Journal of Materials Science and Engineering with Advanced Technology
Volume 9, Number 1, 2014, Pages 27-49

THE EFFECT OF UV IRRADIATION ON SOME TECHNOLOGICAL PROPERTIES OF PLYWOOD PANELS FROM VENEERS DRIED AT DIFFERENT TEMPERATURES

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Abstract

In this study, the effect of UV irradiation on the bonding strength, physical and chemical structure of plywood panels produced from maritime pine (Pinus *pinaster*) veneers manufactured and dried at different temperatures was studied. Accordingly, two different log peeling temperatures (32ºC and 50ºC) and three different veneer drying temperatures (110ºC, 140ºC, and 160ºC) were chosen. Five-ply-plywood panels with 10mm thick were manufactured by using

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Keywords and phrases: veneer drying temperature, UV ırradiation, surface roughness, bonding strength, colour measurement, FTIR-ATR.

Submitted by Zeki Candan.

Received December 30, 2013; Revised January 27, 2014.

melamine-urea formaldehyde resin with 54% solid content. UV irradiation process, bonding strength, colour measurement, and surface roughness tests were conducted on plywood panels according to ASTM G53, EN 314, ISO 7724-2, and DIN 4768 standards, respectively. Effects of UV irradiation on chemical structure of panels were determined with FTIR-ATR analysis. Plywood panels manufactured from veneers peeled at 32ºC log temperature and dried at 140ºC showed the lowest colour change values. The bonding strength values of test panels decreased with UV irradiation for all groups.

1. Introduction

Plywood is the most common material to be used in furniture, building, and construction industries (Piirlaid et al. [29]). Plywood is made of three or more thin layers of wood (veneer) bonded together with an adhesive. Most plywood is pressed into large, flat sheets used in building construction. Other plywood pieces may be formed into simple or compound curves in furniture, boats, and aircraft manufacturing (Thant et al. [33]). In these applications, products might be contact with ground and/or in an above ground environment, where there are often risks of material deterioration. When these products are in contact with ground, biological agents are the main cause of degradation. In case of remaining in an above ground environment, sunlight, and moisture can cause the degradation. These climatic environments cause millions of dollars of material damage every year, and high material cost may be required to replace damaged products. Therefore, the durability of these materials is of special concern for their use in outdoor applications (Matuana and Kamdem [27]).

Weathering is the term used to define the slow degradation of materials exposed to the weather conditions. The degradation mechanism depends on the type of material, but the cause is a combination of factors found in nature; moisture, sunlight, heat/cold, chemical, abrasion by windblown materials, and biological agents. Sunlight (especially UV and visible light) and water play a major role in weathering of wood (Williams [36]).

Exposing to water, heat or other environmental conditions, wood materials with adhesive must have good durability for a long service life. High bond strength and durability depend upon developing excellent adhesive-wood interaction and good dissipation of internal and external forces under end use. Adhesives used to hold substrates together under the desired end use conditions. This means that a bond needs sufficient strength and durability to hold the substrates together under a defined set of conditions. Generally, strength tests and accelerated tests are used to evaluate the suitability of an adhesive for a specific application (Frihart [19]).

In veneer-based panel production, log steaming and veneer drying are the two different thermal processes which directly affect veneer quality for bonding, durability, and physical and mechanical properties of panel products. The main function of log steaming is to soften veneer log temporary and making it more plastic, pliable, more readily peeled, and improving the quality and quantity of material recovered from the log. Log steaming also provides energy saving during the peeling, smooth veneer surfaces by reducing cracks on the veneer due to knife checks and higher tensile strength. Surface characteristics, uniform thickness of veneer, and bonding quality of plywood are influenced by steaming temperature and duration between steaming and peeling processes (Aydın et al. [5]). Gupta and Bist [21] investigated that the optimum heating temperatures of logs for obtaining higher shear strength of plywood varied by wood species.

The purpose of veneer drying is to reduce its moisture content to a suitable range for gluing. Mostly applied drying temperatures are between 90-160°C as called normal in plywood industry. Using high drying temperatures reduce the veneer drying time and increase the capacity. Reduction in drying time and energy consumption offers a great potential for economic benefit to the wood industries (Aydın and Colakoglu [3]). However, drying at very low moisture levels and at very high temperatures or at moderate temperatures for prolonged periods inactivates the veneer surfaces, causing poor wetting of veneer and hence poor bonding (Frihart and Hunt [20]). The surface inactivation might start at 160°C in some species was stated by Christiansen [9]. A number of researchers have shown that high drying temperatures affect the bond strength of plywood (Aydın and Colakoglu [3]; Christiansen [9]; and Lehtinen [26]).

Steaming and drying temperature influence both physical and chemical surface properties of veneer and hence it is bonding characteristics. Peeling and drying defects occurred in inappropriate temperatures may cause adhesion problems during bonding (Rowell [31]). Chemical interference that reduces the bond ability of wood is more complicated and more difficult to detect than the mechanical weakening of wood surfaces. This interference can be from natural causes (migration of extractives to the surface), inadvertent wood alteration (overdrying of the wood surface), or intentional alteration (wood modification). Overdrying and overheating interfere with adhesion by causing extractives to diffuse to the surface, by reorienting surface molecules and exposing the less polar portion, by oxidizing or pyrolyzing the wood, or by irreversibly closing the larger micropores of cell walls. Most wood adhesives are waterborne; therefore, they do not properly be wet and penetrate extractive-covered surfaces (Frihart and Hunt [20]).

Numerous studies have been carried out for the effects of veneer drying temperatures on bondability of veneer surfaces (Aydın and Colakoglu [3]), surface-inactivation and bond strength relationship (Frihart and Hunt [20]), and optimum conditions for surface preparation (River and Vick [30]). However, the bond strength and durability of plywood panels related to the different peeling and drying temperatures were not investigated.

The objective of the study was to determine the effects of log peeling and veneer drying temperatures on the durability of pine (*Pinus pinaster* L.) plywood panels with UV irradiation test. Surface roughness and changes in chemical structure and photostability of panels depending on UV irradiation were also investigated.

2. Material and Methods

2.1. Wood material and manufacturing of plywood

Maritime pine (*Pinus pinaster*), density of 0.45gr/cm^3, was used as wood species in this study. The logs with an average diameter at breast height of 40cm were harvested from Sinop Region, located at the north cost of Turkey. Firstly, all the logs were steamed in industrial conditions before veneer clipping process, and then steamed logs classified into two groups for peeling at two different log temperature: 32ºC and 50ºC, which were generally used in plywood industry and employed by Aydin et al. [5]. Each group logs were kept until they cool down the target core temperature. Target log temperature was measured by inserting tips of the thermometer into log's core. A rotary peeler with a maximum horizontal holding capacity of 80cm was used for veneer manufacturing. In the peeling process, the vertical and horizontal opening were adjusted as 0.5mm and 85% of the veneer thickness, respectively. Veneer sheets with dimensions of 55cm by 55cm by 2mm were clipped and then divided into three equal parts for drying at different temperatures: 110ºC, 140ºC, and 160ºC.

Five-ply-plywood panels with 10mm thick were manufactured by using melamine-urea formaldehyde resin with 54% solid content. Veneer sheets were conditioned to approximately 6-7% moisture content in a conditioning chamber before gluing. The glue was applied at a rate of 160g/m^2 to the single surface of veneer by using a four-roller glue spreader. Assembled samples were pressed in a hot press at a pressure of 8kg/cm^2 and at 110ºC for 10 minutes. Two replicate plywood panels were manufactured for each group. The experimental working plan is shown in Table 1.

Table 1. Experimental working plan

Log peeling temperature (ºC)	Veneer drying temperature (ºC)	Test groups
32	110	B1
	140	B2
	160	B3
50	110	B4
	140	B5
	160	B6

2.2. Surface roughness

The Mitutoyo Surfest SJ-301 instrument was used for surface roughness measurements. The R_z, arithmetic mean of the 10-point height of irregularities, was measured to evaluate surface roughness of untreated and surfaces of the UV irradiated plywood panels according to DIN 4768 [13]. Cut-off length was 2.5mm, sampling length was 12.5mm, and detector tip radius was 5μm in the surface roughness measurements. Twenty veneer samples with $50\text{mm} \times 50\text{mm}$ size were used for each test group to evaluate surface roughness.

2.3. Bonding strength and UV irradiation test

The bonding strength of plywood panels was determined according to EN 314 [15] on a universal testing machine and twenty samples were used for each test group. Plywood panels were tested after the test samples immersed for 24h in water at 20 ± 3ºC. The UV irradiation tests were carried out in accordance with ASTM G53 [1]. The source of radiation consists of fluorescent UV-B lamps, with the emission peak at 313nm. The ageing cycles consisted of 2h of radiation at 50 ± 3ºC and a period of 2h condensation at 60 ± 3ºC. The total duration of the test was 2 weeks (336 hours).

Condensation is more realistic than water spraying because in the external environment the dew is present over longer periods than is generally the case for rain, which usually simulated by a water spray. Condensation is also more severe than water spraying because it occurs at higher temperatures and acts for longer periods of time, allowing more water penetration in test panel. Condensation also assures the purity of the water and its saturation with oxygen (Custódio and Eusébio [10]).

2.4. Colour measurement

Colour measurements were performed with a Konica Minolta CM-600d. The reflection spectrum was acquired from a measuring area of 8mm in the 400-700nm wavelength range; where at two measurements at precisely defined points on the UV irradiated surfaces of each sample were carried out periodically. Thus, colour changes during UV irradiation were always monitored on the same spot of wood. The CIE (Commission Internationale de l'Eclairage) colour parameters L^* (lightness), a^* (along the X axis red (+) to green (–)), and b^* (along the Y axis yellow (+) to blue (–)) were calculated by using the Konica Minolta Colour Data Software CM-S100w $\text{Spectra Magic}^{\text{TM}}$ NX Lite (ISO 7724-2 [24]), from which the colour differences ΔE^* were calculated according to the formula given below:

$$\Delta E^* = (\Delta L^{*^2} + \Delta a^{*^2} + \Delta b^{*^2})^{1/2}. \tag{1}$$

Measurements were always performed at the end of an UV irradiation step to provide consistent specimen conditions during colour measurements. Five replicates were used for each sample to evaluate colour change.

2.5. FTIR-ATR spectra analysis

The FT-IR spectra were obtained by a Perkin-Elmer Spectrum on FT-IR instrument with a Universal ATR Diamond/ZnSe crystal with one reflection. Three accumulated spectra for each sample with a resolution of 16cm^{-1} were obtained. Spectra were displayed in transmittance and limited to the region of interest: 1800cm^{-1} - 800cm^{-1}.

3. Results and Discussion

3.1. Surface roughness and surface cracks

The average R_z values of the veneers and plywood panels before and after UV irradiation tests results were shown in Table 2. One-way analysis of variance was performed for statistical evaluation of the changes in surface roughness of veneer sheets. Student-Newman-Keuls test with 99% confidence level was used to compare the mean values of variance sources and the results for statistical evaluation were presented in Table 3.

Table 2. Surface roughness (R_z values) of veneers and plywood panels

Groups	Veneer samples	Plywood panels	
		Before UV irradiation	After UV irradiation
B1	117,85 (12,07)[a]	98,40 (12,27)	124,36 (11,42)
B2	115,08 (12,27)	71,99 (13,43)	83,92 (14,21)
B3	106,69 (10,46)	73,55 (11,78)	91,61 (11,21)
B4	98,19 (11,04)	72,91 (11,89)	98,09 (10,48)
B5	103,46 (12,83)	73,61 (14,35)	84,97 (11,36)
B6	118,07 (10,09)	74,67 (12,93)	103,78 (13,94)

[a]Values in parenthesis are standard deviations (N = 20).

Table 3. Surface roughness results of Student-Newman-Keuls test at 99% confidence level for veneer sheets

Properties	Factors	LS mean	Homogeneous groups[a]
Surface roughness	Log peeling temperature (°C)		
	32	113,211	a
	50	106,579	b
	Veneer drying temperature (°C)		
	110	108,026	a
	140	109,273	a
	160	112,384	a

[a]Different letters denote a statistically significant difference.

According to the test results, log peeling temperature was found to be a factor that affected surface roughness. The drying temperature of 110°C, 140°C, and 160°C did not show any significant change ($p = 0.01$) in surface roughness of veneer sheets (Table 3). Several studies have been done about the effects of peeling and drying temperatures on surface roughness of veneers (Aydin and Colakoglu [3]; Aydin and Colakoglu [4]; and Dundar et al. [14]). Dundar et al. investigated the effect of drying temperature on surface roughness of sliced makoré (*Tieghemella heckelii*) veneers and rotary cut beech (*Fagus orientalis*) veneers. It was stated that the drying temperatures of 80°C, 95°C, and 105°C did not show any significant change in surface roughness. Unsal et al. [35] also found that there was no significant effect of 100°C, 115°C, and 130°C veneer drying temperatures on the surface roughness of the sliced veneers. On the other hand, Aydin and Colakoglu [2] determined the surface smoothness of both alder and spruce veneers increased with increments in drying temperature. Since the effects of peeling and drying temperatures on veneer quality are species dependent, there are differences in the literature whether lower or higher temperatures provide smooth veneer surfaces. It was reported that higher quality veneer can be achieved by using optimum peeling and drying temperatures for each wood species (Aydin et al. [5]). According to results obtained from this study, it can be suggested that higher peeling and drying temperature are more appropriate for maritime pine from the point of surface quality.

Multifactor analysis of variance was used for statistical evaluation of the changes in surface roughness of plywood panels depending on the log peeling and veneer drying temperatures and UV irradiation. Student-Newman-Keuls test with 99% confidence level was used to compare the mean values of variance sources and the results for statistical evaluation were given in Table 4.

Table 4. Results of Student-Newman-Keuls test at 99% confidence level for plywood panels

Properties	Factors	LS mean	Homogeneous groups[a]
Surface roughness	Log peeling temperature (°C)		
	32	90,643	a
	50	80,510	b
	Veneer drying temperature (°C)		
	140	78,626	a
	160	79,657	a
	110	98,447	b
	UV irradiation		
	Before	73,362	a
	After	97,793	b
Bonding strength	Log peeling temperature (°C)		
	32	1,546	a
	50	1,513	a
	Veneer drying temperature (°C)		
	110	1,426	a
	160	1,443	a
	140	1,718	b
	UV irradiation		
	Before	1,836	a
	After	1,222	b

[a] Different letters denote a statistically significant difference.

The surface roughness values of plywood panels manufactured from the veneers peeled at 32°C log temperature were found significantly higher than those of the panels produced from the veneers peeled at 50°C. No significant difference $(p = 0.01)$ was found between R_z mean values of panels manufactured from the veneers dried at 140°C and 160°C, while that of the panels produced from the veneers dried at 110°C was determined clearly higher. Similar results were found by Aydin and Colakoglu [2]. It was stated that the surface smoothness of both alder and spruce veneers increased with increment in drying temperature. Candan et al. [7] investigated the effect of the hot pressing temperature and pressure on the surface roughness of the thermally compressed Douglas-fir veneers. It was reported that the surface roughness values of the thermally compressed Douglas-fir veneer sheets decreased with increasing press pressure and temperature. Wettability and surface roughness properties of plywood panels under thermal modification were studied by Candan et al. [8]. It was reported that the surface smoothness of the panels improved with increasing temperature up to 170ºC. The panels modified with a temperature of 150ºC or 170ºC had a smoother surface than those of the untreated panels, but the roughness value increased as modification temperature increased to 190ºC (Candan et al. [8]).

The surface roughness values of plywood panels increased significantly after UV irradiation. Temiz et al. [32] investigated the effect of UV irradiation time on surface roughness of wood. It was found that surface roughness values of wood increased with raising UV irradiation time (Temiz et al. [32]). Feist [18] stated that wood surfaces exposed to the weather without any finish are roughened by photo degradation and surface checking, change colour, and slowly erode.

The faces of the test panels were assessed visually and macroscopically, for the aim of verifying the eventual appearance of defects. The system defined ISO 4628 [23] was used to classify the degrees of the degradation. As shown in Figure 1, there were several splits and cracks on the surface of plywood panels. The visual evaluation was carried out to evaluate the cracks caused by UV irradiation. The system used to quantify and define the size of the cracks is described in ISO 4628. The plywood panels manufactured with veneers peeled and dried at different temperature showed that no high cracks and substantially surface properties changes were observed significantly due to UV irradiation, as can be seen from Figure 1 (class 2).

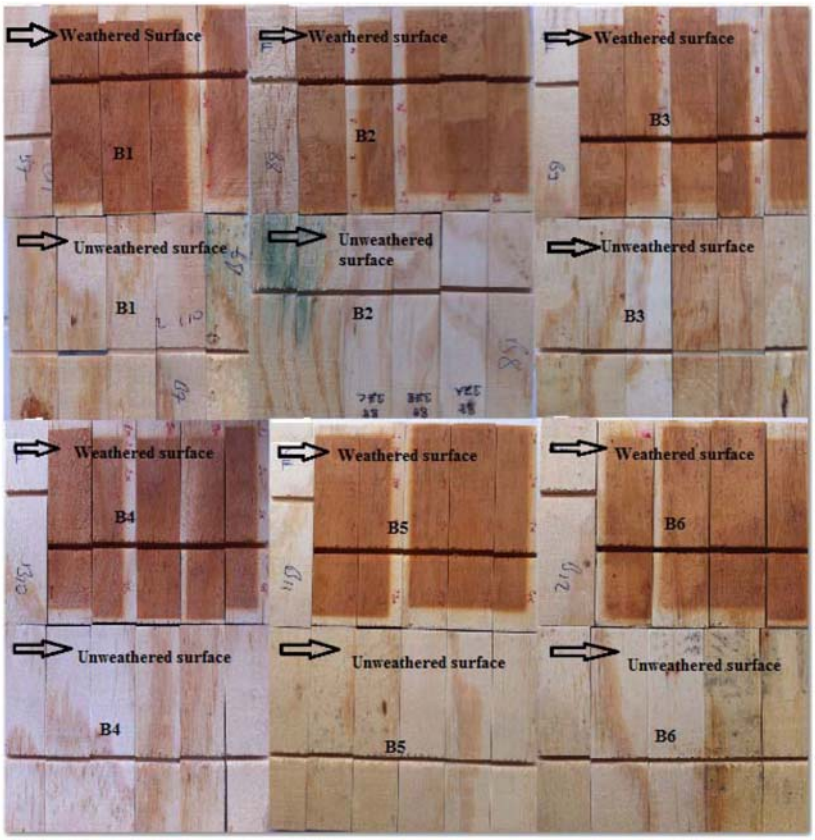

Figure 1. Plywood panel surfaces before and after UV irradiation.

3.2. Bonding strength

Bonding strength capacity of plywood panels before and after UV irradiation were compared and results were given in Figure 2. Multifactor analysis of variance was performed for statistical evaluation of the changes in bonding strength depending on the log peeling temperatures, veneer drying temperatures, and UV irradiation. Student-Newman-Keuls test with 99% confidence level was used to compare the mean values of variance sources and the results for statistical evaluation were presented in Table 4.

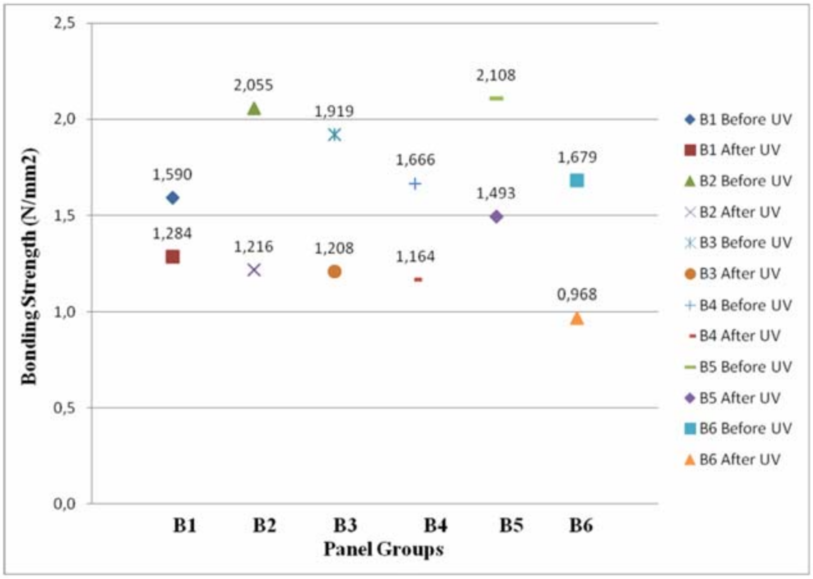

Figure 2. The effect of UV irradiation on bonding strength of plywood panels.

According to the test result, log temperatures during the veneer clipping did not have significant effect on bonding strength of plywood panels. The highest bonding strength values were obtained from the panels manufactured the veneers dried at 140ºC. The bonding strength values of the panels produced from veneers dried at 110ºC and 160ºC were found significantly lower. This may be due to the surface inactivation occurred at these drying temperatures. It is known that surface inactivation of veneers originated from unsuitable drying temperature have negative effect on bonding. Frihart and Hunt [20] stated that drying to very low moisture levels at very high temperatures or at moderate temperatures for prolonged periods inactivates the veneer surfaces, causing poor wetting of veneer and hence poor bonding. The surface inactivation might start at 160ºC in some conifer species was indicated by Christiansen [9].

Bonding strength values of all panels decreased after UV irradiation. However, decreased bonding strength values after UV irradiation were obtained above $1.0 \mathrm{N/mm}^2$, except B6 group. According to EN 314 standard, bonding strength value of $1.0 \mathrm{N/mm}^2$ and above is acceptable for most usage areas. Rowell [31] stated that the MUF adhesive can replace other adhesives that are used for some exterior applications. It was found that bonding strength values of plywood panels manufactured with MUF resin were lower after weathering process than those of before weathering (Demirkır [12]). Biblis [6] also determined that some mechanical properties of exterior structural plywood panels were reduced with natural weathering. The environment to which joints are exposed plays an important role in their durability. Moisture and heat are the most important factors in determining the strength loss of a joint exposed to the service environment. The results of natural and accelerated ageing tests have shown that adhesive joints lose strength due to exposure to high temperature and humidity (Custódio et al. [11]). Therefore, it is obvious that this study showed similar results to prior studies.

3.3. Colour change

Table 5 shows the effect of the UV irradiation on CIE L^* a^* b^* colour properties of plywood panels. Table 5 indicates the changes in the lightness (L^*) of the samples with respect to the exposure time and temperature. Moreover, the negative values of lightness (ΔL^*) and chromaticity coordinates $(\Delta a^*$ and $\Delta b^*)$ indicate that the surface of samples is getting darker. Positive values of Δb^* indicate an increment of yellow colour and negative values an increase of blue colour. Positive values of Δa^* indicate a tendency of wood surface to reddish, while negative values mean a tendency to greenish (Temiz et al. [32]).

Table 5. Colour change of plywood panels during irradiation time

B1				
Time	($^a\Delta$E)	($^a\Delta$L)	($^a\Delta$a)	($^a\Delta$b)
6h	10.1(1.2)	– 6.3(1.7)	2.3(1.5)	7.6(1.9)
18h	16.1(1.4)	– 9.9(1.2)	5.0(1.8)	12.0(1.2)
24h	18.5(2.1)	– 9.8(0.8)	5.9(0.9)	14.5(1.5)
48h	21.3(1.0)	– 13.7(0.9)	7.7(1.6)	14.4(0.8)
168h	26.2(0.9)	– 21.3(1.9)	10.1(0.8)	11.5(0.9)
336h	28.3(1.2)	– 25.3(1.3)	10.7(1.2)	7.7(1.6)

B2				
Time	($^a\Delta$E)	($^a\Delta$L)	($^a\Delta$a)	($^a\Delta$b)
6h	7.2(1.9)	– 4.6(1.3)	0.8(0.9)	5.4(1.2)
18h	14.1(2.2)	– 9.5(1.5)	3.7(0.8)	9.8(0.5)
24h	15.2(1.5)	– 9.4(1.7)	4.2(1.1)	11.8(1.1)
48h	18.6(1.6)	– 12.6(0.9)	5.7(1.7)	12.5(1.4)
168h	25.3(1.9)	– 19.3(1.6)	8.8(1.6)	13.7(1.9)
336h	24.6(1.1)	– 19.8(1.0)	8.9(1.5)	11.5(1.0)

B3				
Time	($^a\Delta$E)	($^a\Delta$L)	($^a\Delta$a)	($^a\Delta$b)
6h	7.0(0.9)	– 3.9(1.2)	0.7(1.5)	5.7(1.0)
18h	9.5(1.2)	– 7.5(1.5)	0.7(1.2)	5.7(1.2)
24h	15.5(1.8)	– 7.3(0.5)	3.5(1.0)	13.2(0.7)
48h	18.2(1.4)	– 11.0(1.9)	5.3(1.7)	13.6(0.9)
168h	25.6(2.1)	– 18.7(1.2)	9.1(0.9)	15.0(1.3)
336h	29.7(1.5)	– 23.8(1.7)	10.7(1.6)	14.3(1.8)

B4				
Time	([a] ΔE)	([a] ΔL)	([a] Δa)	([a] Δb)
6h	8.6(1.1)	– 3.9(1.5)	1.2(0.9)	7.6(1.3)
18h	17.7(2.1)	– 5.7(1.0)	1.3(1.2)	16.5(2.0)
24h	17.7(0.9)	– 8.8(0.7)	4.5(1.4)	14.7(1.9)
48h	21.0(0.7)	– 12.6(2.0)	6.3(1.6)	15.6(1.5)
168h	27.1(1.4)	– 20.3(1.8)	9.7(1.4)	15.2(1.3)
336h	29.4(1.6)	– 24.2(1.3)	10.8(1.1)	12.7(0.9)

B5				
Time	([a] ΔE)	([a] ΔL)	([a] Δa)	([a] Δb)
6h	15.8(0.8)	– 5.3(1.7)	1.3(1.2)	14.8(0.8)
18h	23.4(2.1)	– 10.1(1.4)	4.5(1.5)	20.2(1.9)
24h	24.7(1.3)	– 9.8(1.8)	4.8(1.8)	22.2(1.7)
48h	27.7(1.8)	– 13.5(1.4)	6.9(1.3)	23.2(1.2)
168h	32.9(1.6)	– 22.1(1.6)	10.6(1.6)	22.0(1.4)
336h	33.0(1.7)	– 25.4(1.3)	10.9(1.9)	18.1(1.0)

B6				
Time	([a] ΔE)	([a] ΔL)	([a] Δa)	([a] Δb)
6h	5.6(1.2)	– 4.7(1.0)	0.8(1.6)	3.6(1.2)
18h	11.9(1.5)	– 7.6(1.2)	3.1(1.1)	8.7(1.4)
24h	13.4(1.7)	– 7.1(1.4)	3.5(1.0)	10.7(2.2)
48h	16.7(0.9)	– 11.1(1.6)	5.1(1.7)	11.5(1.5)
168h	24.7(1.5)	– 19.2(1.9)	9.2(1.6)	13.1(1.3)
336h	27.7(1.0)	– 23.6(1.3)	10.1(1.3)	10.5(1.2)

[a] Values in parentheses are standard deviations.

The lowest values of ΔL^* that is most sensitive parameter of the wood surface quality were obtained from the plywood panels manufactured with veneers peeled at 32ºC log temperature and dried at 110ºC temperature (B1) during 336 hours exposure. After 336 hours, the highest colour changes $(\Delta E^* = 33.0)$ were observed on the surfaces of plywood panel manufactured with veneers peeled at 50ºC log temperature and dried at 140ºC drying temperature (B5) between all plywood samples.

In this study, the most effective plywood panel for stabilizing colour was plywood panel manufactured with veneers peeled at 32ºC log temperature and dried at 140ºC drying temperature (B3).

There are some studies concerning the durability of plywood panels against UV exposure (Jebrane et al. [25]; Tshabalala et al. [34]; and Evans et al. [16]). In those studies, plywood and veneers were protected with some chemical modifications and coating materials to be more durable against UV irradiation. However, in this study, plywood panels were not protected with any method to determine the effect of plywood manufacturing conditions, such as log temperature during the peeling process and veneer drying temperature on colour stability of test panels under UV exposure.

The colour changes of the plywood panels are illustrated in Figure 3. Generally, (ΔE^*) the colour stabilization of the plywood panels manufactured with veneers peeled at 32ºC log temperature and dried at 140ºC temperature (B2) were higher than other plywood panels. The results showed that the ΔE^* of the plywood panels increased after 336 hours, and this stage was followed by a gradual increase, corresponding to the whitening observed in the ΔL^* above. The colour change (ΔE^*) increased deeply on the surface of plywood panels manufactured with veneers dried at other drying temperature except of B2 and B6 during UV irradiation. The highest ΔE^* was observed on the plywood panels manufactured with veneers dried at 140ºC temperature (B5).

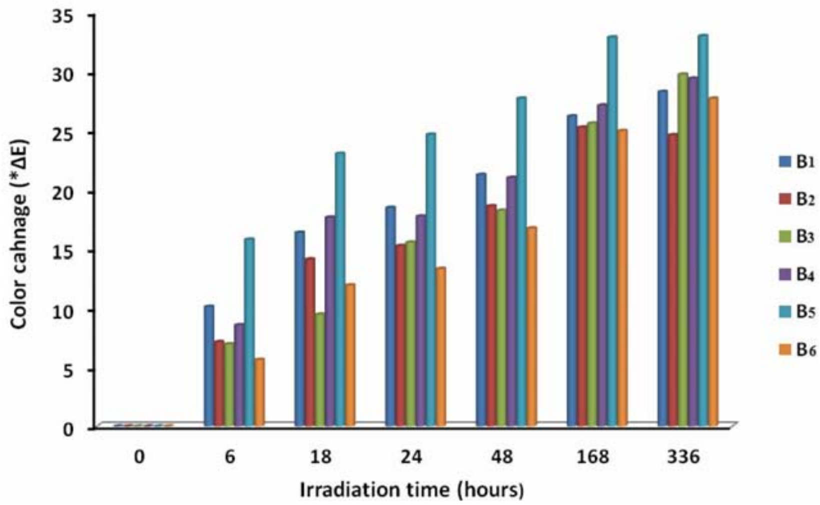

Figure 3. Colour change of plywood panels manufactured with veneers dried at different temperature during irradiation time.

3.4. The effect of UV irradiation on FTIR-ATR spectra

The effect of UV irradiation was significant on the FTIR-ATR spectra of plywood panels. Some studies showed that during UV irradiation of wood, absorption due to carbonyl groups at 1720cm^{-1} and 1735cm^{-1} increased, whereas the absorption for lignin at 1265cm^{-1} and 1510cm^{-1} decreased (Feist and Hon [17]). It was also stated that weakening of peaks at 1450 (CH_3 deformation in lignin and CH_2 bending in xylan) and 1269cm^{-1} indicated that lignin and hemicelluloses in untreated veneers were degraded during weathering (Jebrane et al. [25]). Similar results were observed in this study, especially absorptions at 1265cm^{-1} and 1720cm^{-1} (Figures 4 and 5). The samples exposed to the UV irradiation completely lost their absorption at 1265cm^{-1} and 1510cm^{-1}, due to the leaching of degraded lignin. Because any chemical modification was not applied, very high drying temperature that could be induced degradation was not used, and another chemical changes on FTIR-ATR spectra was not observed. It was summarized the assignments of absorption IR spectra bands in wood from various prior studies in Table 6 (Hergert [22]; Morohoshi [28]).

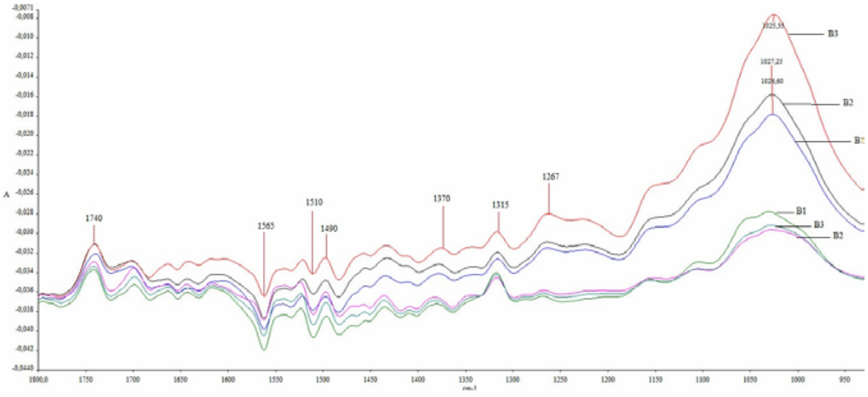

Figure 4. FTIR-ATR spectra of treated and UV irradiated plywood panel manufactured with veneers peeled at 32°C log temperature (B1-B2-B3).

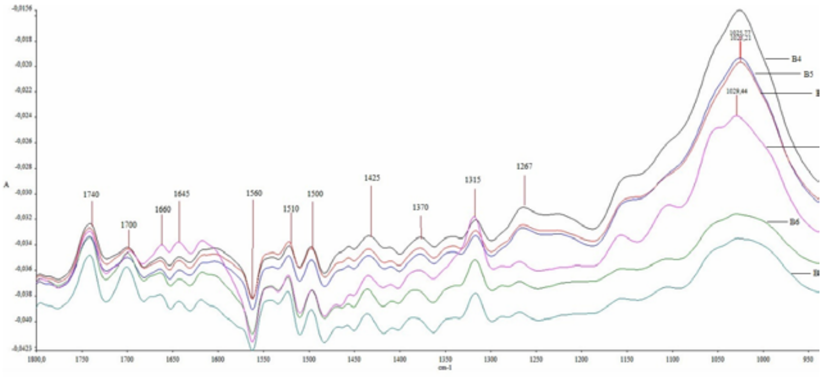

Figure 5. FTIR-ATR spectra of untreated and UV irradiated plywood panel manufactured with veneers peeled at 50°C log temperature (B4-B5-B6).

Table 6. Assignments of absorption IR spectra bands in wood (Hergert [22]; Morohoshi [28])

$Fr(cm^{-1})$	Group and class	Assignments and remarks
1720-40	C = O in unconjugated ketones aldehydes and carboxyl	C = O stretching
1645-60	C = O in para-OH substituted aryl ketones, quinines	Same
1600	C = C in aromatic ring in lignin	Aromatic skeletal vibrations
1510	Same	Same
1425	C = C in aromatic ring CH_2 in carbohydrates	Same Same
1370	C–H in all components in wood	C–H deformation (bending)
1315	C–H in all components in wood	CH_2 wagging
1267	CO in lignin and hemicelluloses	Guaiacyl ring breathing with CO–stretching
1162-1086	C–O–C in cellulose	Antisym, Bridge oxygen stretching

4. Conclusion

It is important to know that what extent of wood based panels, such as plywood, OSB, particleboard, etc. are durable to weathering conditions in terms of their using areas. This study evaluated the effect of UV irradiation on some mechanical, physical, and chemical properties of plywood panels. According to the results, different drying and peeling temperatures obviously have an affect on colour stability during UV irradiation. The colour stabilization of plywood panels from veneers peeled at 32°C was better than that of plywood panels from veneers peeled at 50°C. Also, the lowest values of ΔE had been obtained from the plywood panels manufactured with veneers peeled at 32°C log temperature and dried at 140°C during 336h UV irradiation. There were no high cracks and substantially changes on the plywood panel surfaces exposed to UV irradiation. The bonding strength values of test panels decreased with UV irradiation for all groups.

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