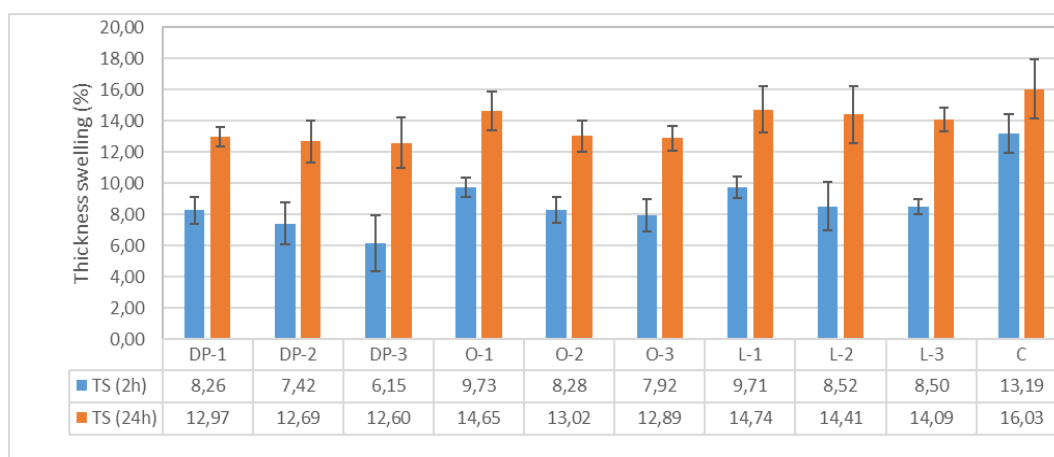


Fig. 3.
TS values for 2 and 24 hours of MDF samples.

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of test samples

The average MOR values and standard deviation values with error bars are shown in Fig. 4. MOR value was found to be between 21.53-22.08 N/mm², 19.77-21.02 N/mm² and 14.69-18.03 N/mm² for DP, O and L panel groups, respectively. The greatest value (22.08 N/mm²) belonged to DP-3 panel group, while the smallest value (14.69 N/mm²) belonged to L-1 panel group. Although the MOR value of the control samples is greater than those of the L panel groups, it is smaller than those of the DP and O panel groups. As seen in Fig. 4, as the fruit sawdust ratio in the mixture increased, there was a small increase in the MOR values of DP and O panel groups, while there was a more significant increase in the L panel group.

The fibers of three fruit tree wood, which are in the hardwood class, are shorter than those of softwoods. In our previous study (Topaloğlu *et al.* 2019), the fiber lengths for loquat, olive and date plum were reported as 1.16 mm, 1.11 mm and 0.94 mm, respectively. Therefore, fiber length may have affected the MOR and MOE values of the produced MDF panels. According to Park *et al.* (2001), MDF panel performance is influenced by wood-fiber characteristics such fiber length and distribution.

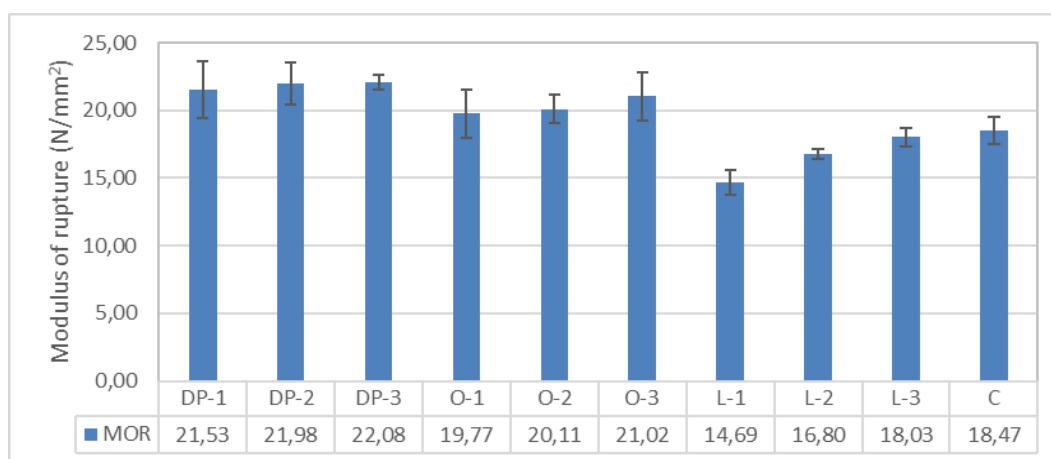


Fig. 4.
MOR values of MDF samples.

Fig. 5 present the average MOE values and standard deviation values with error bars. MOE values of MDF samples showed similar trends to the results of MOR. MOE value was found to be between 2526.58-2821.17 N/mm², 2218.26-2889.06 N/mm² and 1992.31-2325.75 N/mm² for DP, O and L panel groups, respectively. The greatest value (2889.06 N/mm²) belonged to O-3 panel group, while the smallest value (1992.31 N/mm²) belonged to L-1 panel group. It was determined that the MOE value of the control samples was greater than those of the other panel groups, except for the DP-3 and O-3 panel groups. As the fruit sawdust ratio in the mixture increased, there was a clear increase in the MOE values of all three MDF panel groups.

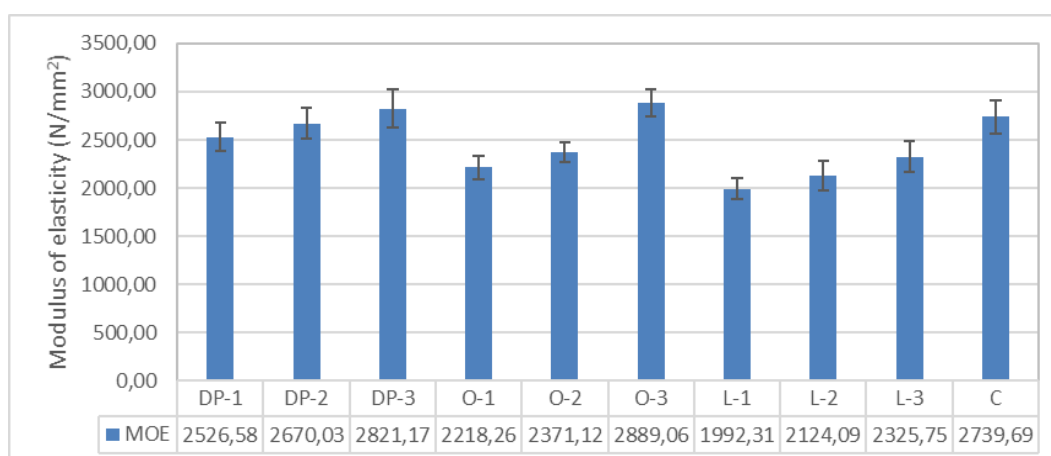


Fig. 5.
MOE values of MDF samples.

Surface Roughness

Average values of surface roughness parameters (R_a , R_q , R_z) values of MDF samples are represented in Fig. 6. According to Fig. 6, the greatest values of R_a , R_q and R_z were recorded for control samples. Panels made from loquat sawdust had the roughest surface. Average R_z values of 42.97 μ m, 44.04 μ m and 45.13 μ m were found for L-1, L-2 and L-3, respectively. When the results were evaluated within each fruit tree groups, it was determined that surface roughness values of MDF samples increased as the sawdust rate increased. However, the values of all three tree groups were smaller than those of control group, meaning that the surface of the control samples was rougher than the other samples. This may be related to the wood-fiber characteristics of the fruit trees in the mixture. The characteristics of the raw material, such as the fiber size and geometry, affect the level of surface roughness (Hiziroglu 1996). Akbulut *et al.* (2000) state that the anatomical structure of the raw material affect the surface roughness of the produced MDF panels. In this study, control MDF samples that was produced from 100% beech wood fibers had the roughest surface (Fig. 6).

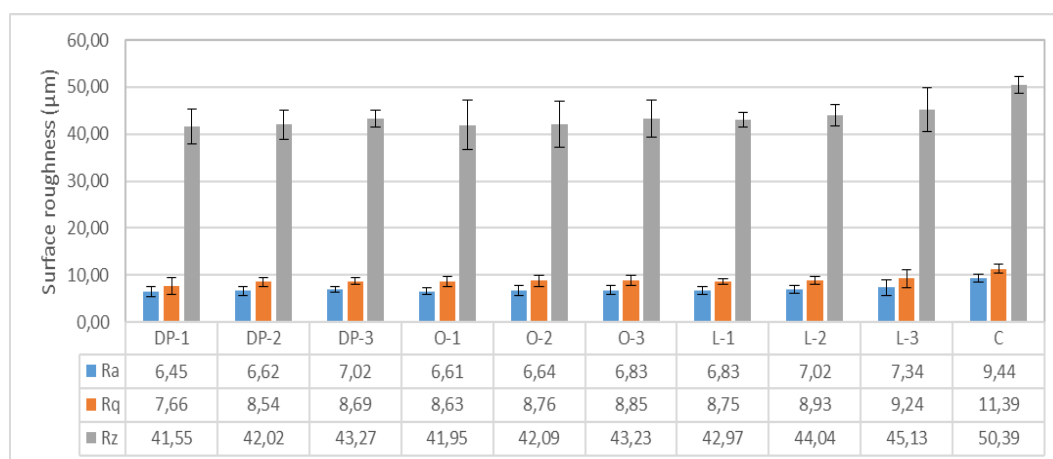


Fig. 6.
 R_a , R_q and R_z values of MDF samples.

Surface Hardness

The surface hardness (Shore D) values of panel groups are presented in Fig. 7. Shore D values was found to be 65.20-70.50, 69.70-75.70 and 67.50-71.30 for DP, O and L panel groups, respectively. The greatest value was determined in the O-3 group with a Shore D hardness value of 75.70, and the smallest value was determined in the control group with a value of 62.20. As a result, it was found that the MDF panel with the hardest surface belonged to the O-3 group, which was produced from the ratio of 30% olive wood sawdust. As seen in Fig. 7, the surface hardness of MDF panels increased with the increase in the proportion of fruit tree sawdust. Control MDF samples produced from 100% beech fibers had the smallest hardness value. It was observed that MDF panel surface, which consists of a mixture of diffuse porous beech wood fibers and diffuse porous fruit tree fibers (Topaloğlu *et al.* 2019), had a harder surface compared to the control sample.

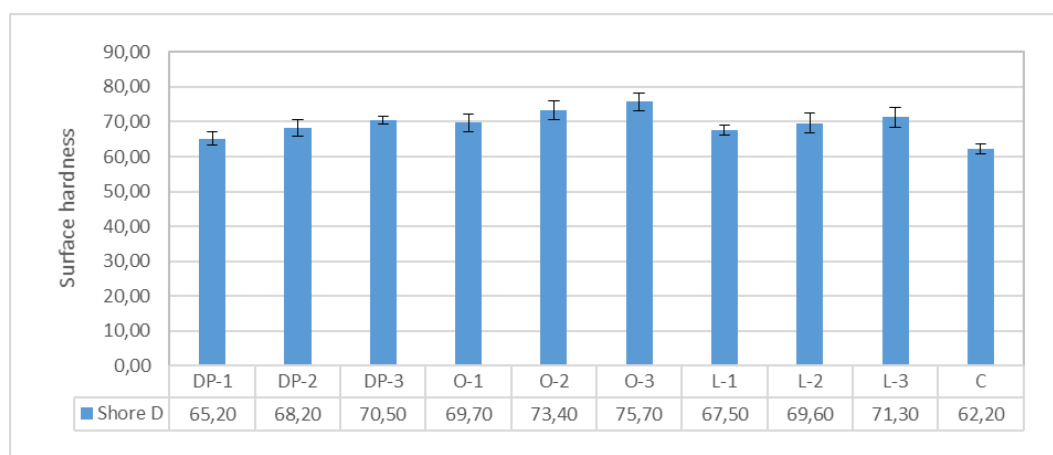


Fig. 7.
Surface hardness values of MDF samples.

CONCLUSIONS

This study was designed to determine the effect of wood sawdust from some fruit trees as additional raw material in fiberboard production. According to the results, all values showed different trend depending on the type and ratio of fruit wood sawdust. The important finding of this study can be summarized as follows:

1. It appears that with the addition of fruit sawdust to the fiber, the WA and TS values of the samples decreased compared to those of the control samples. There was a clear decrease, especially in the 2h WA and TS values of DP and O panel groups.
2. As the sawdust ratio of the fruit trees in the mixture increased, there was a significant increase in the MOR value of the L panel group and an increase in the MOE values of the DP, O and L groups.
3. The surface roughness and surface hardness of the samples in all three MDF groups increased with the increase in the fruit wood sawdust ratio. Smoother and harder surfaces were obtained in these samples compared to the control samples.
4. From the perspective of evaluation of wood wastes, this type of boards can be preferred for general use and decorative purposes, especially in environments that do not require much mechanical load.
5. Considering the limitations of the research, the authors expect to continue the research, taking into account other participation percentages of the wood obtained from various fruit trees.

REFERENCES

- Akbulut T, Hiziroglu S, Ayrimis N (2000) Surface absorption, surface roughness, and formaldehyde emission of Turkish medium density fiberboard. *Forest Products Journal* 50(6):45-48.
- Akgül M, Tozluoğlu A (2008) Utilizing peanut husk (*Arachis hypogaea* L.) in the manufacture of medium-density fiberboards. *Bioresource Technology* 99(13):5590–5594.
- Aliaño-González MJ, Gabaston J, Ortiz-Somovilla V, Cantos-Villar E (2022) Wood waste from fruit trees: Biomolecules and their applications in agri-food industry. *Biomolecules* 12(2):238.
- ASTM D 2240 (2021), Standard test method for rubber property-durometer hardness, American Society for Testing and Materials, West Conshohocken, Pennsylvania, United States, 1–27 s.
- Ayrimis N, Buyuksari U, Avci E, Koc E (2009) Utilization of pine (*Pinus pinea* L.) cone in manufacture of wood-based composite. *Forest Ecology and Management* 259(1):65-70.
- Awang R, Wahab NA, Ibrahim Z, Aziz AA (2023) Medium density fibreboard (MDF) from oil palm fibre: a review. *Malaysian J Anal Sci* 27(3):626-640.
- Bardak S, Nemli G, Sarı B, Baharoglu M, Zekovic E (2010) Manufacture and properties of particleboard composite from waste sanding dusts. *High Temperature Material and Processes* 29(3):159-168.
- Faraca G, Boldrin A, Astrup T (2019) Resource quality of wood waste: The importance of physical and chemical impurities in wood waste for recycling. *Waste Management* 87:135-147.
- Gül M, Akpınar MG (2006) Dünya ve Türkiye meyve üretimindeki gelişmelerin incelenmesi. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, 19(1):15-27 (in Turkish).
- Harmaen AS, Jalaluddin H, Paridah MT (2012) Properties of medium density fibreboard panels made from rubberwood and empty fruit bunches of oil palm biomass. *Journal of Composite Materials* 47(22):2875-2883.
- Hiziroglu S (1996) Surface roughness analysis of wood composites: a stylus method. *Forest Products Journal* 46(7, 8):67.
- ISO 21920-2 (2021) Geometrical product specifications (GPS)-Surface texture: Profile-Part 2: Terms, definitions and surface texture parameters, International Organization for Standardization, Geneva, Switzerland.
- Kiaei M, Bakhshi R (2014) Radial variations of wood different properties in *Diospyros lotus*. *Forest Systems* 23(1):171-177.
- Lin S, Sharpe RH, Janick J (1999) Loquat: Botany and Horticulture. In: Jules Janick (Ed.), *Horticultural Reviews Volume 23* ISBN 0-471-25445-2 John Wiley & Sons, Inc. pp. 233-276.
- Lykidis C, Grigoriou A, Barboutis I (2014) Utilisation of wood biomass residues from fruit tree branches, evergreen hardwood shrubs and Greek fir wood as raw materials for particleboard production. Part A. Mechanical properties. *Wood Material Science & Engineering* 9(4):202-208.

- Lykidis C, Barboutis I, Grigoriou A (2016) Utilization of wood biomass residues from fruit tree branches, evergreen hardwood shrubs, and Greek fir wood as raw materials for particleboard production. Part B. Hygroscopic properties and formaldehyde content. *Wood Material Science & Engineering* 11(5):254-260.
- Mansour-Gueddes SB, Saidana D, Cheraief I, Dkhilali M, Braham M (2018) Biochemical, mineral and anatomical characteristics of the olive tree cv. Chetoui growing in several Tunisian areas. *Acta Scientiarum Polonorum Hortorum Cultus* 17(2):49-70 DOI: 10.24326/asphc.2018.2.5
- Merev N (2003) Odun Anatomisi ve Odun Tanıtımı. Karadeniz Teknik Üniversitesi Matbaası, Trabzon (in Turkish).
- Nemli G, Aydın A (2007) Evaluation of the physical and mechanical properties of particleboard made from the needle litter of *Pinus pinaster* Ait. *Industrial Crops and products* 26(3):252-258.
- Nguyen DL, Luedtke J, Nopens M, Krause A (2023) Production of wood-based panel from recycled wood resource: a literature review. *European Journal of Wood and Wood Products* 81(3):557-570.
- Noda E, Aoki T, Minato K (2002) Physical and chemical characteristics of the blackened portion of Japanese persimmon (*Diospyros kaki*). *Journal of Wood Science*, 48(3):245-249.
- Olszewski A, Kosmela P, Piszczek Ł (2023) A novel approach in wood waste utilization for manufacturing of catalyst-free polyurethane-wood composites (PU-WC). *Sustainable Materials and Technologies* 36 e00619.
- Park BD, Kim YS, Riedl B (2001) Effect of wood-fiber characteristics on medium density fiberboard (MDF) performance. *Journal of the Korean Wood Science and Technology* 29(3):27-35.
- Pędzik M, Auriga R, Kristak L, Antov P, Rogoziński T (2022a) Physical and mechanical properties of particleboard produced with addition of walnut (*Juglans regia* L.) wood residues. *Materials* 15(4):1280.
- Pędzik M, Tomczak K, Janiszewska-Latterini D, Tomczak A, Rogoziński T (2022b) Management of Forest Residues as a Raw Material for the Production of Particleboards. *Forests* 13(11):1933.
- Rauf A, Uddin G, Patel S, Khan A, Halim SA, Bawazeer S, Ahmad K, Muhammad N, Mubarak MS (2017) *Diospyros*, an under-utilized, multi-purpose plant genus: A review. *Biomedicine & Pharmacotherapy* 91:714-730.
- Savov V, Mihajlova J, Grigorov R (2019) Selected physical and mechanical properties of combined wood-based panels from wood fibers and sawdust. *Innov. Woodwork. Ind. Eng.* 2:42-48.
- Taş HH, Sari U (2022). Feasibility of olive tree pruning as alternative raw material for cement bonded particleboard. *PRO LIGNO* 18(4):10-15.
- Topaloğlu E, Öztürk M, Ustaömer D, Serdar B (2019) Doğu Karadeniz Bölgesi'ndeki bazı meyve ağaçlarının odun anatomisi özellikleri ve kâğıt üretimi açısından değerlendirilmesi. *Ormanlık Araştırma Dergisi* 6(2):142-151(in Turkish).
- Tous J, Ferguson L (1996) Mediterranean fruits. pp. 416-430. In: J. Janick (ed.), *Progress in new crops*. ASHS Press, Arlington, VA.
- TS EN 310 (1999) Wood-Based panels-Determination of modulus of elasticity in bending and of bending strength, Turkish Standards Institution, Ankara.
- TS EN 317 (1999) Particleboards and fibreboards - Determination of swelling in thickness after immersion in water, Turkish Standards Institution, Ankara.
- TÜİK (2023) Türkiye İstatistik Kurumu. Online at: <https://data.tuik.gov.tr/Kategori/GetKategori?p=Tarim-111>
- Ustaömer D, Topaloglu E, Ay N (2017) Some properties of fiberboards manufactured with ash (*Fraxinus excelsior* L.) sawdust. *PRO LIGNO* 13(4):242-246.
- Yel H, Çavdar AD, Kalaycioğlu H, Aras U (2014) Influence of Planer Shavings and Waste Particleboards Usage in Core layer on Physical and Mechanical Properties of Three-layer Particleboards. *Kastamonu University Journal of Forestry Faculty* 14(2):215-221.