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Visual and Colorimetry Assessments of Synthetic Resin Impregnated α -Cellulose Decor Paper Laminated Particleboard Surfaces: A Comparative Study

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Research Article

Abstract − This study aims to visually and instrumentally examine the surfaces of particleboards laminated with white decor paper impregnated with α-cellulose-based melamine resin after treatment with five different surface processing agents. Samples of three different types (-A, -B, -C), each with three different grammages, were evaluated according to the TS EN 14323 standard, and color and texture changes were compared. The data were statistically analyzed using ANOVA and the Duncan test. The lowest brightness value (L*: 92.79) was found in samples laminated with 110 g/m² grammage B-type decor paper and treated with water (Wa) and acetone (Ac). The a* color coordinate values were found to be negligible (a*: <1.0), while variations in the b* coordinate were calculated at certain levels. The highest change in the b* coordinate was observed in the acetone-treated surface of the 80 g/m² grammage A-type decor paper (Δb*A80Ac: 0.51), with a difference of 27.4% compared to the control sample. The most significant color changes were found in the 110 g/m² grammage A-type samples treated with water vapor (ΔEA110Wa: 0.61) and the 80 g/m² grammage B-type samples treated with coffee (ΔEB80Co: 0.68); however, these changes were visually undetectable (ΔEB: <0.70). The highest color difference was observed in 90 g/m² grammage C-type samples treated with alcohol (ΔEC90Al: 1.48), followed by acetone (ΔEC90Ac: 1.18) and water (ΔEC90Wa: 0.91). The results indicate a strong correlation between visual perception and colorimetric measurements; however, some marginal differences may be overlooked. This study emphasizes that colorimetric assessments provide more precise results compared to visual evaluations.

Keywords − *Laminated particleboard, Colorimetry, CIE, L*a*b*, Total color difference (ΔE)*

Sentetik Reçine Emprenyeli α-Selüloz Dekor Kağıdı Lamine Yonga Levha Yüzeylerinin Görsel ve Kolorimetrik Değerlendirmeleri: Karşılaştırmalı Bir Çalışma

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Araştırma Makalesi

Öz − Bu çalışma, beyaz dekor kağıdı ile kaplanmış ve α-selüloz bazlı melamin reçine ile emprenye edilmiş yonga levha yüzeylerinin beş farklı yüzey işlem maddesi ile muamele edildikten sonra görsel ve enstrümantal olarak incelenmesini amaçlamaktadır. Üç farklı tür (-A, -B, -C) ve her biri için üç farklı gramajda kaplanmış numuneler TS EN 14323 standardına göre değerlendirilmiş, renk ve doku değişiklikleri karşılaştırılmıştır. Veriler istatistiksel olarak analiz edilerek ANOVA ve Duncan testi kullanılmıştır. En düşük parlaklık değeri (L*: 92.79) 110 g/m² gramajlı B tipi dekor kağıdı ile kaplanmış ve su (Wa) ile aseton (Ac) ile işlenmiş numunelerde tespit edilmiştir. a* renk koordinatı değerleri ihmal edilebilir düzeyde (a*: <1.0) bulunurken, b* koordinatındaki değişimler belirli seviyelerde hesaplanmıştır. En yüksek b* değişimi, aseton ile işlem görmüş 80 g/m² gramajlı A tipi kağıtta (Δb*A80Ac: 0.51, %27.4 fark) gözlenmiştir. En büyük renk değişimi 110 g/m² gramajlı A tipi su buharı ile işlenmiş (ΔEA110Wa: 0.61) ve 80 g/m² gramajlı B tipi kahve ile işlenmiş (ΔEB80Co: 0.68) numunelerde tespit edilmiştir; ancak bu değişimler görsel olarak fark edilemez düzeydedir (ΔEB: <0.70). En yüksek renk farkı, 90 g/m² gramajlı C tipi alkol ile işlem görmüş numunelerde (ΔEC90Al: 1.48) bulunmuş, bunu aseton (ΔEC90Ac: 1.18) ve su (ΔEC90Wa: 0.91) takip etmiştir. Sonuçlar, görsel algı ile kolorimetrik ölçümler arasında genel olarak iyi bir korelasyon olduğunu, ancak bazı marjinal farklılıkların gözden kaçabileceğini göstermektedir. Çalışma, renk ölçüm analizlerinin görsel değerlendirmelere kıyasla daha hassas sonuçlar sunduğunu vurgulamaktadır.

Anahtar Kelimeler − *Lamine yonga levha, kolorimetri, CIE, L*a*b*, Toplam renk farkı (ΔE)*

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1. Introduction

Wood has been one of the primary sources for mankind. Due to its wide range of versatility, it has still widely used materials worldwide. In this context, numerous types of engineering products have been developed and become to be utilized in many end use applications (Ross, 2010; Sahin et al., 2020, Sahin and Onay, 2020). However, wood-composites have gained increasing interest which is considered to be on high value-added engineered materials from once unusable or considered low value wooden materials. Those engineering design wood-composites has begun to be produced in different forms, sizes and usage purposes depending on customer needs over time (Shmulsky and Jones, 2019; Akbulut and Ayrılmıs, 2024). Since the 1980s, interest in the application of decorative treatments to wooden materials surfaces by providing alternative patterns, aesthetic appearance and functionality has begun to increase throughout the world (Aksu, 2009; Ross, 2010; Sahin et al., 2024). However, the utilization of cellulosic papers in wood-based composite industry have become widely accepted, and its use as an alternative to solid wood has gradually increased (Akbulut and Ayrılmıs, 2024).

As it is well known, cellulose is the main skeletal element of paper and cardboard products, the most abundant natural polymer on earth. Typically, it is found in primitive plants (algae) to highly organized trees, as well as in some animal sources (Fengel and Wegener, 2011). In general, when the hydroxyl groups (functional groups) in the structure of the paper come into contact with water or other chemicals, they can undergo a series of reactions, from the simplest softening, swelling or contraction to the complete disintegration of the sheet structure (Young, 2008). However, decorative papers adhered to wood-based board surfaces are produced from pulp with a high α-cellulose ratio, in weights varying between 30-115 g/m^2. The high α-cellulose ratio in sheet structure is to ensure that these papers have sufficient resistance and other desired properties for the processes to be applied later (printing, coloring, resin impregnation, etc.) (Aksu, 2009; Muğla, 2010; Sahin et al., 2024). Regarding this issue, first, a pattern or decor is applied (pattern printing once or twice) on raw papers with high α-cellulose content, then ink is applied, and finally reprinting is done (Aksu, 2009; Muğla, 2010). Therefore, those papers must have adequate qualities properties against multi-stage processing before being applied to wood-based boards. Some of the important quality requirements are the a stain-free on the paper surfaces, homogeneous fiber distribution in the sheet structure, and the absence of other quality-degrading features (Nemli, 2003; Aksu, 2009; Muğla, 2010; Akbulut and Ayrılmış, 2024). It has been well established by numerous researchers that the coating of the surfaces of wood-based board products, such as laminates, melamine films, or paper foils made of synthetic materials is very important in the furniture industry, in order to increase both their aesthetic appearance and durability (Nemli, 2003; Aksu, 2009; Muğla, 2010; Akbulut and Ayrılmış, 2024; Beğlen, 2024). Besides conventional instrumental analyses of decor paper laminated wood surfaces, the visual perception of those products is generally applied due to ease of perceptions by qualified test laboratory personnel. Brandt and Shook (2005) conducted a comprehensive review of research on forest product attributes, highlighting that consumer preferences for wood products are influenced by various product characteristics. In addition to these attributes, the color of laminated boards was found to be an important factor, demonstrating that both visual and tactile perceptions play a significant role in shaping consumer perceptions of these products (Broman, 2001; de Morais and Pereira, 2015; Bhatta et al. 2017).

In forest products industry, the time- and cost-effective various type sensory analysis has already applied to evaluate; consumer preferences (Jonsson, 2008), visual and tactile perceptions of wood surface qualities (Broman, 2001), textural characteristics of wood panels (Zhu et al., 2023), naturalness of the surface textures (Bhatta et al., 2017). It has also reported by de Morais and Pereira (2015) that contrasting relationships between tactile and visual appreciation involving multiple senses in people's appreciation assessments. It has hypothesized that asymmetric or high-contrast textural patterns offer a layered visualization, attracting the attention of viewers (Zhu et al., 2023). Decor paper laminated particleboard as a type of wood panel, has unique appearance characteristics, such as grain and color, which can also have psychological and emotional effects. Many previous studies have focused on visual preferences for the appearance by users of wood surfaces (Johnsson et al., 2008; Ho et al., 2015; Jia and Niu, 2017; Zhu et. al., 2023). Those research clearly indicate that color, grain, and gloss significantly impact the visual aesthetic evaluations. But in the field of visual perception of wood material science research, some studies have also utilized a biased subjective approach. In a more recent study, the eye-tracking method has evolved to assess users real-time reactions to products, helping to predict which products they are likely to prefer. (Ho et al., 2015; Miao et al., 2024).

It is an important aspect to explore the visual and instrumental quality checks of synthetic resin impregnated α -Cellulose decor paper laminated wooden substrates as decorative materials with accurately. In this regard, it is essential for evaluating visually graded laminated particleboard surfaces with numerical methods in order to be certificate final product's optical quality properties. In this study, we have aimed to evaluate visually graded decor paper laminated particleboard surfaces against certain surface agents using spectrophotometry measurements. In this case, we have assumed to find feedback for visually laboratory controls by comparing numeric values with visually grading.

2. Material and Methods

In the study, 18 mm decor paper laminated standard particleboards (580-650 kg/m3) which was prepared for general purposes with urea-formaldehyde resin were selected as base material for surface decorative paper lamination. The standard (high α-cellulose ratio) white decor papers (Type-A, Type-B and Type-C) in three different grammages of each group: 80g/m2, 90g/m2, 110g/m2 were used, supplied from the commercially operated a company located in Germany. These papers were undergone standard synthetic resin impregnation process, immersed first in 55% urea-formaldehyde resin pool, followed second in 50-53% melamine-formaldehyde resin bath, then dried at 140-160 °C to establish a total of desired properties which is ready to be glued to standard raw particle board surfaces. The decorative paper laminated panels obtained at the end of these processes were subjected to a series of quality checks, which certified certain surface quality properties. Three different types of decor papers, which are regarded as different shade of white, were tested, A total of 120 samples (ten samples for each condition in each decor paper grammage) were prepared according to dimensions specifies at TS EN 14323 standard, and conditioned at 20 ºC and 65% relative humidity. The following surface quality controls were made by qualified testing laboratory personnel at a standard testing laboratory of a particleboard producer, in Turkiye. The materials used in the study were obtained from a particleboard plant that carries out large-scale production.

2.1. Resistance to water vapor

In order to determine the surface staining/discoloration characteristics of the decor paper laminated particleboard when they come into contact with water vapor, the samples are placed on boiling water (> 100°C) and exposed to the steam of boiling water for one hour. After the experiment is completed, the surface is dried, and the surfaces are checked with the naked eye from a distance of 250 mm;

· discoloration,
· gloss changes,
· general appearance and blisters etc.,

Taking into account the factors, the rating is made according to the rating criteria specified in TS EN 14323 below, given by the standards.

Grade 1: Blisters and/or crust separation,
Grade 2: A noticeable change in brightness and/or color,
Grade 3: Moderate change in brightness and/or color,
Grade 4: Slight change in brightness and/or color when viewed only from a certain angle,
Grade 5: No change is seen.

2.2. Resistance to staining

This experiment was carried out to evaluate the material's resistance to various types of stains that it may encounter in daily use. The results obtained determine how resistance of the material is to staining, providing information on areas of use and appropriate maintenance methods. The stain/color resistance properties of decorative paper laminated wood composite surfaces are determined according to TS EN 14323 standards. Three samples of 70x70 mm are utilized in the method. The surfaces of the samples are cleaned with a cloth dipped in 30% purity ethyl alcohol. The samples are exposed to staining with substances such as water, coffee, alcohol and acetone and kept for a certain period of time. At the end of the test period, the surfaces of the samples are cleaned again and any color change is evaluated according to the rating system outlined in TS EN 14323.

Class 1: Surface deterioration and/or blistering,
Class 2: Significant change in finish and/or color,
Class 3: Noticeable change in finish and/or color,
Class 4: Polish and/or polish visible only from certain viewing angles slight change in color,
Class 5: No visible change.

2.3. Determination of color (CIE L*a*b*) properties of samples

The colour change properties caused by five different selected dyeing effects on the surfaces of decorative paper laminated test specimens were measured according to the CIE L*a*b* (1976) standard. Also colour changes were measured automatically using D65 daylight at a sensor angle of 20/100 and in a standard environment using an X-Rite 962 (Grand Rapids, Michigan) spectrophotometer. Changes in brightness/darkness (L*), redness/greenness (a*) and yellowness/blueness (b*) can be calculated with this device. Some code numbers are given to difference treatments. These are: Ko: control, Wv: water vapor treatment, Co: coffee treatment, Wa: Water treatment, Al: Alcohol treatment, Ac: Acetone treatment. Figure 1 (a-f) shows some test equipment applied in the laboratory environment for staining/color changes of decorative paper laminated samples.

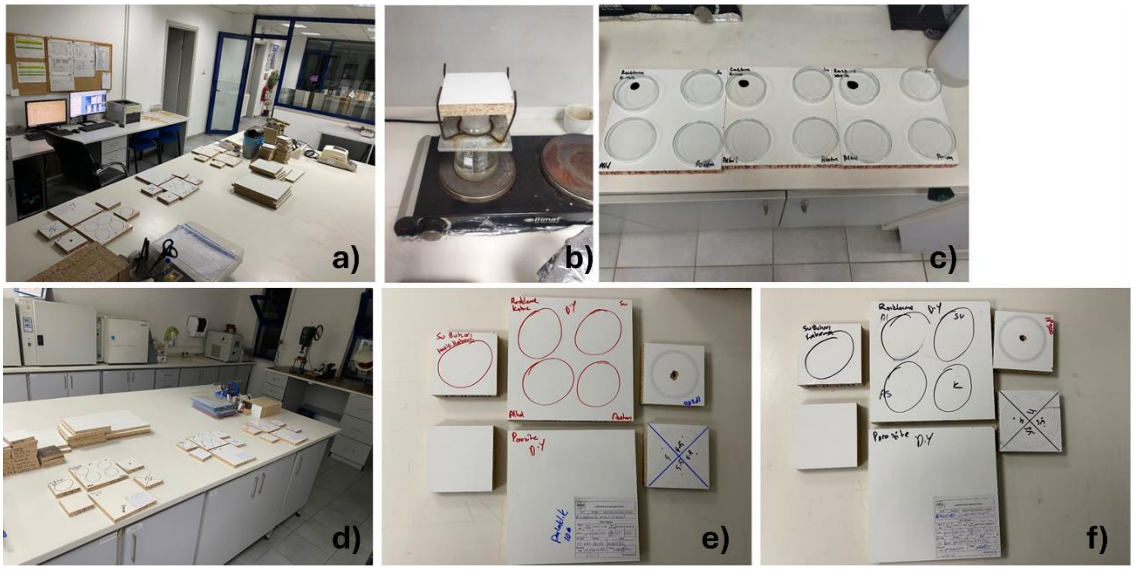

Figure 1. The standard tests for staining resistance quality check in laboratory conditions (a: Test laboratory, b,c: Treatment process, d,e,f: Analysis process)

2.4. Statistical analysis

IBM SPSS Statistics 22 program was used to analyse the data. Analysis of variance (ANOVA) was performed in the statistical evaluation of the data obtained. Data analysis was carried out in the IBM SPSS Statistics 22 program at 95% confidence level. Duncan test was used to compare the samples with each other. Statistical results are categorized as letters with the data in each table. Each group is evaluated within itself.
3. Result and Discussion

Table 1 shows the L* (lightness) properties measured for the controls and the surfaces of particleboard laminated with three different types and grammages of decorative paper, after five different surface treatments. For controls, the highest lightness value of 95.04 (metric) was found with A-type of 80 g/m^2 while the lowest value of 92.65 (metric) was found with B-type of 110 g/m^2 decor paper laminate surfaces, respectively. Those values were indicated only 2.5% differences from control samples, which is in three type of decor papers from three different grammage white color tones. However, surface treatments appeared to marginally lightness value changes, which could not be difference by visually (<1.0 point) in all conditions regardless of treatment chemicals, type of or grammage of laminated decor papers. Moreover, the highest lightness value of 95.55 (metric) was found C-type with water treatments and the lowest lightness value of 92.69 (metric) was found with B-type in 110 g/m^2 decor paper treated with water vapor (Wv), which only show approximately 0.2% and 0.6% differences from counterpart controls, respectively (L*C110: 94.98 and L*B110: 92.65). These could be expected, considering in a strict manufacturing process with utilizing very durable and hard surface thermoset resin formulations (melamine- and urea-formaldehyde) established on those samples (Beğlen, 2024).

Table 1
Lightness (L*) properties of samples

	80 g/m^2			90 g/m^2			110 g/m^2		
Samples	A	B	C	A	B	C	A	B	C
K0	95.04(a) (0.15)	93.42(b) (0.90)	94.61(a) (0.09)	94.94(a) (0.14)	93.31(a) (0.08)	94.72(d) (0.07)	94.58(a) (0.13)	92.65(a) (0.21)	94.98(a) (0.18)
Wv	95.46(e) (0.05)	93.71(f) (0.08)	94.85(b) (0.08)	95.40(f) (0.09)	93.66(b) (0,19)	95.04(f) (0.47)	95.19(f) (0.09)	92.69(b) (0.11)	95.31(b) (0.12)
Co	95.10(c) (0.04)	93.37(a) (0.09)	94.95(e) (0.06)	95.25(e) (0.04)	93.67(c) (0.07)	94.87(e) (0.15)	94.86(c) (0.07)	92.71(c) (0.04)	95.46(e) (0.04)
Wa	95.17(d) (0.08)	93.56(e) (0.05)	94.90(c) (0.07)	95.19(d) (0.09)	93.72(d) (0.09)	94.10(c) (0.81)	94.89(d) (0.07)	92.78(e) (0.12)	95.55(f) (0.07)
Al	95.17(d) (0.06)	93.48(c) (0.04)	94.90(c) (0.12)	95.17(c) (0.10)	93.82(e) (0.07)	93.30(a) (1.74)	94.85(b) (0.08)	92.75(d) (0.10)	95.32(c) (0.04)
Ac	95.06(b) (0.14)	93.51(d) (0.12)	94.92(d) (0.13)	95.13(b) (0.11)	93.84(f) (0.09)	93.72(b) (1.09)	94.90(e) (0.13)	92.79(f) (0.04)	95.45(d) (0.17)

The numbers and letters in parentheses in Table indicate standard deviations and group differences, respectively.

Table 2 shows the redness-greenness (a*) properties of samples. In contrast to lightness, some level different a* values were calculated for not only controls but also after surface treatments. Initially, some level of different a* color coordinate properties were noted for three different types decor papers which are in the range of a*A90: -1.01 (metric) to a*A80: -1.07 (metric) and a*A110: -1.07 (metric) for A-type decor papers, in range of a*B80: 0.67 (metric) to a*B90: 0.79 for B-type decor papers, and in range of a*C110: -0.95 (metric) to a*C90: -0.99(metric) for C-type decor papers. It seems the type of decor paper influences a* coordinate properties, while the grammage is not effective compared to relevant controls. However, a* colour coordinate values were found to be negligible for all samples regardless of the treatment conditions. The lowest a* values of -1.03 (metric) were found with water vapor-treated sample for A-type decor papers, 0.58 (metric) found with acetone-treated sample for B-type papers, and -0.69 (metric) for C-type papers, respectively.

Table 2
Redness- greenness (a*) properties of samples

	80 g/m^2			90 g/m^2			110 g/m^2		
Samples	A	B	C	A	B	C	A	B	C
K0	-1.07(c) (0.06)	0.67(d) (0.10)	-0.98(a) (0.11)	-1.01(e) (0.09)	0.72(a) (0.06)	-0.99(a) (0.01)	-1.07(b) (0.06)	0.71(d) (0.04)	-0.95(e) (0.04)
Wv	-1.05(e) (0.03)	0.65(c) (0.14)	-0.81(c) (0.02)	-1.05(d) (0.03)	0.93(d) (0.04)	-0.77(b) (0.08)	-1.03(e) (0.02)	0.62(a) (0.05)	-1.01(b) (0.05)
Co	-1.08(b) (0.08)	0.72(f) (0.00)	-0.80(d) (0.02)	-1.07(c) (0.02)	0.96(f) (0.02)	-0.76(c) (0.05)	-1.05(d) (0.02)	0.64(b) (0.04)	-0.98(c) (0.08)
Wa	-1.05(e) (0.05)	0.61(b) (0.07)	-0.83(b) (0.02)	-1.09(b) (0.01)	0.95(e) (0.03)	-0.73(d) (0.13)	-1.06(c) (0.02)	0.64(b) (0.05)	-0.97(d) (0.02)
Al	-1.06(d) (0.02)	0.69(e) (0.04)	-0.81(c) (0.02)	-1.09(b) (0.03)	0.90(c) (0.04)	-0.69(e) (0.11)	-1.07(b) (0.03)	0.67(c) (0.05)	-1.02(a) (0.01)
Ac	-1.09(a) (0.01)	0.58(a) (0.06)	-0.81(c) (0.04)	-1.10(a) (0.04)	0.89(b) (0.02)	-0.73(d) (0.08)	-1.08(a) (0.02)	0.67(c) (0.03)	-1.02(a) (0.02)

Table 3 shows the yellow-blue (b*) color properties that were found after five different surface treatments of the similar samples. Although the grammage changes appear to not influence b* values, in contrast to L* and a* coordinates, considerably different b* properties were found initially at three different type of decor papers. Values are clearly indicated that there is a distinct difference between type of decor papers which is subjected to lamination on particleboard surfaces. After the treatments by five different agents, there is also considerably different b* values were found, either increase or decrease according to counterpart control sample. The highest b* coordinate changes were found with acetone treated 80 g/m^2 decor paper surface (Δb*A80Ac: 0.51) for A-type decor papers, followed by water treated 90 g/m^2 decor paper surface (Δb*C90Wa: -0.60) for C-type decor papers, and by coffee treated 90 g/m^2 decor paper surface (Δb*B90Co: 0.41) for B-type decor papers, in that order. Those values calculated to be 27.4%, 15.9% and 5.6% different from controls, respectively.

Table 3
Yellowness-blueness (b*) properties of samples

	80 g/m^2			90 g/m^2			110 g/m^2		
Samples	A	B	C	A	B	C	A	B	C
K0	1.86(a) (0.12)	6.88(b) (0.31)	3.96(e) (0.16)	1.87(f) (0.15)	6.98(b) (0.06)	3.78(d) (0.14)	1.97(f) (0.09)	6.42(f) (0.11)	4.29(d) (0.15)
Wv	1.93(b) (0.08)	6.60(a) (0.31)	3.88(c) (0.06)	1.76(b) (0.05)	6.90(a) (0.06)	3.80(e) (0.15)	1.91(e) (0.08)	6.19(a) (0.07)	4.07(a) (0.09)
Co	1.95(c) (0.06)	7.55(f) (0.07)	3.94(d) (0.01)	1.83(e) (0.81)	7.39(f) (0.19)	3.91(f) (0.05)	1.84(c) (0.08)	6.22(c) (0.04)	4.20(b) (0.08)
Wa	2.03(d) (0.03)	7.20(e) (0.20)	3.80(a) (0.08)	1.75(a) (0.04)	7.24(e) (0.13)	3.18(a) (0.59)	1.87(d) (0.03)	6.21(b) (0.09)	4.39(e) (0.04)
Al	2.30(e) (0.12)	7.15(d) (0.09)	3.88(c) (0.09)	1.77(c) (0.07)	6.99(c) (0.13)	3.48(c) (0.54)	1.79(b) (0.05)	6.30(e) (0.13)	4.20(b) (0.04)
Ac	2.37(f) (0.26)	6.90(c) (0.13)	3.82(b) (0.13)	1.81(d) (0.08)	7.14(d) (0.11)	3.22(b) (0.54)	1.77(a) (0.08)	6.28(d) (0.10)	4.28(c) (0.08)

The numbers and letters in parentheses in Table indicate standard deviations and group differences, respectively

Total color difference (ΔE) is a single numeric value that is commonly used to separate between two colors. This numeric value (metric) allows quantified examination of materials, which is of great importance to those materials that are color-critical. Numerous researchers have already well established to use total color difference (ΔE) to evaluate wooden products for evaluating surface discoloration properties (Sahin et al., 2011; Wei et al., 2017; Beğlen, 2024). In this sense, we have also used color coordinate values to calculate total color difference properties of surface treated decor paper laminated particleboard.

Figure 2 shows the total color difference properties (ΔE) of three types of decor papers which were prepared from three different grammages, subjected to quality check against five different surface treatments. The highest color change values of ΔEA110: 0.61 (metric) and ΔEA90: 0.47 (metric) were found with water vapor-treated samples of 110 g/m^2 and 90 g/m^2 decor paper surfaces, ΔEA80: 0.46 (metric) with alcohol-treated 80 g/m^2 decor paper surfaces, respectively. It could be seen that there are only marginally discolorations were noted (ΔEA: <0.70) for all A-type decor papers, regardless of treatment conditions and grammage of laminated papers. Those level of color changes were reported to be not visually perceived by human eye (Kotradyova et al., 2012). The similar results were also found with B-type papers (Fig.2B) that the color difference was found to be in range of ΔEB80AC: 0.13 (metric) with acetone-treated to ΔEB80Co: 0.68 (metric) with coffee treatment at 80 g/m^2 laminated paper surfaces. These values appeared to be not visually perceived and could be negligeable discolorations (ΔEB: <0.70) for all B-type laminated samples, regardless of treatment conditions and grammage of papers.

For C-type of decor papers (Fig. 2C), except samples of water, alcohol and acetone-treated 80 g/m^2 decor paper surfaces, all other samples show negligible discolorations (ΔEC: <0.70), in all treatment conditions, regardless of grammages and treatment conditions. However, acetone and alcohol-treated 90 g/m^2 C-type decor paper surfaces show a high level of (ΔE:> 1.0) discoloration properties, compare to all other samples. In this study, the highest color difference value of ΔEC90Al: 1.48 (metric) was found with alcohol treatment, followed by ΔEC90AC: 1.18 (metric) with acetone-treated and ΔEC90Wa: 0.91 (metric) with water-treated in 90 g/m^2 grammage C-type decor papers, in that order.

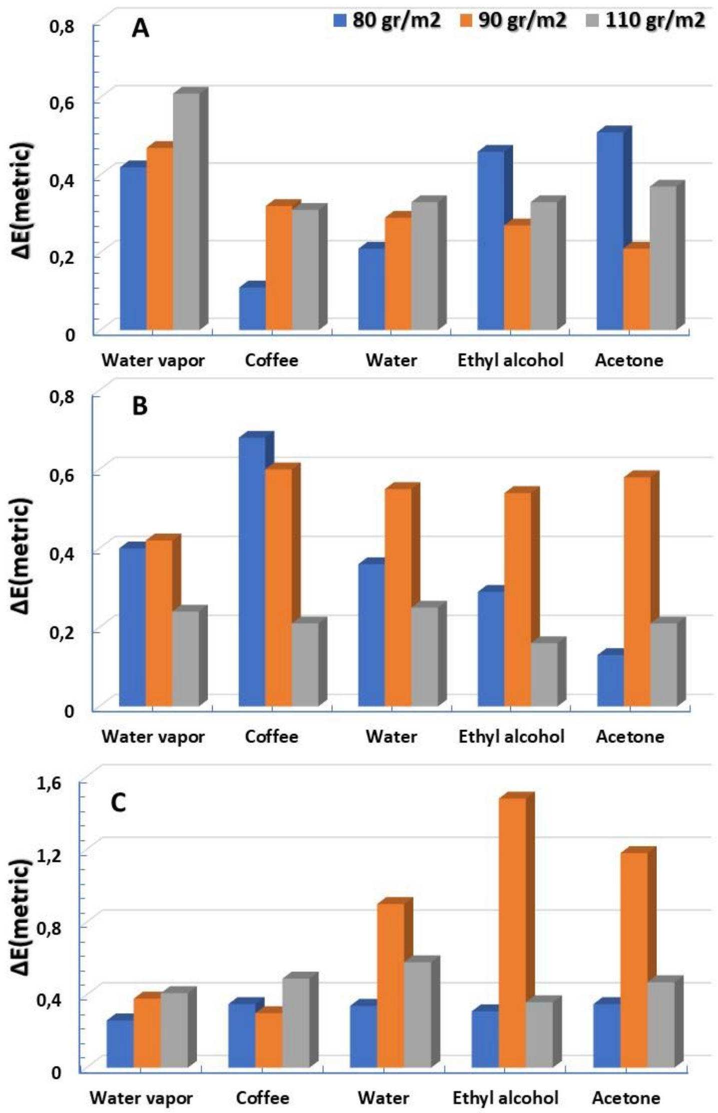

Figure 2. Total color changes of laminated decor papers after five different surface treatments (A: A-type decor papers, B: B-type decor papers, C: C-type decor papers)

Due to time effective approach, surface quality of wooden products (i.e., decor paper laminated wood-based composite products) are often determined visually (sensory analyses) by expert personnel in plants quality testing laboratories. In many cases, these methods have usually worked well when checks made by qualified persons at similar evaluation procedures. However, there have been plenty of literature reports regarding visual perception of wood-based materials while there is increasing interest in combination of visual perception with colorimetric analysis in recent years. Moreover aesthetic perception of orcahr woods colors evaluated by combining questionnaire and colorimetric measurements (Sahin and Onay, 2020). The color, texture and gloss reported to be positively the aesthetic perception of the end user by providing sensory stimuli (Ho et al., 2015). In addition, a more objective methods have also been developed to understand consumers aesthetic perception and quality controls by combining questionnaire and eye movement tracking methods (Jia and Niu, 2017). But it has suggested that it is better to analysis aesthetic preferences to more accurately meet the perceptual needs, using quantitative approaches alone and/or combinations with sensory analyzed (Ho et al., 2015; de Morais and Pereira, 2015; Sahin and Onay, 2020; Zhu et al., 2023). In our study, approximately 120 particleboard samples were investigated, laminated with three different types of decor papers, each of which has three different grammages. All those treated with five different surface staining agents were evaluated by visual perception with qualified laboratory laboratory personnel and quantitatively by a colorimetric method to compare those results.

In terms of TS EN 14323 standard for water vapor treatment analysis, the visually perceived average grades were noted to be 4.45 (S: 0.51) for 80 g/m^2 laminated samples, 4.55 (S: 0.52) for 90 g/m^2 laminated samples, and 4.35 (S: 0.49) for 110 g/m2 laminated samples, respectively. When we were investigated those samples instrumentally, the color coordinate differences for water vapor-treated samples were found to be only marginally variations (<1.0 point) (Tables 1-3). The total color changes were also found to be <1.0, for all three different type papers regardless of grammages (Figure 2). In terms of TS EN 14323 standard for surface coffee contact analysis, the visually perceived average grades were assessed to be 5.0 (S: 0.0), regardless of the type of laminations. However, all three color coordinate differences and total color differences were found to be marginally changed (<1.0 point) (Tables 1-3, Fig. 2), even <0.5 point in most cases.

In terms of TS EN 14323 standard for surface water contact analysis, like coffee analysis, almost similar trend was observed that all visually perceived average grades were established to be 5.0 (S: 0.0) for all the types of papers and grammages. However, the color coordinate differences and total color differences were also found to be marginally changed (<1.0 point) (Tables 1-3, Fig. 2), even <0.5 point in most cases. In terms of TS EN 14323 standard for surface ethyl alcohol contact analysis, all visually perceived average assessments were established to be 5.0 (S: 0.0) for all types of papers and grammages. Although 80 g/m^2 and 110 g/m^2 decor paper laminated samples show negligible color changes and like coffee and water conditions (<1.0 point) in all cases, some noticeable differences were noted for C-type 90 g/m^2 decor paper laminated samples that the total color difference was found to be ΔEC90Al: 1.48 (metric) which is the highest difference noted in this study.

In terms of TS EN 14323 standard for surface acetone contact analysis, like water vapor-, coffee-, water- and ethyl alcohol analysis, all visually perceived average grades were established to be 5.0 (S: 0.0) for all type of papers and grammages. However, only 90 g/m^2 decor paper laminated sample show ΔE>1.0 (metric) difference value of ΔEC90Ac: 1.18 (metric) from counterpart control while rest of samples show negligible color coordinate and total color changes (<1.0 point), regardless of grammages of C-type decor papers laminated samples.

4. Conclusions

This study aims to answer the question of whether there is any relationship between visual perceptions and numerical measurements. The results show a high degree of consistency across measurement methods. There is a very strict manufacturing process for synthetic resin- impregnated α- cellulose decor paper lamination to particleboard surfaces, that could be very durable and have hard surface properties established against deteriorating agents. In this context, this research highlights the importance of properties such as visually and instrumentally determination of discoloration of decor paper laminated particleboard surfaces, which are essential for optimizing the quality of products. It is already well presented that ΔE is measured on a scale from 0 to 100, with 0 indicating less colour difference and 100 indicating full distortion. Regarding that issue, it is suggested by a number of researchers that ΔE<1.0: not perceptible by the human eye but 1.0<ΔE <2.0: could be perceptible through close observation while ΔE>3.0 could be perceptible at a glance (Sahin et al., 2011; Sahin and Onay, 2020). Therefore, it appeared ethyl alcohol and acetone-treated 90 g/m^2 decor paper laminated sample mistakenly was perceived/graded by visually (ΔEC_{90Al}: 1.48 and ΔEC_{90AC}: 1.18). It could be recognized that evaluation of color changes from different types of papers at the same particleboard surfaces at similar treatment conditions is a challenging topic. However, those colorimetric results clearly point towards the visual perception is that well-designed up to some limitations while some level of alterations in the designed colors in the decor paper laminated particleboard. In that case, spectrometry measurements, which are a high sensitive numeric methods could be utilized to check the final optical properties of laminated samples if very high sensitivity necessary.

Author Contributions

Halil Turgut Şahin: Conceptualization, Project administration, Writing – review & editing.
Emre Beğlen: Methodology, Investigation, Data curation.
Uğur Özkan: Methodology, Investigation, Writing – review & editing, Validation.
Merve Cambazoğlu: Methodology, Investigation, Validation.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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