Artvin Çoruh Üniversitesi
Orman Fakültesi Dergisi
ISSN:2146-1880, e-ISSN: 2146-698X
Yıl: 2026, Cilt: 27, Sayı:1, Sayfa: 24-32

ofd.artvin.edu.tr

Artvin Coruh University
Journal of Forestry Faculty
ISSN:2146-1880, e-ISSN: 2146-698X
Year: 2026, Vol: 27, Issue:1, Pages: 24-32

Evaluation of Waste Peeling Veneer Boards in Hybrid Particleboard Production

Atık Soyma Kaplama Levhalarının Hibrit Yongalevha Üretiminde Değerlendirilmesi

Eda KARA[1], Gökay NEMLİ[2] Uğur ARAS[3*]

[1]Karadeniz Technical University, Faculty of Forestry, Department of Forest Industry Engineering, Trabzon
[2]Karadenız Technıcal Unıversıty, Faculty of Forest, Department of Forest Industry Engıneerıng, Division of Wood Mechanıcs and Technology, Trabzon
[3]Karadeniz Technical University, Arsin Vocational School, Department of Forestry, Trabzon, Türkiye

Eser bilgisi/*Article Info*
Araştırma makalesi / *Research article*
DOI: 10.17474/artvinofd.1685089

*Sorumlu yazar/*Corresponding author*
Uğur ARAS
e-mail: uaras@ktu.edu.tr

Gönderilme tarihi/Submission date
27.04.2025
Kabul tarihi/Acceptance date
17.06.2025
Yayımlanma tarihi/Publication date
16.02.2026

Keywords:
Particleboard
Formaldehyde emission
Peel veneer
Physico-mechanical properties

Anahtar kelimeler:
Yongalevha
Formaldehit emisyonu
Soyma kaplama
Fiziko-mekanik özellikler

Abstract

This study examined the physical and mechanical properties, as well as the formaldehyde emission, of particleboards produced using waste-peeling veneer. The studies showed that waste veneers in particleboard production reduced formaldehyde emissions. The highest formaldehyde emission values were obtained from the control group (9.35 mg/100g), while the lowest values were obtained from the board group (7.08 mg/100g) without glue and with three perpendicular veneers. Adding veneers improved the water absorption rate and thickness swelling rate of the particleboards. The highest values of thickness swelling and water absorption were obtained from the control group (35.10% and 82.39%, respectively). The lowest thickness swelling and water absorption values were obtained from the board group, which used three perpendicular glued veneers (23.03% and 60.56%, respectively). Increasing the number of waste veneers used in particleboard production enhanced all quality properties of the particleboard. The modulus of rupture (lowest and highest values for G: 14.98 N/mm² and B: 12.61 N/mm², respectively) and modulus of elasticity (lowest and highest values for G: 1671.95 N/mm² and B: 2118.85 N/mm², respectively) values did not change significantly with the addition of veneer to the middle layer. The internal bond strength decreased with the addition of glueless veneer to the middle layer. In contrast, the application of glue to the veneers did not alter the resistance values (lowest and highest values for B: 0.239 N/mm² and F: 0.583 N/mm², respectively). The inclusion of veneers between the surface and core layers had a positive effect on quality characteristics. The results showed that using waste-peeling veneer sheets improves particleboard properties and can be used in production.

Öz

Bu çalışmada atık soyma kaplama levhaları kullanılarak üretilen yongalevhaların fiziksel, mekanik özellikleri ve formaldehit emisyonu incelenmiştir. Yapılan çalışmalarda, yongalevha üretiminde atık kaplama kullanılması formaldehit emisyonunu azaltmıştır. En yüksek formaldehit emisyonu değerleri kontrol grubundan elde edilirken (9.35 mg/100g), en düşük değerler tutkalsız ve birbirine dik üç adet kaplama kullanılan levha grubundan (7.08 mg/100g) elde edilmiştir. Yongalevhaların su alma oranı ve kalınlık artışı oranları kaplama ilavesi ile iyileşmiştir. En yüksek kalınlık artımı ve su alma değerleri kontrol grubundan elde edilmiştir (sırasıyla %35.10 ve %82.39). En düşük kalınlık artımı ve su alma değerleri ise birbirine dik üç adet tutkallı kaplama kullanılan levha grubundan elde edilmiştir (sırasıyla %23.03 ve %60.56). Yongalevha üretiminde atık kaplama sayısının artması ile yongalevhanın kalite özellikleri iyileşmiştir. Eğilme direnci (en düşük ve en yüksek değerler sırasıyla G: 14.98 N/mm2 ve B: 12.61 N/mm2) ve eğilmede elastikiyet modülü (en düşük ve en yüksek değerler sırasıyla G: 1671.95 N/mm2 ve B: 2118.85 N/mm2) değerleri sadece orta tabakaya kaplama ilavesi ile değişmemiştir. Yüzeye dik çekme direnci orta tabakaya tutkalsız kaplama ilavesi ile azalırken, kaplamalara tutkal sürülmesi ise direnç değerlerini değiştirmemiştir (en düşük ve en yüksek yüzeye dik çekme direnci değerleri sırasıyla B: 0.239 N/mm2 ve F: 0.583 N/mm2). Yüzey ve orta tabakalar arasına kaplama ilavesi kalite özelliklerini olumlu yönde etkilemiştir. Sonuçlar, atık soyma kaplama levhalarının kullanımının yongalevha özelliklerini geliştirici katkı yaptığını ve üretimde kullanabileceğini göstermiştir.

INTRODUCTION

From the last quarter of the twentieth century to the present, developments in the field of industry have led to an increase in greenhouse gas emissions because of excessive consumption of natural raw material resources and fossil fuels and, accordingly, to a gradual increase in global warming. Apart from the fact that industrialization directly causes CO_2 emissions during the production phase, the waste left behind from the raw materials used poses a major environmental problem (Pappu et al. 2007, Mikulčić et al. 2016).

While the world population is increasing day by day, the development of technology causes the limited production resources to decrease day by day and to be completely insufficient in the future. Excessive and uncontrolled use of forest resources by the forest products industry have made existing resources insufficient. Insufficiency in raw material resources causes production costs to increase. Existing resources must be evaluated economically and rationally, considering the increasing consumption of industrial products in parallel with population growth (Schneider et al. 2011, Ulusoy et al. 2016, Wassie 2020).

Wood is a renewable material that can be used for recycling and energy production. Recycling wooden materials can reduce costs by cutting down on the need for new wood materials, as well as reducing transportation and storage expenses. Wood can reduce carbon emissions and carbon footprint by reducing the energy and water used in the production process of the material. In this respect, using wood industry waste as raw materials in re-production instead of energy production becomes important (Zhong et al. 2010, Kim and Song 2014).

Particleboard is a panel product produced from wood material or lignocellulosic waste in the form of particles combined with synthetic glue and bonded together under heat and pressure. The use of particleboards is constantly increasing due to features such as utilizing industrial waste, having smooth surfaces, being coatable, improved resistance to water and moisture, possessing a homogeneous structure, having physical and mechanical properties suited to their use, being resistant to fungi and insects, and exhibiting high dimensional stability (Yel et al. 2014, Ulker and Hiziroglu 2020, Onat and Kelleci 2022). Another reason for this increase could be that furniture used to have a longer lifespan, whereas today, the lifespan of furniture and interior design materials has become increasingly shorter.

In the production of peeling veneers, which are obtained by peeling wood with peeling machines, the wood material is softened by placing it in hot water and steam chambers. It is obtained by peeling the log that is then connected between the points of the peeling machine. The peeling process is carried out until the diameter remains 8–10 cm. Very long veneer can be obtained across the width of the log. Peel veneers mainly produce plywood, LVL (Laminated Veneer Lumber) and packaging material.

Wood-based hybrid composites combine wood components of different sizes within the same plate with synthetic glues. The strength of these hybrid panels can be greater than traditional panels made of the same materials and with the same density values (Mustefaga et al. 2024).

Various studies have been conducted on hybrid wood composites, and the production of environmentally friendly composites has been aimed by using natural-based materials such as annual plants and organic wastes (Baharuddin et al. 2023, Kawalerczyk et al. 2024, Güler et al. 2024), paper and textile wastes (Hamouda et al. 2019, Konukcu and Engin 2024), waste woods (Bardak and Nemli 2018, Yang et al. 2024), and polymer-based wastes (Ayrilmis et al. 2012, Rofdi et al. 2024).

In general, the use of veneer waste in the production of wood composites is in the form of veneer particles (Aras and Yel 2023) and top surface veneers (Kelleci et al. 2023, Sun et al. 2024). This study explored the effect of using peeling veneer waste in different combinations on three-layer particle boards on their physical and mechanical properties, and formaldehyde emission values were investigated. Thus, the possibility of using waste peel veneers as additives in particleboard production has been determined.

MATERIAL AND METHOD

Material

In the production of the board, 40-year-old Coastal Pine (*Pinus pinaster* Ait.) wood and waste veneer from Common Birch (*Betula pendula* Roth.) were used to produce hybrid particleboards. Common Birch logs came to our country as imports from Ukraine. It was determined that the wood density used was 0.520 g/cm^3, and the veneer density was 0.634 g/cm^3. The veneer was peeled to a thickness of 1 mm. 65% urea-formaldehyde (UF) adhesive was used in production. The formaldehyde/urea mole ratio is 1.20. Compared to dry chip weight, the UF usage ratio is 9% in the core layer and 11% in the surface layer. A 20% solution of ammonium chloride was used as a hardener at a rate of 1% by weight of the solid adhesive.

Method

Coastal Pine (*Pinus pinaster*) wood was brought to the laboratory, and its bark was peeled. Following this, it was sawn to a thickness of 2.5 cm by the operating instructions of the rough chipping machine. A Robert Hildebrand brand, laboratory type, two-blade rough chipper, was used in the rough chipping process. Then, the particles were brought to appropriate sizes for board production in a fine chipping machine consisting of 6 hammers and 16 knives. The particles were dried to 1% moisture content in a laboratory-type dryer and classified into two sizes using a vibrating horizontal screen for the core (1.5 mm-3 mm) and face (0.5 mm-1.5 mm) layers. The sieved particles and waste birch veneers were dried in a laboratory-type drying oven at 100 °C to 3% moisture. A forming frame of 500 mm × 525 mm x 12 mm thick wedges was used to prepare the board draft. The shelling ratio (surface: core) was 40:60%. The target density of the boards was determined as 0.65 g/cm^3. The sheet blanks were pressed on a laboratory-type, electrically heated, single-layer hydraulic press with a sheet size of 70 cm×89 cm. The boards were hot pressed at 150 °C. The time and pressure of pressing in this experiment were 6 minutes and 25 kg/cm^2, respectively. The pressed boards were kept in the air conditioning room with a temperature of 20 °C and 65% humidity for four weeks. Samples of the produced and the experimental design of the particleboards are given in Figure 1 and Table 1, respectively.



Figure 1. Samples of the produced particleboards

The relevant standards conducted the physical and mechanical properties of the test samples. The measurements of density (D), moisture content (MC), thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond strength (IB) were conducted following the EN 323 (1993), EN 322 (1993), EN 317 (1993), ASTM D1037 (2006), EN 310 (1993), and TS EN 319 (1993) standards, respectively. Additionally, formaldehyde emission was measured using the perforator method by ISO 12460-5 (2015).

SPSS 21 (IBM V21.0.0, New York, USA) statistical software was used to determine the effect of adhesive and veneer usage on formaldehyde emission and to verify the significance of physical and mechanical properties. In evaluating data obtained from experiments, when more than two samples and a single factor were involved, mean values were compared using a one-way analysis of variance (ANOVA). The Duncan test was used to determine whether the variables had a significant effect. If a significant effect was found, the mean values were compared using the t-test applied to the two samples for that factor.

Table 1. The experimental design of the particleboards

Board type	Use of waste veneer	Applying glue and hardener to the veneer**
A*	-	-
B	Middle of the board (1 piece)	-
C	Parallel to the fibers between the layers (2 pieces)	-
D	The fibers between the layers and in the middle of the plate are perpendicular to each other. (3 pieces)	-
E	Middle of the board (1 piece)	+
F	Parallel to the fibers between the layers (2 pieces)	+
G	The fibers between the layers and in the middle of the plate are perpendicular to each other (3 pieces)	+

*: Control board, **: UF adhesive 150 g/m^2, hardener; 1% ammonium chloride by weight of the solid adhesive

RESULT AND DISCUSSION

Physical Properties

The density values of the boards were found to be between 0.648 - 0.655 g/cm^3. The values obtained were found to be close to the target density. It was observed that these changes were following the tolerance (± 10%) specified in the EN 312 (2010) standard. The moisture values of the boards were found to be between 9.68% - 9.84%. According to the D and MC analysis results, there was no significant difference in the density and moisture content of the samples. The average TS and WA values of the test boards and their homogeneity group distributions are given in Figures 2 and 3.

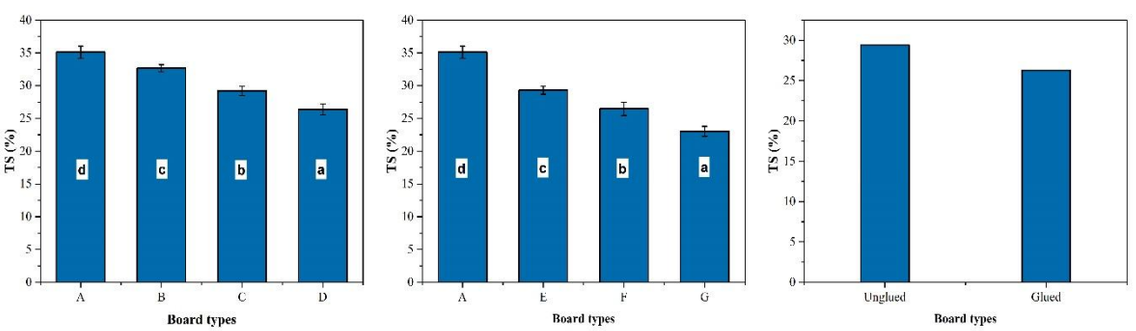


Figure 2. Effect of waste veneers on the thickness swelling values of the boards

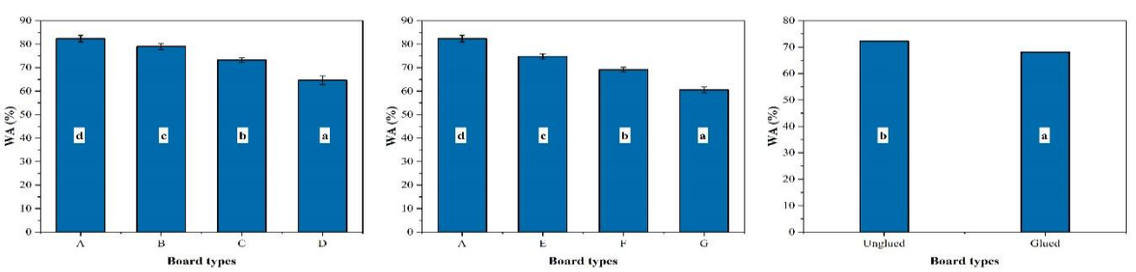


Figure 3. Effect of waste veneers on the water absorption values of the boards

As a result of the TS and WA tests, it was determined that the effect of the use of glueless veneer on the thickness swelling and water absorption rate was statistically significant ($p<0.001$). The highest TS and WA values were obtained in samples from test boards produced by the control group (A), with 35.1% and 82.39%, respectively. The lowest TS and WA values, 26.38% and 64.62%, were obtained from the boards produced using three glueless veneers, respectively (D). The TS and WA ratio decreases with the use of glueless veneers. In other words, as the number of veneers used increases, the TS and WA decreases. The decrease in TS and WA values shows that water diffusion decreases.

The increase in the number of veneers used on board may have caused the veneer with a higher density to have an inhibitory effect on water diffusion. In the production of the boards, the veneer thickness was reduced from the board thickness in the dosage. Using veneer reduced the particle ratio and the glue in the board. Therefore, the board's internal void ratio decreased, and the water absorption rate declined. The veneers used have higher specific gravity than the particle and, thus, have a tighter structure. For this reason, as the number of veneers used on the board increased, the TS and WA ratio in the samples taken from the test boards decreased (Nemli et al. 2006, Choupani Chaydarreh et al. 2022). In addition, the reduction of the total surface area with the use of veneers may also have increased the dimensional stability.

It was determined that the gluing veneer was statistically significant on the TS and WA values ($p<0,001$). The highest TS and WA values were obtained from the samples taken from the test boards produced by the control group (A). The lowest TS and WA values were obtained from the board group (G) using three veneers, with 23.03% and 60.56%, respectively. The TS and WA values decrease with gluing veneers. This is because the glue applied to both sides of the veneer fills the gaps in the board and the veneers (Nemli et al. 2002). Gluing also statistically significantly affected the TS and WA ratio ($p<0.001$). Increasing the glue usage rate in the boards positively affects dimensional stability (Medved et al. 2011).

Mechanical Properties

The average MOR and MOE values of the test boards and their homogeneity group distributions are given in Figures 4 and 5. As a result of the study, it was determined that the effect of glueless veneer on ED and EEM values was significant. In the boards using glueless veneer, the highest MOR values of 14.04 MPa were obtained in the boards produced using three veneers (D) ($p<0.001$). No statistically significant difference was found between the MOR values of the other board groups. The highest MOE values were obtained in boards (C and D) produced using three glueless veneers. Since the bending properties are more related to the surface layers of the board, the veneers used in the middle layer had little effect on the bending strength values.

It was found that glued veneers significantly affected the bending strength ($p<0.001$). Among the board groups produced using glue, the highest MOR values (14.80 MPa and 14.98 MPa) and MOE values (2084 MPa and 2119 MPa) were obtained from boards with three veneers (Groups F and G). This may be because the veneer with high density becomes a denser material with glue when the glue is placed between the outer layers of the boards, and the veneer conducts more heat due to the steam process (Bardak et al. 2010, Baharoglu et al. 2012). It was determined that the boards' MOR and MOE values increased with glue ($p<0.001$). Studies show that the mechanical properties of the particleboard improve with the increase in the amount of glue (Wronka and Kowaluk 2022, Gisip et al. 2022).

In the EN 312 (2010) standard, the minimum MOR and MOE values of the (P2) boards for furniture to be used indoors are given as 13 MPa and 1800 MPa. Values by the standard were obtained in the panel groups using three veneers. The other board groups meet the (P1) board standards for general use (12.5 MPa).

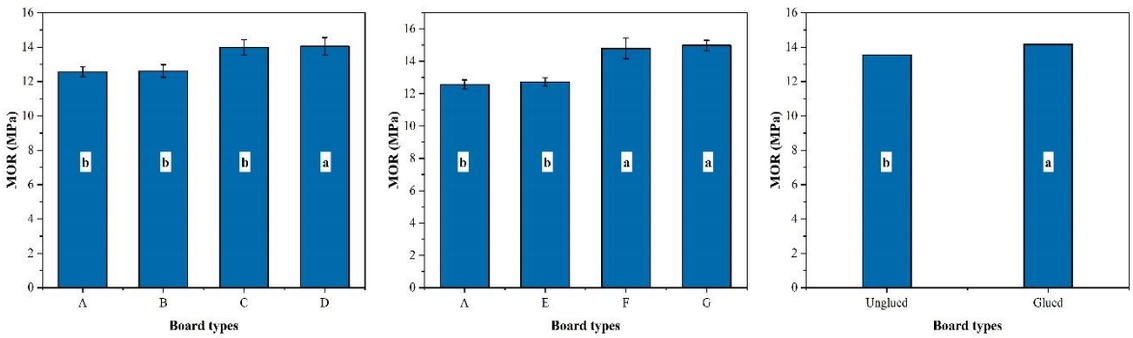


Figure 4. Effect of waste veneers on the modulus of rupture values of the boards

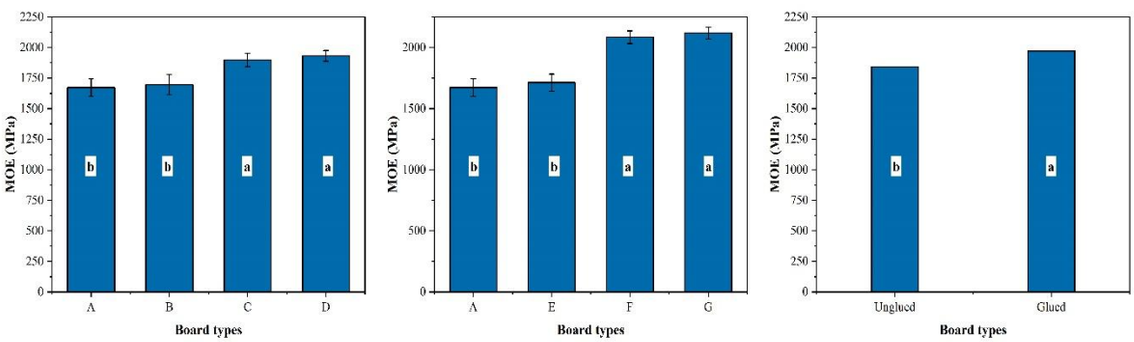


Figure 5. Effect of waste veneers on the modulus of elasticity values of the boards

The average IB values of the test boards and their homogeneity group distributions are given in Figure 6. It was determined that glueless veneer significantly affected IB values ($p<0.001$). The highest IB value of 0.445 MPa was obtained from the board group with one veneer parallel to the fibers between the surfaces (C). The IB value is related to the middle layer of the board. Therefore, when examining the results of boards with veneer placed in the middle layer, the veneer placed in the middle of the board has reduced the IB values. Since their density, chemical structure, pH, and anatomical structures are different, it is more difficult for these materials to stick together. The IB values have decreased due to insufficient adhesion. It reached the highest value in Group C due to the absence of veneer in the middle layer. In addition, the denser surface layer accelerated heat conduction and transfer, causing the middle layer to remain longer under the same pressing conditions. As a result, the IB values increased slightly (Baharoglu et al. 2013, Silva et al. 2019, Choupani Chaydarreh et al. 2023).

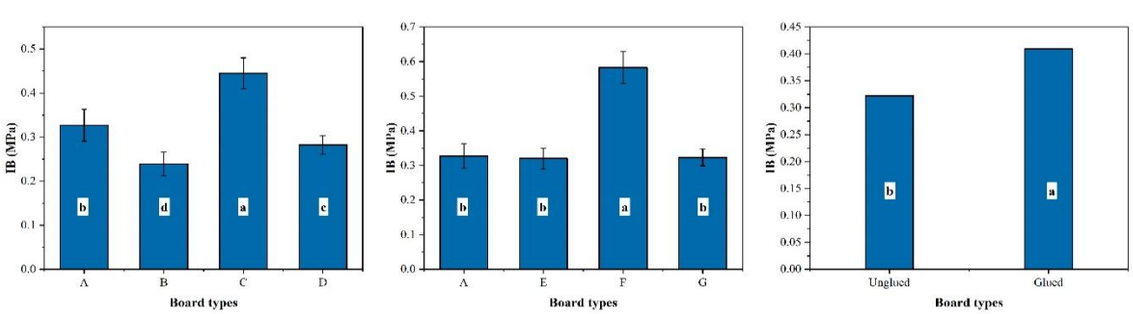


Figure 6.Effect of waste veneers on the internal bond strength values of the boards

The glued veneer also affected IB values ($p<0.001$). The highest values of 0.583 MPa were obtained from the board group with one veneer parallel to the fibers between the surfaces (F). There was no statistically significant difference between the other groups. The gluing process influenced the IB values of the surface ($p<0.001$). Applying glue to the veneers ensured that the veneer and the particle adhered better, resulting in a tighter and denser board. Studies using glue have shown that the mechanical properties of particleboard increase with increasing glue amount (Rahman et al. 2019, Baharuddin et al. 2023). Group C and F boards meet the minimum IB values of (P2) boards for furniture used in interior spaces specified in EN 312 (2010) standard (0.4 MPa). Other board groups meet the (P1) board standards for general use (0.28 MPa).

Formaldehyde Emission

The average FE values of the test boards and their homogeneity group distributions are given in Figure 7. It was determined that the use of glueless veneer significantly affected FE. The highest FE values were obtained from the Group A control board (9.35 mg/100g). The lowest values were obtained from the Group D board group using three veneers (7.03 mg/100g). As the number of veneers used on the boards increased, FE values decreased. The veneer thickness was subtracted from the board thickness while dosing, causing the surface and middle layer particles to decrease. Since the middle layer and surface layer particles decreased, the amount of glue used decreased. Therefore, as the number of veneers increased, emissions decreased. In addition, FE values decreased due to the tight structure formed within the board (Baharoğlu et al. 2012).

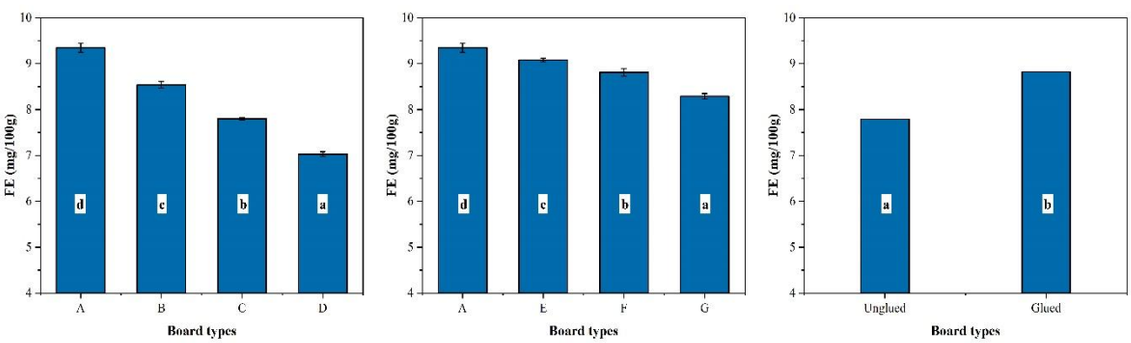


Figure 7. Effect of waste veneers on the formaldehyde emission values of the boards

The effect of glued veneer on FE values was significant ($p<0.001$). Lower emission values were also obtained in the board groups using glue compared to the control group. The lowest values were found in group G using three coatings (8.29 mg/100g). It has been determined that FE values decrease as the number of glued veneers on the board increases. This is because the veneer thickness is subtracted from the board thickness when dosing. Although glue is applied to both veneer surfaces, the amount of glue also decreases with the decrease of surface and middle layer particles. Therefore, as the number of veneers increases, the FE values of the board with a tight structure decrease.

It has been determined that gluing significantly affects FE values due to the formaldehyde content in the glue applied to the coatings. Increasing glue in particleboard production generally increases emission values (Saito et al. 2021, Yang et al. 2024).

CONCLUSION

The results indicated that the dimensional stability increased with the increase in the number of waste peeling veneers used in the board and the glue application to these veneers. In parallel, the modulus of rupture and modulus of elasticity values also increased with the veneer placed between the board's surfaces and the glue application to these veneers. Since the internal bond strength values are related to the middle layer, a decrease in the values was observed with the

glue-free veneer right in the middle, and an increase in the values was observed with the application of glue to the veneer placed right in the middle. A decrease was observed in the formaldehyde emission values as the number of veneers used on board increased. Still, formaldehyde emissions increased slightly compared to glue-free veneers with the application of glue to the veneer.

When the calculation is made by subtracting the coating thickness in the dosage using veneer in particleboard production, there is a decrease in the amount of glue. This means that we produce environmentally friendly material. In the study conducted, glue and particle savings were achieved using veneer, and the mechanical and physical properties increased compared to the control board. In this respect, using waste peeling veneers in particleboard production will enable the production of boards with higher technological properties and be more environmentally friendly.

REFERENCES

Aras U, Yel H (2023) The effect of press parameters on the physical and mechanical properties of cement-bonded particleboards produced from veneer wastes. *Journal of Anatolian Environmental and Animal Sciences,* 8(3):300-305. https://doi.org/10.35229/jaes.1296776

ASTM D1037 (2006) Standard Test Method for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials. United States.

Ayrilmis N, Kwon JH, Han TH (2012) Improving core bond strength and dimensional stability of particleboard using polymer powder in core layer. *Composites Part B: Engineering*, 43(8): 3462-3466. https://doi.org/10.1016/j.compositesb.2012.01.039

Baharoglu M, Nemli G, Sarı B, Bardak S, Ayrılmış N (2012) The influence of moisture content of rawmaterial on the physical and mechanical properties, surface roughness, wettability and formaldehyde emission of particle board composite. *Composites Part B: Engineering*, 43(5): 2448-2451. https://doi.org/10.1016/j.compositesb.2011.10.020

Baharoğlu M, Nemli G, Sarı B, Birtürk T, Bardak S (2013) Effects of anatomical and chemical properties of wood on the quality of particleboard. *Composites: Part B, Engineering*, 52: 282–285. https://doi.org/10.1016/j.compositesb.2013.04.009

Baharuddin MN, Zain NM, Harun WSW, Roslin EN, Ghazali FA, Som SNM (2023) Development and performance of particleboard from various types of organic waste and adhesives: a review. *International Journal of Adhesion and Adhesives*, 124: 103378. https://doi.org/10.1016/j.ijadhadh.2023.103378

Bardak S, Nemli G, Sari B, Baharoglu M, Zekovic E (2010) Manufacture and properties of particleboard composite from waste sanding dusts. *High Temperature Materials and Processes*, 29(3): 159-168. https://doi.org/10.1515/HTMP.2010.29.3.159

Bardak S, Nemli G (2018) Use of screening machine wastes for manufacturing of particleboard composite. *Journal of Bartin Faculty of Forestry,* 20(1):81-86. https://doi.org/10.24011/barofd.382428

Choupani Chaydarreh K, Lin X, Guan L, Hu (2022) Interaction between particle size and mixing ratio on porosity and properties of tea oil Camellia (*Camellia oleifera* Abel.) shells-based particleboard. *Journal of Wood Science*, 68(1): 43. https://doi.org/10.1186/s10086-022-02052-3

Choupani Chaydarreh K, Li Y, Lin X, Zhang W, Hu C (2023) Heat transfer efficiency and pMDI curing behavior during hot-pressing process of tea oil Camellia (*Camellia oleifera* Abel.) shell particleboard. *Polymers,* 15(4): 959. https://doi.org/10.3390/polym15040959

EN 310 (1993) Wood-based Panels, Determination of Modulus of Elasticity in Bending and Bending Strength. European Commission for Standardization, Brussels.

EN 312 (2010) Particleboards–specifications. European Commission for Standardization, Brussels.

EN 317 (1993) Particlepanels and Fiberpanels, Determination of Swelling in Thickness after Immersion. European Commission for Standardization, Brussels.

EN 319 (1993) Particlepanels and Fiberpanels, Determination of Tensile Strength Perpendicular to the Plane of the Board. European Commission for Standardization, Brussels.

EN 322 (1993) Wood-based Panels, Determination of moisture content. European Commission for Standardization, Brussels.

EN 323 (1993) Wood-based Panels, Determination of Density. European Commission for Standardization, Brussels.

Gisip J, Asri NLAM, Anwar AIM, Najib A (2022) Effects of resin content on mechanical and physical properties of treated kenaf particleboard. *Scientific Research Journal*, 19(2): 81-96. https://doi.org/10.24191/srj.v19i2.17580

Güler C, Sarikaya A, Sertkaya AA, Canli E (2024) Almond shell particle containing particleboard mechanical and physical properties. *Construction and Building Materials,* 431: 136565. https://doi.org/10.1016/j.conbuildmat.2024.136565

Hamouda T, Hassanin AH, Saba N, Demirelli M, Kilic A, Candan Z, Jawaid M (2019) Evaluation of mechanical and physical properties of hybrid composites from food packaging and textiles wastes. *Journal of Polymers and the Environment*, 27: 489-497. https://doi.org/10.1007/s10924-019-01369-3

ISO 12460-5 (2015) Wood-based Panels-Determination of Formaldehyde Release-Part 5: Extraction Method (Called the Perforator Method). European Commission for Standardization, Brussels.

Kawalerczyk J, Dukarska D, Antov P, Stuper-Szablewska K, Dziurk D, Mirski (2024) Activated carbon from coconut shells as a modifier of urea–formaldehyde resin in particleboard production. *Applied Sciences,* 14(13): 5627. https://doi.org/10.3390/app14135627

Kelleci O, Köksal SE, Tekingündüz G (2023) Production and characterization of particle board laminated with wall-paper and wood veneer. *Journal of Bartin Faculty of Forestry,* 25(2): 211-222. https://doi.org/10.24011/barofd.1239433

Kim MH, Song HB (2014) Analysis of the global warming potential for wood waste recycling systems. *Journal of Cleaner Production,* 69: 199-207. https://doi.org/10.1016/j.jclepro.2014.01.039

Konukcu AC, Engin M (2024) Shredded waste office paper as a component with wood particles in the production of particleboard. *BioResources*, 19(3): 5935. https://doi.org/10.15376/biores.19.3.5935-5948

Medved S, Antonović A, Jambreković V (2011) Impact of resin content on swelling pressure of three layer perticleboard bonded with urea-formaldehyde adhesive. *Drvna Industrija*, 62(1): 37-42. https://doi.org/10.5552/drind.2011.1025

Mikulčić H, Klemeš JJ, Vujanović M, Urbaniec K, Duić N (2016) Reducing greenhouse gasses emissions by fostering the deployment of alternative raw materials and energy sources in the cleaner cement manufacturing process. *Journal of Cleaner Production,* 136: 119-132. https://doi.org/10.1016/j.jclepro.2016.04.145

Mustefaga EC, Sozim PCL, Bednarczuk E, Barbosa AVX, Hillig E (2024) Hybrid panels produced with particles and veneers of pine wood in different compositions. *Revista Árvore*, 48: e4825. https://doi.org/10.53661/1806-9088202448263740

Nemli G, Demirel S, Zekoviç E (2006) The influences of moisture content of the particle, paraffin usage and wood species on the some technological properties of particleboard. Artvin Forestry Faculty Journal, 7(2): 81-93.

Nemli G, Kalaycıoğlu H, Ay N, & Şahin H. (2002) Determination of suitability of Douglas-fir (*Pseudotsuga Menziesii (mirb.) franco*) species for particleboard production. *Artvin Coruh University Journal of Forestry Faculty*, 3(1): 17-23.

Onat SM, Kelleci O (2022) Effects of silane treatment on physical and mechanical properties of particleboards prepared with urea formaldehyde. *Drvna İndustrija, 73*(4): 439-444. https://doi.org/10.5552/drvind.2022.2134

Pappu A, Saxena M, Asolekar SR (2007) Solid wastes generation in India and their recycling potential in building materials. *Building and Environment*, 42(6): 2311-2320. https://doi.org/10.1016/j.buildenv.2006.04.015

Rahman WMNWA, Yatim AA, Zlan AA, Kasim J, Yunus NY (2019) Effects of the resin content and particle size on the properties of particleboard made of Neolamarckia and Leucaena particles. *BioResources,* 14(3): 6079-6087. https://doi.org/10.15376/biores.14.3.6079-6087

Rofdi MI, Tamat NSM, Nuryawan A, Sakagami H, Hermawan A (2024) Studies on particleboard production using Expanded Polystyrene (EPS) waste as a binder for construction applications. *Construction and Building Materials*, 449: 138279. https://doi.org/10.1016/j.conbuildmat.2024.138279

Saito K, Hirabayashi Y, Yamanaka S (2021) Reduction of formaldehyde emission from urea-formaldehyde resin with a small quantity of graphene oxide. *RSC Advances*, 11(52):32830-32836. https://doi.org/10.1039/D1RA06717F

Schneider UA, Havlík P, Schmid E, Valin H, Mosnier A, Obersteiner M, Fritz S (2011) Impacts of population growth, economic development, and technical change on global food production and consumption. *Agricultural Systems*, 104(2): 204-215. https://doi.org/10.1016/j.agsy.2010.11.003

Silva LCL, Lima FO, Chahud E, Christoforo AL, Lahr FAR, Favarim HR, de Campos CI (2019) Heat transfer and physical-mechanical properties analysis of particleboard produced with ZnO nanoparticles addition. *Bioresources*, 14: 9904–9915. https://doi.org/10.15376/biores.14.4.9904-9915

Sun Y, Liu Y, Wang W, Shan W, Shen T (2024) The use of wood veneer to beautify wood plastic composites*. International Journal of Adhesion and Adhesives*, 132: 103659. https://doi.org/10.1016/j.ijadhadh.2024.103659

Ulker O, Hiziroglu S (2020) Some properties of eastern red cedar (*Juniperus virginiana* l.) particleboard panels made using modified starch as binder. *Drvna Industrija*, 71(4): 371-377. https://doi.org/10.5552/drvind.2020.1947

Ulusoy H, Atılgan A, Peker H (2016) Dıscussıon of forest products industry in term of ecologıcal. *Afyon Kocatepe University Journal of Science and Engineering*, 16(1): 92-106. https://doi.org/10.5578/fmbd.16926

Wassie SB (2020) Natural resource degradation tendencies in Ethiopia: a review. *Environmental Systems Research*, 9(1): 1-29. https://doi.org/10.1186/s40068-020-00194-1

Wronka A, Kowaluk G (2022) The influence of multiple mechanical recycling of particleboards on their selected mechanical and physical properties. *Materials,* 15(23): 8487. https://doi.org/10.3390/ma15238487

Yang S, Galih NM, Kim J, Lee H, Kang S (2024) Physical and mechanical properties of particleboard mixed with waste ACQ-treated wood. *Journal of Material Cycles and Waste Management*, 26(1): 410-420. https://doi.org/10.1007/s10163-023-01837-y

Yel H, Çavdar AD, Kalaycıoglu 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.

Zhong ZW, Song B, Zaki MBM (2010) Life-cycle assessment of flash pyrolysis of wood waste. *Journal of Cleaner Production*, 18(12): 1177-1183. https://doi.org/10.1016/j.jclepro.2010.03.017