Bartın Orman Fakültesi Dergisi | Journal of Bartin Faculty of Forestry
2023, 25(2): 211–222 | DOI: 10.24011/barofd.1239433

Production and Characterization of Particle Board Laminated with Wall-paper and Wood Veneer

Orhan Kelleci[1], Süheyla Esin Köksal[2,*], Gül Tekingündüz[3]

[1,2,3] Bolu Abant Izzet Baysal University, Mudurnu Sureyya Astarci Vocational School, Department of Forestry, Bolu, Turkey

Article History
Received: 19.01.2023
Accepted: 15.05.2023
Published: 15.08.2023

Research Article

Abstract − In this study, the lamination process on the particle board (PB) surface was carried out during the board production and the possibilities of saving wood raw material, time, labor and cost by producing the board without the need for cooling, sanding and a separate lamination process were investigated. For this purpose, ready-to-use boards were obtained by covering the board surfaces with wallpaper (WP) and beech veneer (BV) with a single hot press process. The boards were obtained by placing wallpaper and beech veneer on the surface of the chipboard draft prepared in a single layer with a thickness of 16 mm and pressing. No fine wood chips were used on the surface. 1mm thickness BV and 300 gr/m^2 WP were used to cover the PB surfaces. Urea formaldehyde (UF) was treated the surface of 2 % humid wood chips (CL) according to its dry weight by 10 % and ammonium sulfate (AS) with 4 % according to solid UF. Concentration of UF and AS were 65 % and 30 % before the treated the wood chips. Particle boards were produced at 650 kg/m^3, at 190°C for 10 minute, by applying 30 kg/cm^2 pressure on PB. Density, water absorption (WA), thickness swelling (TS), modulus of rupture and elasticity (MOR and MOE), internal bond (IB), density profile and formaldehyde emission were determined according to the relevant TSE standards. According to the obtained results, IB strength of the coated PBs were lower than the control PB. But MOR and MOE strength were high then control samples due to BV and WP. Formaldehyde emissions of covered PBs were less than control samples. As a result, it was concluded that it is possible to produce the PB by pressing at the same time with coating materials. However, it is not currently suitable for furniture production due to its low IB strength, but it can be used as construction building material such as prefabricated house wall.

Keywords – *Formaldehyde emissions, particleboard, production efficiency, wood-based panel.*

Duvar Kağıdı ve Ahşap Kaplama ile Lamine Edilen Yonga Levhaların Üretimi ve Karakterizasyonu

[1,2,3] Bolu Abant İzzet Baysal Üniversitesi, Mudurnu Süreyya Astarcı Meslek Yüksekokulu, Ormancılık Bölümü, Bolu, Türkiye

Article History
Received: 19.01.2023
Accepted: 15.05.2023
Published: 15.08.2023

Research Article

Öz – Bu çalışmada yonga levha yüzeyine laminasyon işlemi levha üretimi sırasında gerçekleştirilmiş ve soğutma, zımparalama ve ayrı bir laminasyon işlemlerine ihtiyaç duyulmadan levha üretilerek odun hammaddesinden, zamandan, işçilikten ve maliyetten tasarruf sağlanma olanakları araştırılmıştır. Bu amaçla, tek sıcak pres işlemi ile levha yüzeyleri duvar kağıdı (WP) ve kayın kaplama (BV) ile kaplanmış ve kullanıma hazır levhalar elde edilmiştir. Levhalar, tek kat 16 mm kalınlığında hazırlanan yonga levha taslağının yüzeyine duvar kağıdı ve kayın kaplama yerleştirilip preslenerek elde edilmiştir. Yüzeyde ince odun talaşı kullanılmamıştır. Levha yüzeylerini kaplamak için 1mm kalınlıkta kayın kaplama ve 300 gr/m^2 duvar kağıdı kullanılmıştır. Levha üretimi için % 2 rutubette talaşa (CL) tam kuru ağırlığına oranla % 10 katı üre formaldehit (UF) ve katı tutkal oranına göre % 4 katı amonyum sülfat (AS) kullanılmıştır. UF ve AS sırasıyla % 65 ve % 30 konsantrasyonda hazırlanarak yongalara basınçlı hava ile püskürtülmüştür. Levhalar 190°C'de, 10 dakika boyunca 30 kg/cm^2 basınç uygulanarak 650 kg/m^3 yoğunlukta üretilmiştir. Yoğunluk, su alma (WA), kalınlığına şişme (TS), eğilme direnci ve elastikiyet modülü (MOR ve MOE), yüzeye dik yapışma direnci (IB), yoğunluk profili ve formaldehit emisyonu ilgili TSE standartlarına göre belirlenmiştir. Elde edilen sonuçlara göre, kaplanmış yonga levhaların yüzeye dik yapışma dirençleri kontrol örneklerinden daha düşük bulunmuştur. Ancak levhaların kayın kaplama ve duvar kağıtları ile kaplanması, eğilme direnci ve elastikiyet modülünün kontrol örneklerinden daha yüksek olmasına sebep olmuştur. Ayrıca kaplanmış levhalarda formaldehit emisyonlarının kontrol örneklerinden daha az olduğu tespit edilmiştir. Yapılan çalışma ile yonga levhaların kaplama malzemeleri ile aynı anda preslenerek üretilmesinin mümkün olduğu sonucuna varılmıştır. Ancak iç yapışma direncinin düşük olması sebebiyle kaplamalı olarak üretilen levhalar mobilya üretimine uygun görülmemekle birlikte bu levhalar prefabrik ev duvarı gibi inşaat yapı malzemesi üretiminde değerlendirilebilecektir.

Keywords – *Formaldehit emisyonu, yonga levha, üretim verimliliği, ahşap esaslı panel.*

[1] orhankelleci@ibu.edu.tr
[2] esinkoksal@ibu.edu.tr
[3] gulakbulut@ibu.edu.tr
*Corresponding Author

1. Introduction

The consumption of forest products is increasing due to the rapid population growth in the world, and the existing wood raw material cannot meet the needs of the industry. The efficient use of wood material or its protection by various methods (impregnation, heat treatment, acetylation, etc.) also means the preservation of forest assets. As a result, it is necessary to evaluate wood in the most economical way and to ensure its rational use (Kalaycıoğlu, 1997). Wood composite boards such as particle board (PB) and medium density fiberboard (MDF) have been produced in order to ensure maximum efficiency from wood raw materials. Wood-based board products have an important place in the forest products industry. PB and MDF are heavily preferred in many areas due to their properties. These can be listed as follows. They have a smooth surface, can be produced in the desired thickness, have a relatively homogeneous structure, can be combined with nails, screws and glues, can be produced in large sizes, and top surface treatments can be applied (İstek et al., 2017). In addition, other advantages are that they can be produced resistant to biotic and abiotic pests and fire, they can be easily processed, there are no defects such as knots, rot and fiber curl seen in solid wood materials, and they are relatively cheap (Eroğlu & Usta, 2000; Istek et al., 2010).

PBs are generally used in the furniture industry and therefore surfaces of the boards are coated various colors and patterns. Thus, PBs' surfaces must be smooth, hard, and durable so that they can be coated and laminated. For this reason, PBs consist of a high-density (900-1000 kg/m^3) bottom and top layer (SL) and a lower-density (500-550 kg/m^3) core layer (CL). SL layers consist of fine wood particles than CL. As the material size decreased, its surface area was increase. Thus, more area occur where they must be glued. It means that more glue and more cost.

PB's surfaces can be covered with laminates, phenolic kraft papers, polyvinyl acetate-based decorative papers, polyvinyl chloride-based papers, various resin-impregnated papers, ammonium sulfamate-impregnated papers, and thin papers. In addition, surface coating materials such as foils, hot transfer films, wood veneer sheets, lacquer paint and pattern printing can be also used (İstek et al., 2017; Kara et al., 2014; Muğla et al., 2014). Also, PBs were covered to suppress the absorption of water and moisture and to eliminate the release of formaldehyde (Vansteenkiste, 1981). The performance of coated board depends on the quality of the board and the type of coating material (Hoag, 1993; Sparkes, 1993). Conventionally PB boards production process were summarized below.

1. Board (PB or MDF) is produced,

2. Boards are conditioned at room temperature for 2 days,

3. The boards surface are sanded for smoothness and thickness calibration,

4. The boards surface are covered with the desired coating material,

5. The covered boards are laminated by hot press (Istek et al., 2010).

There has not been much research on the physical and mechanical properties of particle boards coated with different surface coating materials. Some studies are as follows. Dziurka and Doniesienia (2013) produced lightweight boards from wood and rape straw particles at a single cycle hot. It was reported that rape straw particles can be used in the production of lightweight particle boards and are a good alternative to wood chips. Particleboards made from rape straw coated with beech veneer to strengthen the sub-surface layers during the pressing process have better properties than the corresponding woodchip-based particleboards. Also, these PBs provided the necessary IB strength (0.35 MPa) according to particleboards (MOR 11 N/mm^2, MOE 1600 N/mm^2, EN 312). Rowell et al. (1989) examined the dimensional stability, decay resistance and mechanical properties of veneer coated low density PB made of acetylated wood and reported that acetylated PBs showed excellent dimensional stability in both liquid water and moisture tests and an 8-week soil block. In the test, they were resistant to attack by *Tyromyces palustris* and *Trametes versicolor*. In a study on increasing the bond strength between wood composites and wood veneers, it was reported that wood veneers provide better adhesion strength when maleic anhydride polyethylene (MAPE) film is used. Atar (1994) revealed that unstable furniture shelves also show little bending under constant loads when solid wood veneer is adhered to the edges and surfaces of fiberboards and particleboards. In a study by Akkılıç (2004), finish foil (0.32 mm thick, decoratively printed, resin-impregnated special paper), laminate (0.7 mm thick HPL) and Oak veneer (Quercus petrea. 0.6 mm thick) were used as surface coating materials and it was reported that physical and mechanical properties of particle board (PB) coated with different surface materials have improved depending on the surface coating material. Badila (2014) studied about powder coating of veneered particle board surfaces by hot pressing and reported that optimum results are obtained for all six coating types with a single coat and a coating thickness of around 100-140 µm. Budakçı (2010) studied to determine the adhesion strength of Scots pine (*Pinus sylvestris* L.), Sessile oak (*Quercus petraea* L.), Eafstern beech (*Fagus orientalis* L.) wood veneer and synthetic resin panel (laminate) on 18 mm particle board, medium density fiberboard (MDF) and ply-wood material in different amounts (100, 150, 200 g/m^2) which were stuck with Polyvinyl acetate (PVAc), Urea-formaldehyde (UF) and contact (rubber based) adhesives. The highest adhesion strength was observed on laminate on which adhesive was applied with 200 g/m^2 PVAc adhesive on plywood, the lowest adhesion strength was observed on particle board which was stuck with 200 g/m^2 contact adhesive on Eastern beech veneer. In a study, radial and tangential veneers made of pine, beech and oak were adhered to particleboard, MDF, oriented particleboard (OSB) surfaces with polyvinyl acetate (PVA) and UF glue. The highest adhesion strength was obtained from radially oriented coatings. The adhesion resistance of tangential wood coatings to the boards was low (Kılıç, 2006). In another study Göker et al. (1984) reported that when the surfaces of 16, 19 and 25 mm thick ocal type particle boards are covered with wood veneer, their strength properties increase. Nemli ve Çolakoğlu (2005) studied about the influence of lamination technique on the properties of particleboard and reported that the coating of particleboard surfaces decreased the formaldehyde emission and veneer coating was more effective than melamine paper on the thickness swelling, bending strength, and modulus of elasticity properties of the PB. In these studies, initially PB or MDF were produced then surface of boards were coated or laminated by a hot press exclude Dziurka and Doniesienia (2013) and Rowell (1989). These two studies are similar with our study in term of PB production method which is single cycle that is PB production, and its lamination stages were made same hot press at once. But, these two studies were studied about dimensional stability, decay resistance, low-density and alternative raw material to wood such as straw rape.

This study focuses on two problems. First, to reduce the amount of wood in the PB. Second, to make laminating the PB top surface easier and cost-effective. The aim of the study is to produce single layer finished PB by veneered with BV and WP. In this way, to ensure to produce the PB by less wood raw material. Also, to produce the finished board by BV and WP at heat press at once. In this way, the boards will not need to be cooled, sanded and pressed in a separate hot press, thus saving time, money and labor.

2. Materials and Methods

Materials

Wood chips (CL), urea formaldehyde (UF) and ammonium sulfate (AS) used in the study were supplied from Yıldız Entegre Bolu firm. CL moisture ratio was calculated as 2 % before gluing and 13 % after gluing according to Equation 1. CL sieve analysis results are given in Table 1 and some physical properties of AS and UF are given in Table 2. Samples thickness swelling and water absorbtion quantity were calculated according to equation 2 and equation 3 respevtivelly.

$$Moisture\ Content\ (MC)(\%) = \frac{M_h - M_0}{M_0} \times 100 \qquad (1)$$

M_h: Humid mass, M_0: Dry mass.

$$Water\ Absorption\ (\mathrm{WA})(\%) = \frac{M_i - M_\mathrm{f}}{M_\mathrm{i}} \times 100 \qquad (2)$$

M_i: Initial mass, M_f: Final mass.

$$Thickness\ Swelling\ (\mathrm{TS})(\%) = \frac{T_i - T_\mathrm{f}}{T_\mathrm{i}} \times 100 \qquad (3)$$

T_i: Initial thickness, T_f: Final thickness.

Table 1
Screened wood chip fractional analyses

Size (mm)	Weight (g)	Rate (%)
7<	536	10%
7×7	420	8%
4×4	487	9%
2×2	495	10%
1×1	482	9%
0.8×0.8	412	8%
0.5×0.5	396	8%
0.4×0.4	487	9%
0.3×0.3	433	8%
0.2×0.2	423	8%
0.1×0.1	398	8%
0.1>	221	4%
Total	5190	100%

1 m^3 partcile board cost can be calculated according to updated price of the wood, resin and ammonium sulphate. In the study, 650 kg wood, 91 kg UF resin (65 % concentaration) and 8 kg AS (30 % concentration) were used for 1 m^3 particle board production.

Table 2
Materials properties in PB

Materials	status	Solid Content (%)	Density (gr/cm^3)	pH	Viscosity (cp)
UF	solution	65	1.284	7.4	300
AS	solution	30	1.154	5.4	12

Preparations of PB

UF glue, AS hardener and CL chips were dosed at the mixing ratios given in Table 2. For each PB samples, 1700 gr CL chips at 2 % humidity were poured into a 180-liter concrete mixer. The mouth of the mixer is covered with a metal plate with a 30 mm diameter hole in the middle. UF glue solution dosed at the rates specified in Table 3 was sprayed into the mixer with an air gun at 4 bar pressure within 60 seconds. After the spraying process, the mixer continued to work for 2 minutes, and an effective mixing of the glue and chips was ensured. The glued chips were taken from the mixer and poured manually in a mold with an area of 500 x 500 mm. There is 2 mm steel sheet at the bottom of the mold. UF glue was applied to the surfaces of wood veneer by 100 g/m^2 and paper coatings with a sponge. After the adhesive coatings were placed on the PB mat, a 2 mm thick steel sheet was placed on them. The prepared PB mat was placed between the hot press heating plates. The PB mats were pressed in a hot press at 190 °C for 10 minute at were sized 400 x 400 mm and conditioned for 48 hours. The conditioned PBs were cut on a circular saw and samples (8 samples for each test) were prepared for mechanical and physical analysis. Totally 4 different PB samples were produced including control group and they were symbolized CTRL, BV, WP and BV-WP. The meanings of the sample symbols are given in Table 3.

Methods

Test samples and dimensions were prepared according to TS EN 325 (2012) and TS EN 326 (1999). After the sizing of PB by cutting of edges, the test specimens were kept at 20 ± 2 °C and 65 % ± 5 % relative humidity

(RH) for two weeks. The physical and mechanical analyzes of the test samples were determined according to the relevant standards. Density (DN; n = 8), thickness swelling (TS; n = 8), moisture (MC; n = 8), internal bond (IB, n = 8), bending (MOR; n = 8) and modulus of elasticity (MOE; n =8) were made according to TS EN 323 (1999), TS EN 317 (2005), TS EN 322 (1999), TS EN 319 (1999), TS EN 310 (1999) standards, respectively. Formaldehyde emission was determined by perforator method according to TS 4894 EN 120. Analysis results were evaluated using the SPSS statistical software program. One-way analysis of variance (ANOVA) was performed to determine statistically significant differences between samples (P <0.05). In addition, Duncan's test was used to analyze significant differences between groups.

Table 3
Materials ratios in PB.

UF/CL (w/w)	Sample Code	Produced PB and Coating Materials	CL (gr)	UF[1] (gr)	AS[2] (gr)	Produced PB
10% solid UF	CTRL	Uncoated PB samples	1700	235	20	2
	BV	Beech veneer coated PB (top and bottom sur-	1700	235	20	2
	WP	Wallpaper coated PB (top and bottom surface)	1700	235	20	2
	BV-WP	Beech veneer and wallpaper coated PB (top and	1700	235	20	2

1: 65% solid Urea-formaldehyde solution, 2: 30% solid Ammonium sulfate

3. Results and Discussion

Physical analysis results

According to the MC analysis results, it was determined that there was not a significant difference in the moisture content of the samples. It was seen at Table 4 that BV has lowest and BV-WP has highest MC value. Coating materials blocked the emission of wood-based composites (B. D. Park et al., 2016; J. Y. Park et al., 2013; Shishlov et al., 2021). It can be said that WP blocked the moisture emission of PB more efficiently than BV coating. There are significant differences between the TS values of the samples. The highest TS value is in CTRL samples. Here, it can be said that the coating materials both BV and WP reduce the water absorption of PBs. Same TS results obtained other studies. Nemli and Çolakoğlu (2005) reported that surface coating materials decreased the thickness swelling and formaldehyde emission of particleboard, significantly. Hwang et al. (2006) also reported that thickness swelling of the liquid packaging paperboard (LP) particleboards were smaller than those of the other particleboards.

The increase rates of 2-hour and 24-hour TS values of the samples are similar. There is approximately 29 % difference between the 2 hour and 24-hour TS values of the samples. Thickness swelling is an important feature for the end-uses of wooden boards. The wooden board will swell when it gets moisture, and this can cause breakage at the joining points. For this reason, it is better to cover the surfaces of PBs with coating materials that minimize moisture exchange. According to the 2-hour and 24-hour TS analysis results, it was determined that BV showed a better coating property than WP. Same result obtained by Büyüksarı (2012) and Nemli et al. (2005).

Table 4
Physical properties of PB test samples.

Samples	MC (%) Sig: 0,093***	TS (2hr) Sig: 0,000***	TS (24 hr) Sig: 0,001***	WA (2 hr) Sig: 0,000***	WA (24 hr) Sig: 0,000***	Density (kg/m^3) Sig: 0,096***
BV	3,79 A** (±0,9)*	45 A (±15)	63 A (±28)	71 A (±14)	101 A (±23)	786 A (±27)
WP	4,01 AB (±0,6)	67 BC (±10)	87 B (±11)	119 B (±11)	146 B (±14)	780 A (±23)
BV-WP	4,6 B (±0,6)	63 B (±8)	81 B (±9)	113 B (±12)	138 B (±13)	772 A (±24)
CTRL	4,4 AB (±0,2)	77 C (±2)	94 B (±2)	109 B (±4)	132 B (±5)	782 A (±3)

*Standard deviation, **Letters symbolize the Duncan analyzes groups, ***One-way Anova significant level

The water absorption (WA) values of the samples are also similar to the TS values. The best water absorption blocking properties was obtained BV sample. Similar results were obtained in other studies about wood veneer coating materials. Cahyono et al. (2020) laminated the MDF surfaces with avocado (*Persea americana*), mahogany (*Swietenia mahogani*), and pine (*Pinus merkusii*) veneers and reported that the wood veneer lamination decreased the water absorption of bord. Also, Büyüksari et al. (2012) reported that when the board were compressed, WA values for both 2-h and 24-h decreased with increasing press pressure and temperature. They explain this issue as follows, it may be related to the densification of the surface and decreasing porosity of the veneers. When wood material is alive, it likes water, but when it is used as timber, they do not like water. For this reason, an important part of the studies are on preventing the water exchange of wooden materials from ambiance. For instance, Kartal (2001) treated the PB with chromated copper arsenate (CCA) and achieved to decrease wettability, water absorption and thickness swelling of PB. Özkan et al. (2020) impregnated the wood materials by waste oil and reported that waste oil decreased the water absorption of wood materials, and it improves the physical properties of wood in terms of impregnating material. Karabulut (2022) produced fireproof, water-repellent polymeric composite particle board from peanut shells and reported that its water holding capacity was reduced from 37 percent to 20 percent with the addition of phenol formaldehyde. Also, many studies have been carried out similar to these studies (Gözalan, 2016; Güler et al., 2015; Nemli et al., 2006).

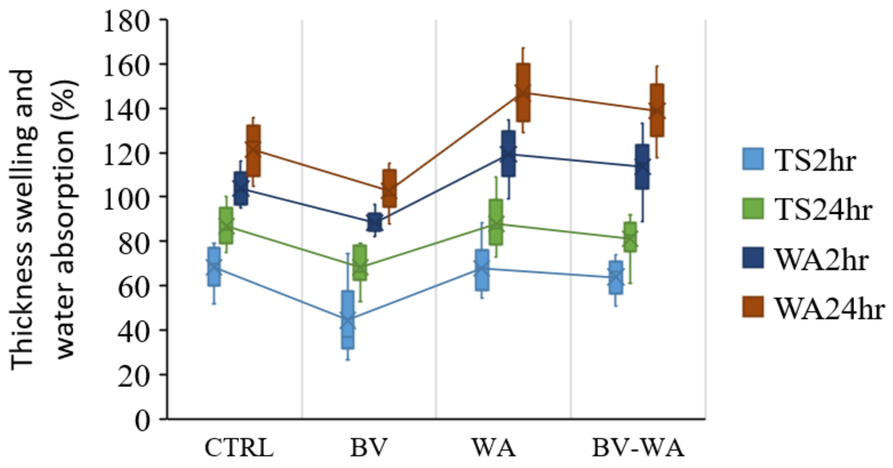

Fig. 1. Physical properties of PB: Thickness swelling (TS) and water absorption (WA).

It is seen in Fig. 1 that the analysis results of the samples show similar curves. Also, there are significant differences between the PBs densities. Both BV and WP coating materials alter the PBs densities. The density of the samples were increased by BV coating material at the highest rate (756 kg/m^3). But this is not important significant as statistically. The high densities of the PB provide high mechanical properties. In PB production, the mechanical properties of the board generally improve as the densities increase. But in this study, the differences in mechanical properties were caused by the surface coating materials.

Density profile

The top and bottom surfaces of the PB must be smooth and hard in the case of coating or laminating its surfaces. In order to achieve this purpose, the surface layers of PBs are produced more densely (900-1100 kg/m^3) than core layer (500-550 kg/m^3) (Istek et al., 2010). Therefore, finer wood chips are used in the surface layer. As the wood chips get smaller, their surface area also increases. This means more area that needs to be covered with glue (Schwarz et al., 1968). Therefore, the solid glue ratio used in the surface layer is higher than in the core layer while producing PB. This type of PB production creates a density profile as in Fig. 2d.

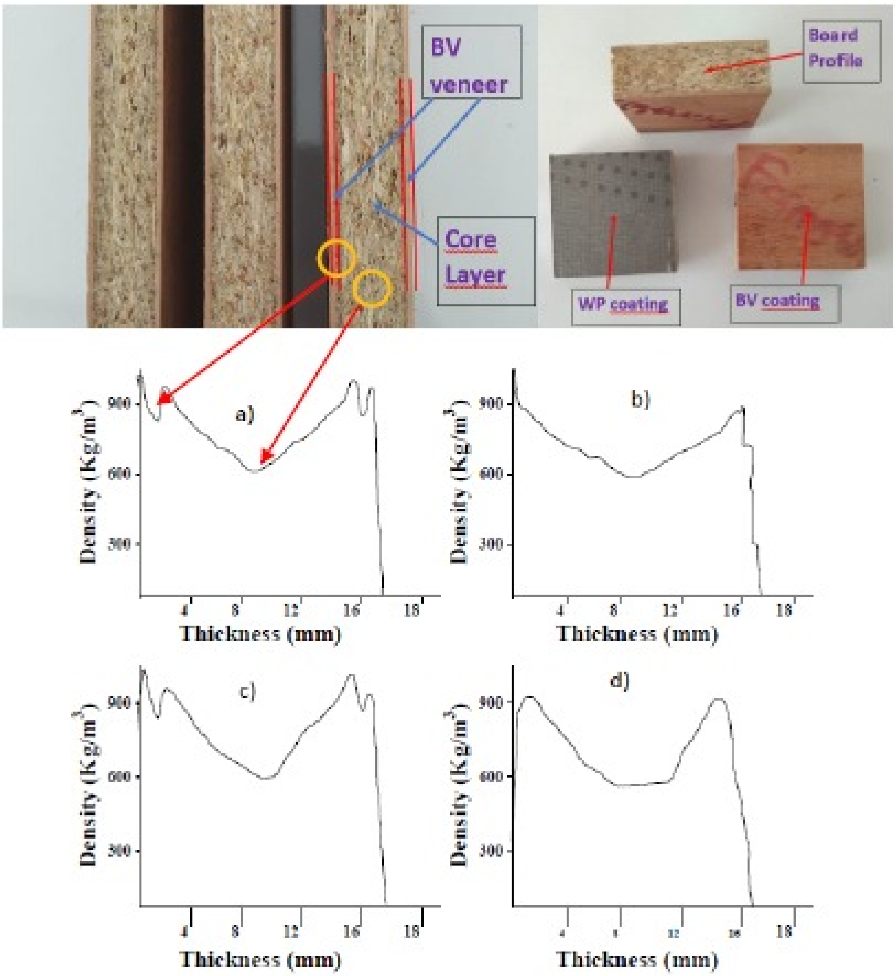

Fig. 2. Density profiles of samples, a) coated with beech veneer (BV), b) coated with wall paper (WP), c) coated with beech veneer and wall paper (BV-WP), d), uncoated PB sample.

The surface density of PB particularly affects the MOE and MOR strength. The bending strength increases as surfaces density increases (Wong et al., 1999). It was seen in Table 5 that the surface density of BV-WP higher than other samples. This caused the MOR strength to be higher than BV and WP (Table 6). All samples' central densities were nearly same because the samples were produced same CL wood particles. But surface densities were different because samples were laminated with different materials (with BV, WP and BV-WP). The surface densities of all coated samples were higher than CTRL because the coating materials increased the surface density of PB. Higher surfaces density was obtained from BV-WP. When Fig. 2a and Fig. 2c is examined, it is seen that there are sudden drops in density between the coating material and the PB. This situation is not seen in Fig. 2b and Fig. 2d. This means that there are some gaps between the coating material and the PB. In this case, the desired strong adhesion between the coating material and the PB was not achieved. However, the coating of the surface increased the bending resistances. Similar density profile curve was obtained by Dziurka and Doniesienia (2013).

Table 5
PBs' density profiles.

Samples	Surface density (kg/m^3)	Average density (kg/m^3)	Central density (kg/m^3)	From peak to peak (mm)
BV	1046	786	630	14,4
WP	1011	780	675	12,9
BV-WP	1062	772	658	13,1
CTRL	900	782	681	12.3

Mechanical analysis results

Surface coating materials increase the MOR strength of PBs (Nemli et al., 2003, 2005). In this study, the highest MOR strength was obtained from BV-WP samples. Similar results were obtained in similar studies with different surface coatings (Buyuksari, 2012; Ibrisevic et al., 2019). In general, the bending strengths of PBs increase as their density increases, but here (Table 6) the BV coated PBs have the highest densities, but the MOR strengths are low.

Table 6. Mechanical properties of PB test samples.

Samples	MOR (N/mm^2) Sig: 0,000***	MOE (N/mm^2) Sig: 0,207***	IB (N/mm^2) Sig: 0,000***
BV	12,5 B** (±2,5)*	3426 A (±796)	0,10 A (±0,07)
WP	12,6 B (±1,6)	3082 A (±340)	0,14 A (±0,03)
BV-WP	14,3 C (±1,1)	3465 A (±165)	0,10 A (±0,04)
CTRL	10,4 A (±0,7)	3244 A (±63)	0,29 B (±0,17)

*Standard deviation, **Letters symbolize the Duncan analyzes groups, ***One-way Anova significant level

UF glue was used for bonding BV and WP coating materials to PBs. UF is an adhesive that cures under the influence of temperature. The adhesion strength of UF decreases when sufficient heating does not provide. It can be said that the BV coating blocked the press heating to the PBs' inner part and therefore negatively affects the curing of the UF. This caused low MOR strength on BV coated PB although its densities were high. It was seen in fig. 3 that MOR strength range of BV was so large. It means that veneer laminations is a attention needed issue in terms of press heating and pressure. If the press temperatures, press pressure and amount of glue are not the same in each pressing, the MOR resistances can be in a wide range. In this study, the MOR resistance range was a bit too large, although it had been noted. Also, contrary to MOR strength of BV was low, the MOE strength was high. Here, it can be said that BV gives to PB more elastic properties. If BV did not hinder the thermal conductivity, it could further increase the mechanical properties.

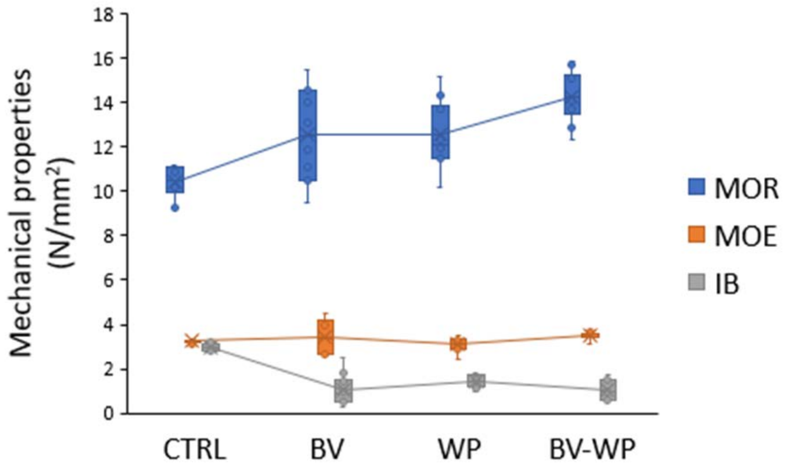

Fig. 3. Mechanical properties of PB: Modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), density.

It is seen in Fig. 3 that the analysis results show similar curves that are similar in which Fig. 2 exclude IB strength of CTRL (0,29 Mpa). Best IB strength was obtained CTRL samples. Here, it can be said that covering materials (BV and WP) negatively affect the IB strength because they hindered to heating transfer to the PB inner parts. Therefore, UF adhesive could not cure, and sufficient bonding was not carried out between the wood particles. This problem can be overcome by using thinner (0,5-1 mm) BV and WP coatings and increa-sing the press temperature (200-2005 °C). Overall, it can be said that BV, WP and BV-WP covering materials increased the MOR strength and density of PB but decreased the IB strength of PB according to analysis results. In other studies, it was reported that BV coated PBs have better performance than PBs coated with other types of coatings. The high density of BV was the main factor affecting this performance. Mechanical strength was also improved with any increased adhesive spread rate onto the particleboard substrate (Ibrisevic et al., 2019).

Formaldehyde emission

UF (65 % concentration) was used in the production of PB. The UF/wood chip solids ratio is 10 %. According to the formaldehyde emission analysis, the emissions of BV, WP and BW-WP samples are lower than CTRL. It has also been reported in different studies that coating the surfaces of PBs reduces the emission values (Kim et al., 2010; Nemli & Çolakoğlu, 2005; Ulker et al., 2021). Formaldehyde emission is harmful on human health. It has been measured that the probability of indoor pollution can be 10 times higher than outdoor pollution (Zhang and Smith, 2003). For this reason, formaldehyde quantity must be decreased from indoor furniture. Sun et al. (2016) studied about volatile organic compound (VOC) and reported that the PB released Acetic acid, Butyl ester, Benzaldehyde, Ethylbenzene, Benzyl Alcohol, Acetophenone, Tetradecan are harmful to environment. Controlling VOC emissions by the authorities is very important for the protection of adult and child health. These arrangements are also useful for controlling indoor odor problems from furniture. Recently, two board manufacturers in Europe reported that they are using high renewable content "no added-formaldehyde" (NAF) adhesives in the production of PB. A few years ago, two German factories (chipboard, MDF) used quebracho (*Schinopsis* sp.) and wattle (*Acacia* sp.) tannin-based adhesives in the production of PB (Roffael et al., 2000) Despite these developments, the main adhesives used in the European wood-based panel industry today contain formaldehyde.

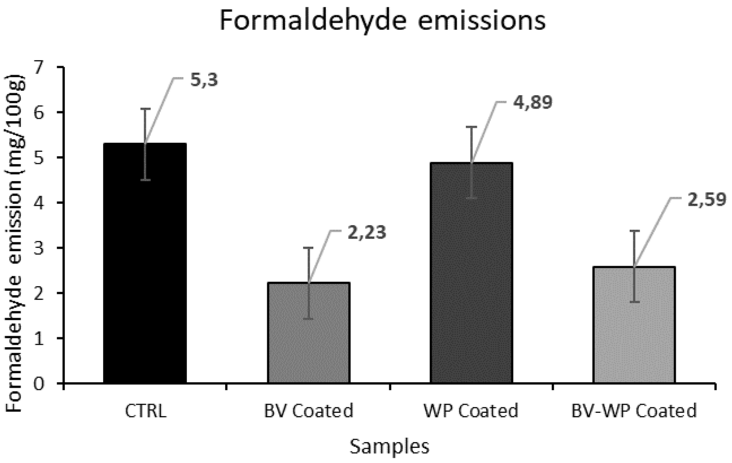

Fig. 4. PBs' formaldehyde emission results.

In this study, both PB's formaldehyde emission quantities were decreased thanks to coating it by BV, WP and BV-WP and the PB lamination method has been facilitated. Fig. 4 shows that coating the PB with BV or WP decrease the formaldehyde emissions by about 40 %. Also, it can be said that covering with BV is more effective than coating with WP.

4. Conclusions

In this study, the top and bottom surface layers of PBs were canceled and BV and WP coatings were used instead of these surfaces. Thus, it is aimed to save wood raw material by canceling the surface layer, which has a high density and constitutes approximately 30 % of the board mass. Also, un-sanded PBs cannot be laminated because of surface roughness and uncalibrated thickness in the conventional PB production. But, in this method it is possible because the PB lamination process was carried out at the time of PB production. Overall, PB lamination process can be realized with low cost thanks to this method and can be saved labor and time. Here, BV and WP were used to cover on PB mat and laminated by a heat press. Then produced PB were characterized for mechanical and physical properties. Obtained result showed that uncoated CTRL sample has best IB strength but lowest MOR. This mean is BV and WP layer hindered the heating transferring to PBs inner part. This issue caused the uncured UF adhesive in the PB core. Thus, wood particle could not be bond each other sufficiently. In mechanical properties, exclude the IB strength, MOR and MOE better than CTRL. Also, in term of physical properties WP and BV-WP better than CTRL or same. Formaldehyde emissions were decreased thanks to laminating with BV and WP (from 5,3 to 2,23 mg/100gr). BV was more effective than WP in term of decreasing emission. It can be concluded that, if the BV was used thinner (may be 0,5-1 mm) its physical properties can be better. As a result, PB laminations process can be realized on single layer PB and in this way can be saved time, labor and wood raw materials. With this method, pressure on the forest can be decreased and realized clear and environment friendly production.

Acknowledgement

This research received specific grant from Yıldız Entegre that were adhesives and wood chips used in the study.

Autor Contributions

Orhan Kelleci planned and designed the analysis.

Süheyla Esin Köksal collected and analyzed data.

Gül Tekingündüz collected and analyzed data.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

References

Akkılıç, H. (2004). Farklı yüzey malzemeleri ile kaplanan yonga levhaların teknolojik özellikleri. *İstanbul Üniversitesi Orman Fakültesi Dergisi*, 54(2), 109–126.

Atar, M. (1994). Mobilya Endüstrisinde Hareketli Ahşap Dolap Raflarının Sabit Yükler Altındaki Sehimleri (Master’s thesis). Graduate School of Natural and Applied Sciences.

Badila, M., Jocham, C., Zhang, W., Schmidt, T., Wuzella, G., Müller, U. and Kandelbauer, A. (2014). Powder coating of veneered particle board surfaces by hot pressing. *Progress in Organic Coatings*, 77(10), 1547–1553. https://doi.org/10.1016/J.PORGCOAT.2013.09.018

Budakci, M. (2010). The determınatıon of adhesıon strength of wood veneer and synthetıc resın panel (lamınate) adhesıves. *Wood Research*, 55(2), 125–136.

Buyuksari, U. (2012). Physical and mechanical properties of particleboard laminated with thermally compressed veneer. *BioResources*, 7(1), 1084–1091.

Büyüksari, Ü., Hiziroglu, S., Akkiliç, H. and Ayrilmiş, N. (2012). Mechanical and physical properties of medium density fiberboard panels laminated with thermally compressed veneer. *Composites Part B: Engineering*, 43(2), 110–114. https://doi.org/10.1016/J.COMPOSITESB.2011.11.040

Büyüksarı, Ü. (2012). Physıcal and mechanıcal propertıes of partıcleboard lamınated wıth thermally compressed veneer. *BioResources*, 7(1), 1084–1091.

Cahyono, T. D., Yanti, H., Anisah, L. N., Massijaya, M. Y. and Iswanto, A. H. (2020). Linear Expansion and Durability of a Composite Boards (MDF Laminated Using Three Selected Wood Veneers) against Drywood Termites. *Journal of the Korean Wood Science and Technology*, 48(6), 907–916. https://doi.org/10.5658/WOOD.2020.48.6.907

Dziurka, D. and Doniesienia, R. (2013). Lightweight boards from wood and rape straw particles. *Drewno. Prace Naukowe. Doniesienia. Komunikaty*, 56(190), 19–31. https://doi.org/10.12841/wood.1644-3985.051.02

Eroğlu, H. and Usta, M. (2000). *Lif levha üretim teknolojisi*, 351s, Karadeniz Teknik Üniversitesi, Orman Fakültesi, Genel Yayın No: 200, Fakülte Yayın No: 30, Trabzon. In dergipark.org.tr (2000th ed., Issue 1). Karadeniz Teknik Üniversitesi, Orman Fakültesi.

Göker, Y., Kantay, R. and Kurtoğlu, A. (1984). Researches on the technological features of three layered and okal type particleboards. In academia.edu. Istanbul University Faculty of Forestry.

Gözalan, M. (2016). Yonga levhalarda parafin kullanım miktarının optimizasyonu üzerine araştırmalar (Master’s thesis). Bartin University.

Güler, C., Karademir, A. and Işik, H. (2015). Yongalevhalarda alkil keten dimer'in alternatif hidrofobik madde olarak kullanimi ve etkisi. *Selcuk University Journal of Engineering Sciences*, 14(2), 163–170.
Hoag, M. (1993). Particleboard and medium density fibreboard: surface-testing substrates for laminating applications. *European Plastic Laminates Forum, Germany*, 33–40.
Hwang, G. S., Wang, E. I. C. and Su, Y. C. (2006). Preparation of composite board using foil-laminated and plastic-laminated liquid packaging paperboard as raw materials. *Journal of Wood Science*, 52(3), 230–235. https://doi.org/10.1007/S10086-005-0757-0/METRICS
İstek, A., Gözalan, M. and Özlüsoylu, İ. (2017). Yonga levha özelliklerine yüzey kaplama veya boyama işlemlerinin etkisi. *Kastamonu University Journal of Forestry Faculty*, 17(4), 619–629. https://doi.org/10.17475/kastorman.180279
İstek, A., Özlüsoylu, İ. and Gözalan, M. (2017). Yonga levha özelliklerine yüzey kaplama veya boyama işlemlerinin etkisi. *Kastamonu Universitesi Orman Fakültesi Dergisi*, 17(4), 619–629. https://doi.org/10.17475/kastorman.180279
Ibrisevic, A., Obucina, M. and Hajdarevic, S. (2019). Effect of Particleboard Coating on Flexual Strength and Modulus of Elasticity. *In Proceedings of the 30th International DAAAM Symposium*, 892–0896. https://doi.org/10.2507/30th.daaam.proceedings.124
Istek, A., Aydemir, D. and Aksu, S. (2010). The effect of decor paper and resin type on the physical, mechanical, and surface quality properties of particleboards coated with impregnated decor papers. *BioResources*, 5(2), 1074–1083.
Kalaycıoğlu, H. (1997). OSB Levhaları (Yönlendirilmiş Yongalevhalar). Faculty of Forestry, *Spring Term Seminar Serial*, 120–125.
Kara, M., İstek, A. and Esgin, E. (2014). The effect of lamination conditions on surface characteristics of particleboard. *3rd International Non-Wood Forest Products Symposıum*, 1031–1037.
Karabulut, A. (2022). Yer Fıstığı Kabuğundan Yanmaz, Su Tutmaz Polimerik Kompozit Yonga Levha Üretimi. *Politeknik Dergisi*, 25(2), 685–689. https://doi.org/10.2339/POLITEKNIK.845419
Kartal, S. (2001). Wettebality, water absorption and thickness swelling of particleboard made from remediated CCA-treated wood. *Journal of the Faculty of Forestry Istanbul University*, 51(1), 53–62.
Kim, K., Kim, S., Kim, H. and Park, J. (2010). Formaldehyde and TVOC emission behaviors according to finishing treatment with surface materials using 20 L chamber and FLEC. *Journal of Hazardous Materials*, 177(1-3), 90-94., 177(1–3), 90–94.
Kılıç, İ. (2006). Determining the adhesion strength of veneer on some wood-based boards (Master's thesis). Gazi Üniversity.
Muğla, K., İstek, A. and Yazıcı, H. (2014). MDF levhalarda farklı kaplamaların yüzey kalite özellikleri üzerine etkisinin belirlenmesi. *1. Ulusal Meslek Yüksekokulları Sosyal ve Teknik Bilimler Kongresi* (MESTEK), 464–469.
Nemli, G. and Çolakoğlu, G. (2005). The influence of lamination technique on the properties of particleboard. *Building and Environment*, 40(1), 83–87. https://doi.org/10.1016/J.BUILDENV.2004.05.007
Nemli, G. and Demirel, S. (2007). Relationship between the density profile and the technological properties of the particleboard composite. *Journal of Composite Materials*, 41(15), 1793–1802. https://doi.org/10.1177/0021998307069892
Nemli, G., Demirel, S. and Zekoviç, E. (2006). Yonga rutubeti, parafin kullanımı ve ağaç cinsinin yongalevhanın bazı teknolojik özellikleri üzerine etkileri. *Artvin Orman Fakültesi Dergisi*, 7(2), 81–93.
Nemli, G., Gezer, E. D. and Hiziroğlu, S. (2003). The changes in important quality properties of continuous pressed laminates (CPL) with some changes in thickness and press parameters. *Building and Environment*, 38(7), 913–917. https://doi.org/10.1016/S0360-1323(03)00030-1
Nemli, G., Örs, Y. and Kalaycioğlu, H. (2005). The choosing of suitable decorative surface coating material types for interior end use applications of particleboard. *Construction and Building Materials*, 19(4), 307–312. https://doi.org/10.1016/J.CONBUILDMAT.2004.07.015
Özkan, E., Arpaci, Ş. S. and Tomak, D. (2020). Atık yağ ile emprenye işleminin ahşap malzemenin fiziksel özelliklerine etkisi. *Ağaç ve Orman*, 1(1), 36–41.
Park, B. D., Kang, E. C., Lee, S. M. and Park, J. Y. (2016). Formaldehyde Emission of Wood-Based Composite Panels with Different Surface Lamination Materials Using Desiccator Method. *Journal of the Korean Wood Science and Technology*, 44(4), 600–606.
Park, J. Y., Lee, S. M., Park, B. D., Lim, J. Y., Jang, S. G. and Kim, S. (2013). Effect of surface laminate type on the emission of volatile organic compounds from wood-based composite panels. *Journal of Adhesion*

Science and Technology, 27(5–6), 620–631.

Roffael, E., Dix, B. and Okum, J. (2000). Use of spruce tannin as a binder in particleboards and medium density fiberboards (MDF). *Holz Als Roh-Und Werkstoff*, 58(5), 301-305.

Rowell, R., Imamura, Y., Kawai, S. and Norimoto, M. (1989). Dimensional stability, decay resistance, and mechanical properties of veneer-faced low-density particleboards made from acetylated wood. *Wood and Fiber Science*, 21(1), 67–79.

Schwarz, F. E., Andersen, R. L. and Kageler, A. G. (1968). Resin distribution and how variations affect board quality. *Proceedings of the Second Particleboard Symposium*, 7–29.

Shishlov, O. F., Baulina, N. S., Glukhikh, V. v., O. S. El'tsov, Shafran, Y. M., Buryndin, V. G. and Stoyanov, O. v. (2021). Synthesis of Cardanol-Containing Resols for Producing Phenolic Films: Protective Coatings for Wood Composites. *Polymer Science-Series D*, 14(3), 328–334.

Sparkes, T. (1993). Substrate selection for end use applications. *European Plastic Laminates Forum*, 27–31.

Sun, X., Shao, K. and Wang, T. (2016). Detection of volatile organic compounds (VOCs) from exhaled breath as noninvasive methods for cancer diagnosis. *Analytical and bioanalytical chemistry*, 408, 2759-2780.

TS 4894. Wood based panels- Determination of formaldehyde content- Extraction method called the perforator method, Turkish Standards Institute, Ankara-Turkey, 1999.

TS EN 310. Wood-based panels- Determination of modulus of elasticity in bending and of bending strength, Turkish Standards Institute, Ankara-Turkey, 1999.

TS EN 317. Particleboards and fiberboards- Determination of swelling in thickness after immersion in water, Turkish Standards Institute, Ankara-Turkey, 2005.

TS EN 319. Particleboards and fiberboards-Determination of internal bonding strength, Turkish Standards, Ankara-Turkey, 1999.

TS EN 322. Ahşap esaslı levhalar-Rutubet miktarının tayini, Turkish Standards Institute, Ankara-Turkey, 1999.

TS EN 323. Wood- Based panels- Determination of density, Turkish Standards Institute, Ankara-Turkey, 1999.

TS EN 325. Wood-based panels- Determination of dimensions of test pieces, Turkish Standards Institute, Ankara-Turkey, 2012.

TS EN 326. Wood-based panels- Sampling, cutting and inspection-sampling test pieces and expression of test results, Turkish Standards Institute, Ankara-Turkey, 1999.

Ulker, O. C., Ulker, O. and Hiziroglu, S. (2021). Volatile Organic Compounds (VOCs) Emitted from Coated Furniture Units. *Coatings*, 11(7), 806.

Vansteenkiste, R. (1981). Surface treatment of wood based panels. *Seminar on Wood Based Panels and Furniture Industries.*

Wong, E. D., Zhang, M., Wang, Q. and Kawai, S. (1999). Formation of the density profile and its effects on the properties of particleboard. *Wood Science and Technology*, 33(4), 327–340.

Zhang, J. and Smith, K. R. (2003). Indoor air pollution: A global health concern. *British Medical Bulletin*, 68(1), 209–225.