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# Effects of utilizing olive pits and waste melamine-impregnated paper in particleboard manufacturing on board properties

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**ABSTRACT:** The demand for wood and wood-based products continues to rise steadily with the growth of the global population. Medium-density fiberboard (MDF), particleboard, and oriented strand board (OSB) are among the most sought-after materials. This increasing demand necessitates the more rational and sustainable utilization of forest resources. This study aimed to investigate the effects of replacing core layer particles with olive pit residues in particleboard production on the boards' physical properties. Additionally, waste melamine-impregnated paper (MIP), a by-product of the wood-based panel industry, was evaluated as an adhesive to determine its impact when combined with olive pits in particleboard production. Olive pits were incorporated into the core layer in five different proportions, and MIP was used exclusively as an adhesive at a fixed ratio of 25%. The particleboards' physical and mechanical properties were analyzed per the relevant TS EN standards. The results indicated that while the incorporation of olive pit residues improved the physical properties of the boards, a decline in their mechanical properties was observed. Consequently, it was concluded that blending olive pit residues with conventional core layer particles would be a more suitable approach rather than using them as a sole replacement.

**Keywords**: Olive pit, MIP waste, Particleboard, Physical properties

# Yongalevha üretiminde zeytin çekirdeği ve atık melamin emdirilmiş kağıt kullanımının levha özellikleri üzerine etkilerinin belirlenmesi

**ÖZ:** Dünya nüfusunun artmasıyla birlikte ahşap ve ahşap bazlı ürünlere olan ilgi ve ihtiyaç gün geçtikçe artmaktadır. Artan ihtiyaçlar doğrultusunda en çok talep gören ürünlerin başında orta yoğunluklu lif levha (MDF), yonga levha ve yönlendirilmiş yonga levha (OSB) en çok aranan malzemeler arasındadır. Artan bu talepler orman kaynaklarının daha akılcı ve sürdürülebilir kullanımını gerekli kılmaktadır. Bu çalışmada, yonga levha üretiminde çekirdek katman parçacıklarının zeytin çekirdeği artıkları ile değiştirilmesinin levhaların fiziksel özellikleri üzerine etkilerinin incelenmesi amaçlanmıştır. Bunun yanı sıra yine bir ahşap bazlı levha sektörü üretim atığı olan atık melamin emdirilmiş kağıtları (MEK) çalışma kapsamında tutkal olarak değerlendirilerek zeytin çekirdeği ile birlikte yonga levha üretiminde kullanılmasının etkileri araştırılmıştır. Çekirdek tabakasına beş ayrı oranda zeytin çekirdekleri katılmış, yapıştırıcı olarak sadece atık MEK sabit %25 oranında kullanılmıştır. Yonga levhaların fiziksel ve mekanik özellikleri ilgili TS EN standartlarına göre analiz edilmiştir. Çalışmanın çıktısı olarak zeytin çekirdeği atıklarının kullanımı ile levhaların fiziksel özelikleri iyileşirken mekanik özelliklerinde azalmalar söz konusu olmuştur. Sonuç olarak sadece zeytin çekirdeği atıkları orta tabaka yongası olarak kullanılması yerine orta tabaka yongaları ile belirli oranlarda karıştırılarak kullanılmasının daha uygun olacağı kanaatine varılmıştır.

**Anahtar kelimeler**: Zeytin çekirdeği, Atık MEK, Yonga levha, Fiziksel özellikler

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## 1 Introduction

The demand for wood and wood-based products has been steadily increasing with the growth of the global population. Medium-Density Fiberboard (MDF), particleboard, and Oriented Strand Board (OSB) are among the most sought-after products. This rising demand necessitates the rational and sustainable usage of forest resources. Türkiye ranks fifth globally and third in Europe in particleboard production with an annual production volume of approximately 5 million cubic meters (ORSİAD, 2019). Türkiye imports a significant amount of wood chips from abroad due to its high production levels and the limited availability of domestic raw materials. This reliance on imports not only leads to substantial foreign currency outflows but also poses challenges to the national economy.

The conservation of natural resources and the reduction of carbon footprints have become increasingly important. Recycling waste materials into high-value-added products plays a critical role in achieving these goals. In this context, the reintegration of waste lignocellulosic materials into production processes can contribute to reducing the demand for forest resources to some extent.

The surfaces of the boards are coated with melamine-impregnated paper (MIP) to achieve an aesthetically pleasing appearance during particleboard production. The coating not only enhances the visual appeal of wood-based panels but also minimizes water absorption through the surface, thereby helping to maintain the panel's moisture content. Additionally, it improves the structural properties of the panels and acts as a barrier reducing the release of harmful substances such as formaldehyde and pesticides (Nemli et al., 2005). A medium-sized paper-impregnation factory generates approximately 400 tons of melamine-impregnated paper waste (MIPW) annually during MIP production (Le Fur et al., 2004). Researchers have explored the reutilization of this valuable waste which contains approximately 50–55% adhesive content (Le Fur et al. 2004, Alpár and Winkler 2006, Silva et al. 2012, Ayrılmış, 2012; Çavdar et al., 2013; Başboğa 2018; Sani and Enayati, 2020, Bozkurt et al. 2021; Kutluata et al., 2023; Zhang et al., 2023; Zhuo et al., 2024). Başboğa (2018) and Başboğa et al. (2018) demonstrated in their comprehensive studies that MIPWs could be effectively utilized in particleboard production. However, while the produced boards met or exceeded the mechanical strength requirements specified by standards, their physical properties such as thickness swelling and water absorption failed to meet the standard thresholds.

Global olive oil production is approximately 3.1 million tons annually (IOC, 2021). European Union countries lead global olive oil production with a production volume of around 2 million tons while Türkiye ranks third with an annual output of 227,500 tons (IOC, 2021). Olive oil production generates approximately 30% (Monteiro et al., 2009) to 60% (Valvez et al., 2021) solid waste posing significant storage challenges for producers and contributing to environmental pollution. Moreover, the disposal of these wastes into water or soil can result in severe environmental issues including contamination and increased greenhouse gas emissions (Sharma et al., 2019). Many of these wastes do not have a clear and viable economic recovery. On the other hand, waste management poses a significant challenge due to its high associated costs (Valvez at al., 2021).

Companies often utilize olive pit (OP) waste for electricity and/or thermal energy production due to the high costs associated with advanced technological solutions for waste disposal which require complex chemical processes (Valvez et al., 2021). Researchers are actively exploring alternative methods for repurposing (OP) waste. Some studies have investigated the effects of using OP waste as a lignocellulosic filler in thermoplastic-based composite production (Ayrılmış and Büyüksarı, 2010; Banat and Fares, 2015; Kaya et al., 2018; Taşdemir and Kaştan, 2021; Jurado-Contreras et al., 2022). A review study highlighted the utilization of OP waste in composite production with various thermoplastics (polystyrene, polylactic acid, polyvinyl chloride, polypropylene, and polycaprolactone), thermosets (phenol-formaldehyde, unsaturated polyester, and epoxy), and rubbers (elastomers) such as acrylonitrile butadiene rubber (Valvez et al., 2021). Additionally, some researchers have focused on evaluating the potential of olive pit waste in cement-bonded particleboard (Aras et al., 2022) and particleboard production (Elbir et al., 2012; Farag et al., 2020; Nemli et al., 2023). Elbir et al. (2012) conducted a study in which olive pits from three different olive species were separately mixed with Maritime pine (Pinus pinaster) chips at four different ratios (0%, 5%, 10%, and 15%) to produce single-layer particleboards using urea-formaldehyde-based resin. The results indicated that the groups containing olive pit (OP) waste exhibited better decay resistance compared to the groups without OP waste. Farag et al. (2020) produced single-layer particleboards by combining unsaturated polyester with OP waste at an 80/20 ratio. Their findings demonstrated that the produced particleboards' physical and mechanical properties met European standards' requirements. In another study, Nemli et al. (2023) utilized OP waste at four different ratios (0%, 10%, 20%, and 30%) mixed with White Poplar (Populus alba L.) chips to manufacture three-layer particleboards using phenol-formaldehyde-based resin. The OP waste was incorporated only into the core layer. Additionally, OP waste was modified with sodium hydroxide and the effects of this modification were also examined. The study reported that incorporating 10% OP waste resulted in a slight reduction in the mechanical properties of the boards compared to the control group; however, this reduction was not statistically significant. Furthermore, increasing the amount of OP waste improved the physical properties of the boards.

This study aimed to evaluate the effects of incorporating OP waste, mixed with MIP waste and core layer particles, on the properties of three-layer particleboards. Previous studies demonstrated that particleboards produced using MIP waste successfully met the required mechanical properties outlined in standards, but failed to achieve satisfactory physical properties serving as a foundation for this research. Furthermore, the hydrophobic characteristics of OP waste attributed to its oil content and its reported ability to improve the physical properties of particleboards in earlier studies provided additional motivation for this investigation.

## 2 Materials and Methods

### 2.1 Materials

In this study, dry wood particle mixtures used in the commercial production of particleboards were obtained from Kastamonu Integrated Wood Industry factories (Balıkesir particleboard facilities) while olive pits were sourced from local olive oil production facilities in Bursa as lignocellulosic raw materials. The wood particles comprised 90% Turkish red pine (Pinus brutia) and 10% oak (Quercus spp.). Two different particle sizes were employed to produce three-layer particleboards: fine particles (Figure 1a) were used for the surface layers and coarse particles (Figure 1b) for the core layer. Olive pit residues (Figure 1c) were incorporated into the core layer at five different proportions (0%, 25%, 50%, 75%, and 100%) by mixing with the core particles. Waste melamine-impregnated paper (MIP) (Figure 1d) was utilized as the adhesive in board production, and no additional adhesive was used. The impregnation line of the Kastamonu Integrated Adana MDF Plant served as the MIP's supply. Furthermore, no water-repellent chemicals or hardeners were included in the study.

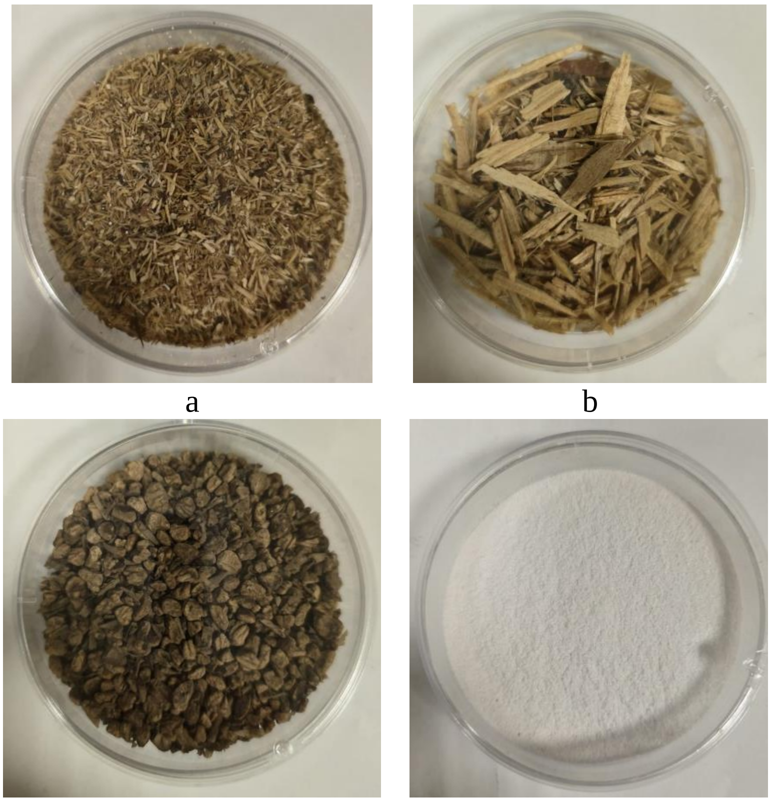


**Figure 1.** Main materials used in particleboard production: a-) fine particle, b-) coarse particle, c-) olive pit residues, d-) MIP

## 2.2 Methods

In the study, the moisture contents of the lignocellulosic materials and MIP wastes were first determined. The moisture content of the olive pit (OP) wastes designated as a replacement for core layer particles was approximately 14.93%. The OP wastes were dried at 80 ± 2°C for 48 hours to reduce this value. Following this treatment, the moisture contents of the OP wastes, coarse particles, fine particles, and MIP wastes utilized in particleboard production were determined to be approximately 4.37%, 3.781%, 4.214%, and 6.539%, respectively.

The melamine impregnation process involves two separate production lines. In the first line, alpha cellulose papers are saturated with adhesive while the surfaces are coated with melamine-formaldehyde adhesive in the second line. The waste MIP used in this study contained approximately 84% urea-formaldehyde adhesive and 16% melamine-formaldehyde adhesive from the first line. In the second line, 100% melamine-formaldehyde adhesive was applied. The waste MIP materials utilized in the study comprised approximately 52% solid adhesive content. Initially, the waste MIP was ground using a pulverizer equipped with a cooling system. Subsequently, the ground material was subjected to dimensional classification using a vibrating sieve. For the study, only MIP particles that passed through a 0.3 mm sieve but were retained on a 0.2 mm sieve were used. The composition in the core and surface layers based on the overall panel weight contained 25% MIPW which was reported as the best usage ratio in a previous study (Başboğa, 2018). The production formulation is presented in Table 1. In the scope of this study, only core layer particles were mixed with OP residues at specific ratios. Therefore, the production table includes only the variation rates of core layer particles.

**Table 1.** Content of the core layer particles

| ID | Wood Particle Mixtures (%) | Olive Pits (%) |
|---|---|---|
| **OP0** | 100 | 0 |
| **OP25** | 75 | 25 |
| **OP50** | 50 | 50 |
| **OP75** | 25 | 75 |
| **OP100** | 0 | 100 |

In the particleboard, the face layers constitute 33% of the total panel weight while the core layer accounts for 67%. The target density in the production of the panels was set at 700 kg/m³. The particles, OP and MIP wastes were dry-mixed in a high-intensity mixer to achieve a homogeneous blend. The obtained mixtures were laid into the frame of 350 mm X 300 mm by the production formula. The particleboards were produced using a Cemil Usta hot press with a pressure range of 50-80 Bar. The target thickness of the boards was set at 13 mm. The pressing process was carried out at a temperature of 190 °C for 240 seconds. The particleboards were conditioned at 20 °C and 65% relative humidity after pressing. The boards were trimmed on all four edges following the conditioning process. Test samples were then prepared in accordance with the relevant standards. Five different particleboard groups were produced for the study with each group consisting of three layers (two surface layers and one core layer). Two particleboards were produced for each group and five samples from each board were selected for testing to evaluate their properties. Ten samples were tested for each group to assess all the relevant attributes in total. The performance of the specimens was measured in a climate-controlled laboratory.

### 2.2.1 Determination of physical properties

The physical properties such as density, thickness swelling (TS), and water adsorption (WA) were also measured in compliance with the criteria in the standard. The densities of the boards were determined using the air-dried density method by the TS EN 323 (CEN 1999a) standard. The samples' TS and WA (2h and 24h) properties were determined according to the TS EN 317 standards.

### 2.2.2 Determination of mechanical properties

The mechanical properties such as bending strength, modulus of elasticity and internal bond strength were determined in accordance with TS EN 310 (CEN 1999b) and TS EN 319 (CEN 1999d), respectively. A Shimadzu AG-IC Universal testing machine was used to evaluate the mechanical properties. In all properties testing, ten samples were checked for each group and five of them were analyzed for each produced panel.

### 2.2.3 Data analysis

Design-Expert® Version 7.0.3 statistical software program was utilized to determine the interaction of OP rate on physical and mechanical properties of the manufactured board. ANOVA test was performed to determine the effects of the OP amount on the panels' properties. A total of 50 specimens, ten from each group, were experimented with for the physical and mechanical measurements. The effects of olive pit waste amount on particleboards' physical and mechanical properties produced with waste MIP as an adhesive were investigated.

## 3 Results and Discussions

The production process was successfully completed using olive pit residues as core layer particles and melamine-impregnated paper wastes as an adhesive. The results of the mechanical and physical tests are summarized in Table 2.

**Table 2.** Summary of the results of the study

| ID | Density ($g/cm^3$) | IBS ($N/mm^2$) | BS ($N/mm^2$) | MOE ($N/mm^2$) | TS (2h) (%) | TS (24h) (%) | WA (2h) (%) | WA (24h) (%) |
|---|---|---|---|---|---|---|---|---|
| OP0 | 0.683(0.056)* | 0.51 (0.14) | 10.87 (2.82) | 1934 (249) | 16.5 (2.38) | 18.0 (1.83) | 81.5 (13.23) | 89.5 (13.18) |
| OP25 | 0.695 (0.037) | 0.48 (0.22) | 7.56 (0.85) | 1420 (145) | 14.5 (0.58) | 16.3 (0.96) | 78.8 (8.54) | 85.5 (10.38) |
| OP50 | 0.690 (0.049) | 0.26 (0.13) | 5.18 (0.82) | 979 (138) | 14.5 (1.29) | 17.3 (1.50) | 76.0 (10.52) | 81.8 (9.14) |
| OP75 | 0.659 (0.023) | 0.10 (0.07) | 2.54 (1.39) | 466 (308) | 12.8 (0.50) | 15.8 (1.26) | 79.0 (4.24) | 83.8 (4.65) |
| OP100 | 0.734 (0.036) | 0.02 (0.01) | 1.50 (0.14) | 250 (33) | 12.5 (2.08) | 16.50 (4.20) | 69.8 (5.56) | 77.5 (6.03) |

*Values in parenthesis are standard deviations.

### 3.1 Results of physical properties

The density interaction graph for the panel groups is presented in Figure 2. Examining the graph reveals that the density values of the produced board groups are closely aligned. When analyzing the standard deviation values of the obtained density results, it is evident that all board groups exhibit close results. Statistical analysis indicated that the proportion of olive pit (OP) waste usage had no significant effect on the density values ($P = 0.2104$). The produced boards had density values ranging from 0.659 to 0.734 $g/cm^3$.

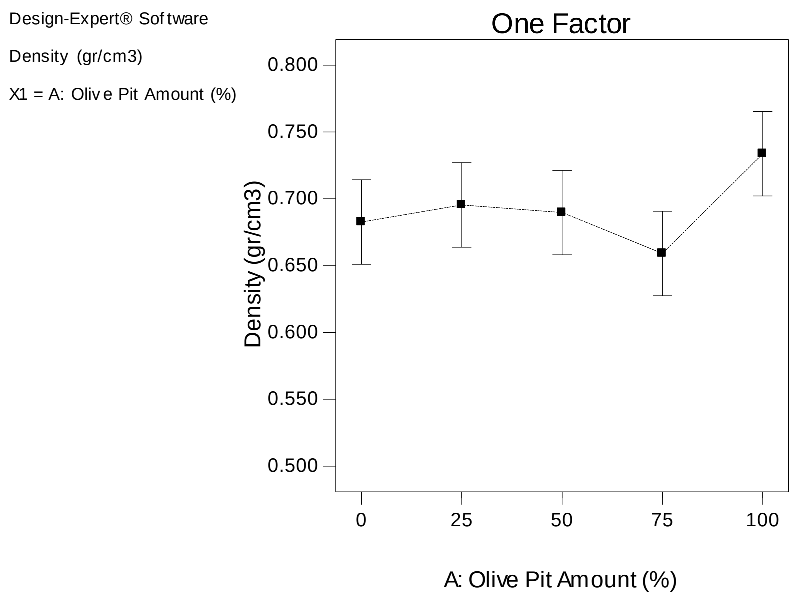


**Figure 2.** Interaction graph of density properties

The effects of OP waste content on the thickness swelling properties of the boards after 2 hours of water immersion are presented in the interaction graph in Figure 3. Statistical analysis revealed that the OP waste ratio significantly impacted thickness swelling properties (2 hours) (P = 0.0094). As the amount of OP wastes in the core layer increased, an improvement in the 2-hour thickness swelling values was observed.

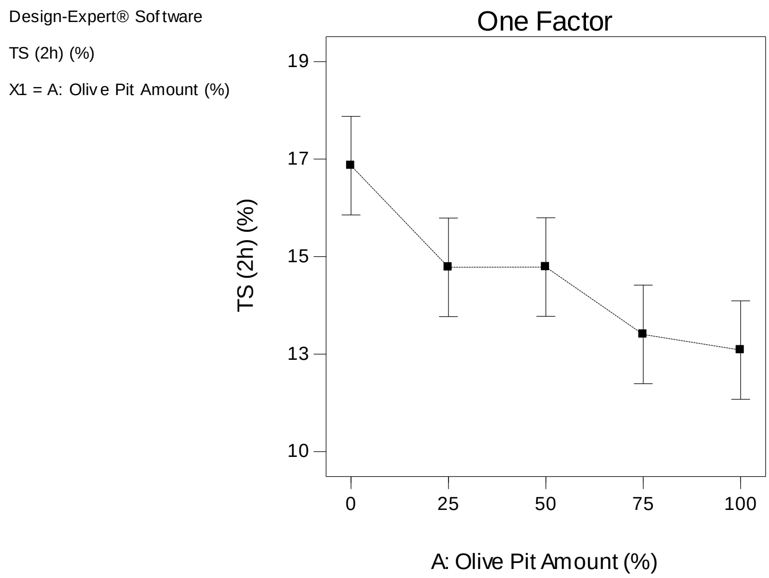


**Figure 3.** Interaction graph of thickness swelling properties for 2 hours

When testing physical properties such as thickness swelling and water absorption, particleboards typically begin absorbing water from their weakest point, the core layer. Due to their oily nature, OP residues in the core layer exhibited water-repellent characteristics, leading to reduced thickness swelling values. In contrast, wood particles, which have a more fibrous structure and abundant hydroxyl groups, readily bonded with water and absorbed it more easily. Unlike wood particles, olive pits lack these branched structures and have a dense and compact composition which likely contributed to their lower water absorption capacity. Additionally, previous studies have reported that OP waste contains a high concentration of phenolic compounds (Erbil et al., 2012; Nemli et al., 2023) which are known to act as water-repellent chemicals (Cameron and Pizzi, 1986; Baharoğlu et al., 2013). Furthermore, Nasser (2012) noted in his study that the oil compounds present in wood structures form a thin protective layer against water enhancing its moisture resistance. This explains the improvement of boards' thickness swelling properties as the amount of OP wastes increased. The oils within the olive pits further inhibited water penetration into the chips, thereby enhancing the thickness swelling properties. Boards containing 75% and 100% OP wastes demonstrated the best performance in this regard. While the control group failed to meet the maximum thickness swelling requirement of 15% specified for P2 particleboards, all boards containing OP wastes met the standard. The best result was achieved in the OP100 group, which used 100% OP wastes in the core layer, with a thickness swelling value of 12.57%.

The interaction graph in Figure 4 illustrates the effects of OP wastes on the 24-hour thickness swelling properties of the boards. The graph indicates that the boards containing OP wastes performed better thickness swelling than the control group. However, statistical analysis revealed that the ratio of OP wastes had no significant effect on the 24-hour thickness swelling properties (P = 0.6940).

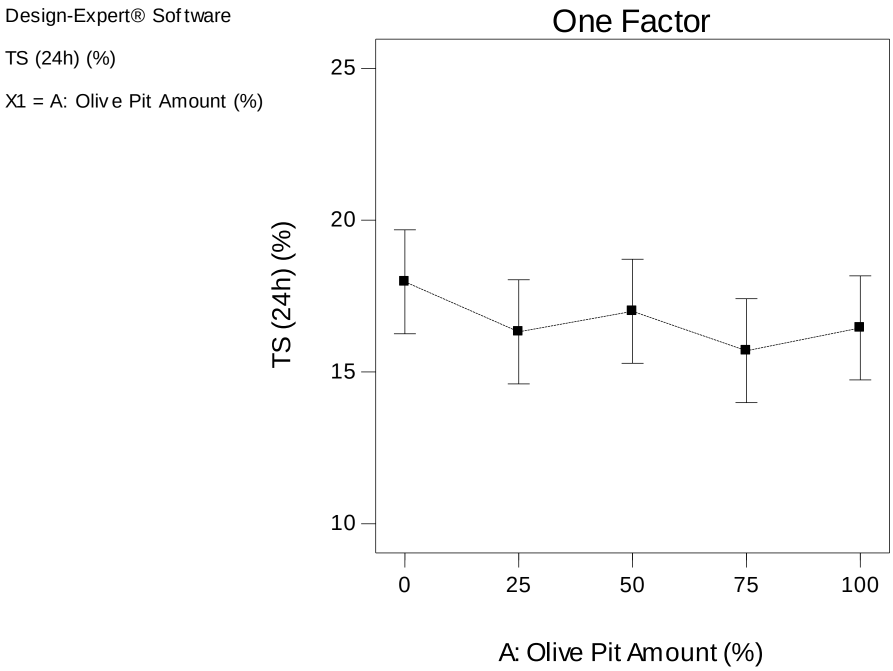


**Figure 4.** Interaction graph of thickness swelling properties for 24 hours

Although the usage of OP wastes in the core layer reduced the thickness swelling values, the amount of wastes used did not have a statistically significant impact on the 24-hour thickness swelling performance of the boards. Among all groups, the best 24-hour thickness swelling result was observed in the OP75 group where 75% OP wastes were used in the core layer. The thickness swelling value for this group was found to be 15.80%, slightly exceeding the maximum standard requirement of 15% by a margin of 0.80%. Despite this slight deviation, the result is close to the standard and reflects an improvement compared to the control group.

Figures 5 and 6 present the interaction graphs for the water absorption properties of the produced particleboards after 2 hours and 24 hours, respectively. The interaction graph in Figure 4 shows a slight decreasing trend in water absorption values with increasing amounts of OP wastes. However, the standard deviations of the groups indicate that the average water absorption values are within similar ranges. ANOVA analysis revealed that the amount of OP wastes had no statistically significant effect on the 2-hour water absorption properties of the boards ($P = 0.4264$). The boards containing 50% and 100% OP wastes exhibited the lowest water absorption rates. Water absorption increased rapidly during the 2-hour test but the water absorption rate began to slow as the 24-hour test approached completion. This slowdown is attributed to the voids within the boards becoming nearly saturated with water, after this point suggesting that additional water was absorbed primarily by the wood particles. The maximum allowable value specified in the standard for water absorption is 80%. All groups except the control group met this requirement. The best 2-hour water absorption performance was achieved by the OP100 group with a water absorption rate of 69.8%.

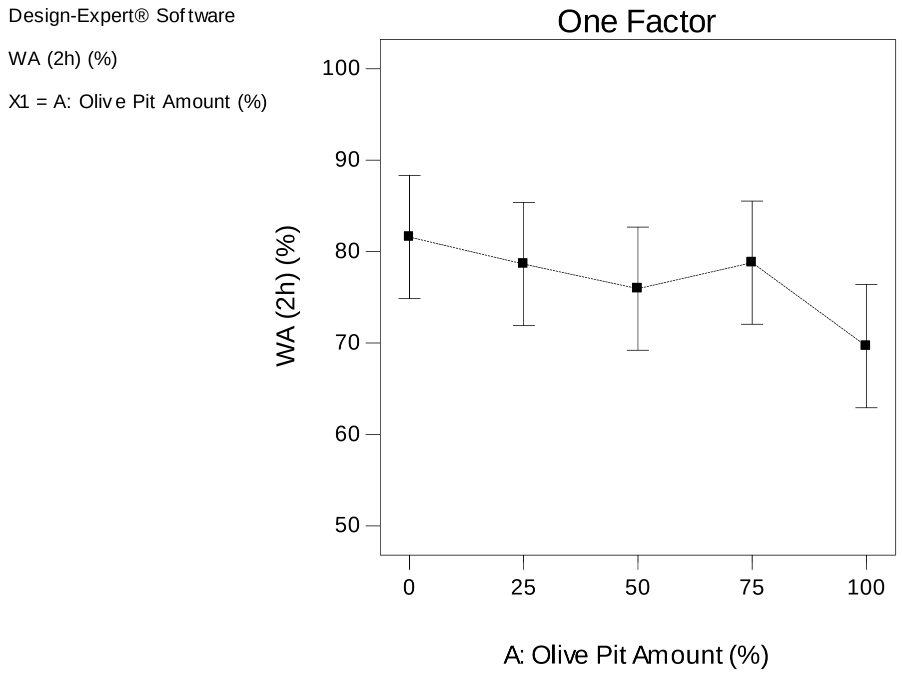


**Figure 5.** Interaction graph of water absorption properties for 2 hours

An analysis of the 24-hour water absorption properties of the particleboards revealed that the amount of OP wastes had no statistically significant effect on water absorption characteristics (P = 0.4596). As the duration of water exposure increased, the water absorption values also showed an upward trend. At the end of the 24-hour exposure period, the particleboard groups absorbed on average 8.6% more water. Among all groups, only the OP100 group demonstrated a water absorption value below the maximum allowable limit of 80%.

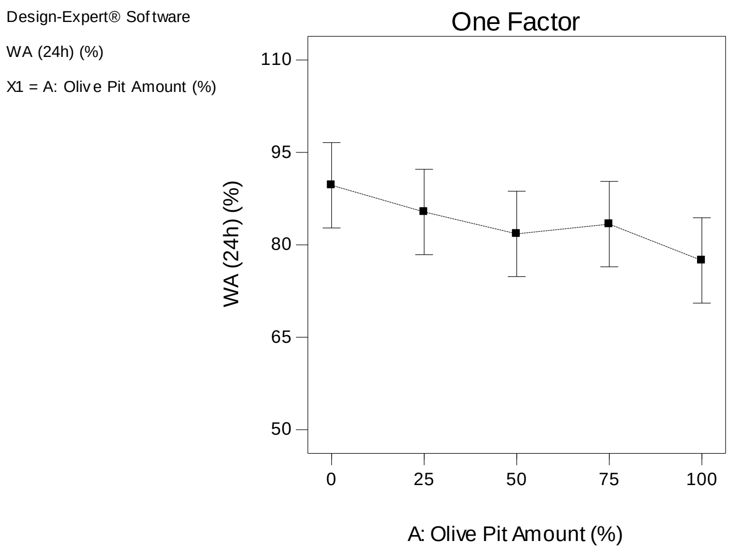


**Figure 6.** Interaction graph of water absorption properties for 24 hours

### 3.2 Results of mechanical properties

The interaction graph illustrating the effect of the amount of olive pit (OP) wastes on the internal bond (IB) strength of the particleboards is presented in Figure 7. ANOVA analysis revealed that the amount of OP wastes used in the core layer significantly influenced the IB strength values of the boards ($P < 0.0001$). Results comparable to the control group were obtained when OP wastes were used at a 25% ratio. However, as the amount of OP wastes continued to increase, a notable decrease in IB strength values was observed. This reduction is thought to result from the oils in OP wastes acting as a paraffin-like substance, adversely affecting adhesion strength. In the particleboard industry, paraffin and similar water-repellent chemicals coat the surface of particles hindering adhesive bonding. Excessive usage of such chemicals weakens the IB strength of the panels (Başboğa et al., 2024). A higher adhesive application is required to overcome this issue (Bozkurt and Göker, 1985; Baharoğlu et al., 2014). Weak bonding in the core layer ultimately leads to lower IB strength values.

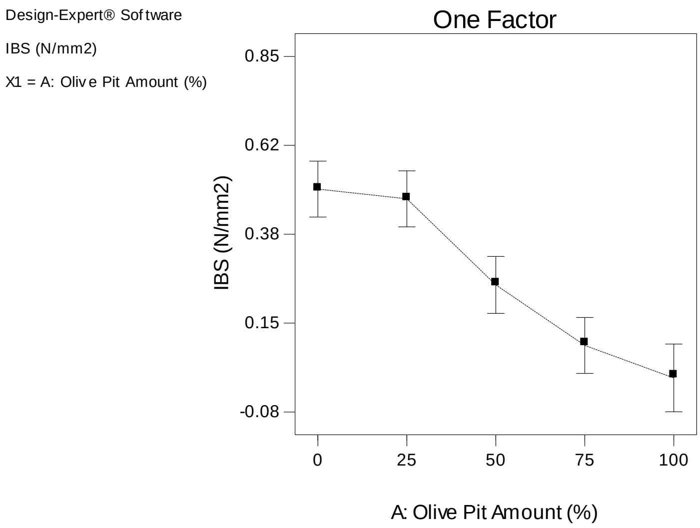


**Figure 7.** Interaction graph of internal bond strength properties

Furthermore, it is believed that increasing the proportion of olive pit (OP) waste, which possesses a coarser and harder texture compared to the long and soft fibers of core layer wood chips, leads to a more porous structure within the panels. This increased porosity is thought to contribute to the reduction in mechanical properties. Similar findings have been reported in the literature (Aras et al., 2022). Additionally, Cosereanu et al. (2015) stated that particles with a long and slender geometry and uniform structure tend to provide better bonding and a more homogeneous composition. Hashim et al. (2010) also emphasized that chip geometry significantly influences bending strength and internal bond strength. The sharp and coarse geometry of OP waste might have negatively affected the internal bond strength values. Observations in this study are consistent with findings reported in the literature (Nemli et al., 2023).

Among the produced board groups, the highest IB strength values were recorded in the control group and the group containing 25% OP wastes with values of 0.51 N/mm² and 0.48 N/mm², respectively. When the amount of OP wastes increased to 50%, the IB strength decreased by approximately 50% reaching 0.26 N/mm². After incorporating 25% OP wastes, further increases in their proportion resulted in a sharp decline in IB strength values. For particleboards manufactured for general-purpose use under the P2 classification, the standard requirement of 0.35 N/mm² for IB strength was met by the control group and the boards containing 25% OP wastes. The boards with 50% OP wastes exhibited IB strength values close to the standard threshold.

The interaction graph for the bending strength (BS) (Fig. 8) indicates that the amount of OP waste significantly influenced the BS properties of the particleboards ($P < 0.0001$). As the proportion of OP wastes in the core layer increased, the BS values of the boards showed a marked decline. This reduction is believed to be due to the oils in the olive pits, which act as a paraffin-like substance, hindering adhesion between the particles.

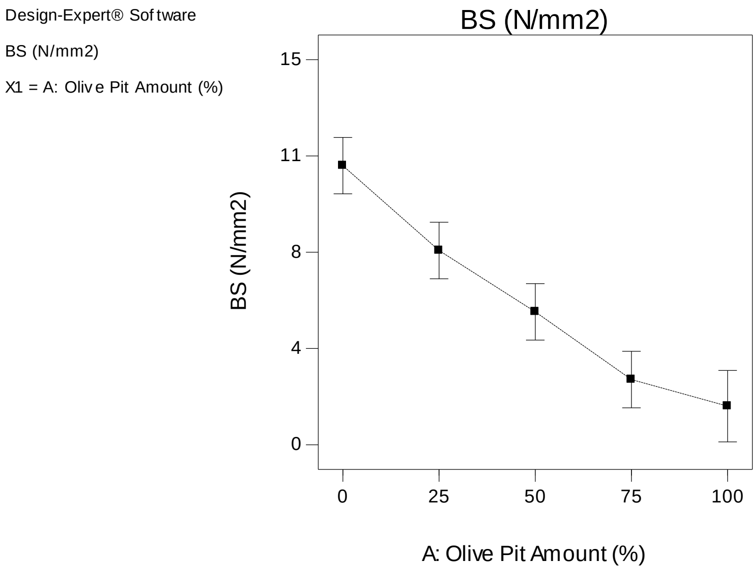


**Figure 8.** Interaction graph of bending strength properties

Additionally, the structure of wood particles allowed the dry waste MIP powder to adhere more effectively enabling a more uniform and higher-quality mat formation. However, the same performance was not achieved with olive pits which caused difficulties during mat formation. Due to their smaller particle size, the MIP powders tended to separate from the olive pits and settle into the lower layers. This segregation likely contributed significantly to the observed reduction in BS values. The highest BS value was observed in the control group boards with an average of 10.84 N/mm² while the lowest value, 1.50 N/mm², was recorded in boards where 100% OP wastes were used in the core layer. None of the produced board groups met the standard BS requirement of 11 N/mm² for P2 classification particleboards. Moreover, the control group boards exhibited BS values that were very close to the standard requirement.

The interaction graph for the modulus of elasticity (MOE) in Figure 9 shows a clear decrease in MOE values as the proportion of OP wastes in the core layer increased. It was determined that the usage ratio of OP residues affected the MOE values significantly ($P < 0.0001$). Results similar to those observed for the bending strength were noted. Among the produced boards, only the control group met the minimum MOE requirement of 1600 N/mm² specified for P2 general-purpose panels achieving a value of 1934 N/mm². The MOE value measured in boards containing 25% olive pit residue was 1420 N/mm² which is close to the standard.

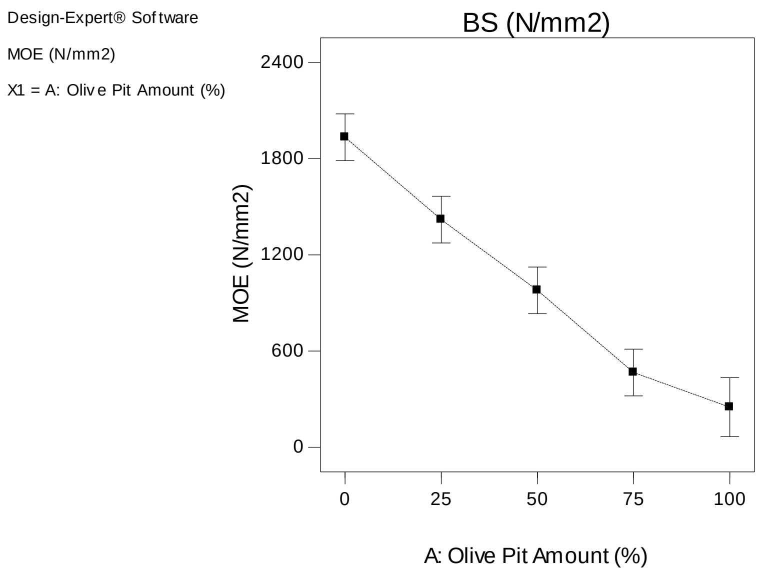


**Figure 9.** Interaction graph of MOE properties

## 4 Conclusions and Recommendations

As a result of this study, the production of particleboard groups utilizing olive pit wastes either mixed with core layer particles or used solo with melamine-impregnated paper (MIP) waste serving as an adhesive was successfully achieved. The findings of the study led to the following conclusions:

- The utilization of waste olive pits as a substitute for core layer particles positively influenced the physical properties of the produced boards while adversely affecting their mechanical strength properties.
- Increasing the ratio of waste olive pits particularly improved the thickness swelling characteristics. However, as the ratio of waste olive pits increased, a significant impact on mechanical performance was observed with all measured mechanical properties showing a noticeable decline.

In conclusion, while waste olive pits were successfully utilized alongside MIP waste in particleboard production, it is suggested that using lower proportions of olive pits could enhance the physical properties of the boards while minimizing adverse effects on their mechanical performance.

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**Author Contributions**
**İbrahim Halil Başboğa:** Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Validation, Visualization, Resources, Supervision, Writing – original draft. **Sefer Budak:** Conducting the research, Manufacturing panels, Performing the analyses, Resources, Drafting the manuscript. **Emre Karatağ**: Conducting the research, Manufacturing panels, Performing the analyses, Resources, Drafting the manuscript. **Doğan Memiş**:

Conducting the research, Manufacturing panels, Performing the analyses, Mechanical testing, Resources, Drafting the manuscript.

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**Conflict of interest**
There are no conflicts of interest among the authors.

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