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Numerical determination of synthetic resin impregnated α-cellulose decor paper laminated particleboard surfaces

Sentetik reçine emprenyeli α-selüloz dekor kâğıdı ile lamine edilmiş yonga levha yüzeylerinin nümerik olarak belirlenmesi

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Abstract: There have been numerous applications for aesthetic surface application to wooden products is so widespread that when we discuss the appearance of wood materials, it usually refers to the visual characteristics of the surface after it has been coated. However, decor paper laminated wood-based panel products have unique appearance characteristics, such as grain and color, which can have psychological and physiological effects on the users. In this context, the primary aim of this study to numerically evaluate three different types (Type-A, -B, and -C) at three different grammage (80 gr/cm^2; 90 gr/cm^2; 110 gr/cm^2) of white decor paper laminated particleboard surfaces which subjected to five different surface treatments according to TS EN 14323 standard. The data obtained were evaluated statistically and ANOVA test was performed. In addition, the Duncan test was applied to determine the differences between the groups. The selected five different surface treatment agents appeared to impact on surface optical properties, some level either increase or decrease compared to counterpart controls. The highest chromacity differences were found with alcohol (A_{80IV}: 17.90%) and acetone (A_{80V}: 21.41%) treated A-type 80 gr/cm^2 and acetone treated (C_{90V}:-10.29%) C- type 90 gr/cm^2 decor paper laminated samples that might be perceived by visually (> 10.0 point). However, alcohol (IV) and acetone (V) treated samples in 80 gr/cm^2 of A-types show the highest hue value differences of Δh_{80IV}: 5.11^0 and Δh_{A80V}: 5.16^0, respectively while the rest of the samples show only marginally canges, for all treatment conditions (<± 3.0 degrees), regardless of type and grammage of laminated decor papers. Interestingly, all C-type 110 gr/cm^2 decor paper surfaces (low gloss decor papers) show some level higher gloss values after treatments than counterpart controls, which is the highest gloss value of 21.18 Gu was found with water vapor treated sample. It is worth noting that there are some level differences (%) of CIE X (red), and Y (yellow) and Z (blue) tristimulus changes were found with certain treatment conditions. Besides type of decor papers, the grammage appear to impact on tristimulus changes that the highest stimuli change value of X_{A90I}: 4.51% was found with water treated A-type decor paper sample, followed by Y_{B90I}: 3.40% with water treated B-type decor paper sample, and X_{A90I}: 2.44% with water vapor treated A-type decor paper sample, while rest of show only marginally changes (<± 1.5%), compare to other samples.

Özet: Ahşap ürünlerin yüzeylerinde estetik uygulamaların yaygın kullanımı nedeniyle, ahşap malzemelerin görünümünden bahsedildiğinde genellikle kaplama sonrası yüzeyin görsel özellikleri anlaşılmaktadır. Ancak, dekor kâğıdı ile lamine edilmiş ahşap esaslı panel ürünleri, benzersiz desen ve renk gibi görsel özelliklere sahiptir ve bu özellikler kullanıcılar üzerinde psikolojik ve fizyolojik etkiler yaratabilir. Bu bağlamda, çalışmanın temel amacı, üç farklı tipte (Tip-A, -B ve -C) ve üç farklı gramajda (80 gr/cm²; 90 gr/cm²; 110 gr/cm²) beyaz dekor kâğıdı lamine edilmiş yonga levha yüzeylerini, TS EN 14323 standardına uygun olarak uygulanan beş farklı yüzey işlemi sonrası sayısal olarak değerlendirmektir. Elde edilen veriler istatistiksel olarak değerlendirilmiş ve ANOVA testi yapılmıştır. Ayrıca gruplar arasındaki farklılıkları belirlemek için Duncan testi uygulanmıştır. Seçilen beş farklı yüzey işlem ajanının yüzey optik özellikleri üzerinde, kontrol gruplarına kıyasla, belirli bir seviyede artış veya azalış yönünde etkisi olduğu gözlemlenmiştir. En yüksek kromatiklik farkları, alkol (A_{80IV}: %17.90) ve aseton (A_{80V}: %21.41) ile işlenmiş A tipi 80 gr/cm² örneklerde ve aseton ile işlenmiş (C_{90V}: %-10.29) C tipi 90 gr/cm² örneklerde tespit edilmiştir. Bu farklar görsel olarak algılanabilir düzeyde olup (>10.0 puan), alkol (IV) ve aseton (V) ile işlenmiş 80 gr/cm² A tipi örnekler en yüksek ton değeri farklarını sırasıyla Δh_{A80IV}: 5.11^0 ve Δh_{A80V}: 5.16^0 olarak göstermiştir. Diğer örneklerde ise işlem koşullarına bakılmaksızın tüm dekor kâğıdı tipleri ve gramajlarında yalnızca marjinal değişiklikler (<±3.0 derece) gözlemlenmiştir. İlginç bir şekilde, tüm C tipi 110 gr/cm² (düşük parlaklık) dekor kâğıdı yüzeyleri, kontrol gruplarına kıyasla işlem sonrası daha yüksek parlaklık değerleri göstermiştir. En yüksek parlaklık değeri, su buharı ile işlenmiş örnekte 21.18 Gu olarak bulunmuştur. Ayrıca, CIE X (kırmızı), Y (sarı) ve Z (mavi) üç uyaran değişikliklerinde belirli işlem koşullarında bazı düzeylerde farklılıklar gözlemlenmiştir. Dekor kâğıdı tipine ek olarak, gramajın da üç uyaran değişiklikleri üzerinde etkili olduğu tespit edilmiştir. En yüksek uyaran değişim değeri, su ile işlenmiş A tipi örnekte X_{A90I}: %4.51 olarak bulunurken, bunu sırasıyla su ile işlenmiş B tipi örnekte Y_{B90I}: %3.40 ve su buharı ile işlenmiş A tipi örnekte X_{A90I}: %2.44 takip etmiştir. Diğer örneklerde ise bu değişimler yalnızca marjinal düzeyde kalmıştır (<±1.5%).

INTRODUCTION

It has begun to act more consciously toward the more rational use of natural forest resources worldwide. Improving forestry maintenance and cultivation techniques, operating them more efficiently, choosing fast-growing tree species, and investigating the possibilities of utilizing other biomass that can be used instead of or together with wood are just a few of them (Bowyer 2008, Sahin et al. 2020, Sahin and Onay 2020). However, it is a cost-effective manufacturing process to produce wood-based composites, particularly by combining low value, small-sized wood pieces with synthetic glues (Ross 2010, Shmulsky and Jones 2019, Pizzi et al. 2020). In this context, thanks to versatility of wood, which can allow to be produced numerous engineering and architectural products in certain size with desired technological performance features (Ross 2010, Sahin et al. 2021). In this utilization, wood raw material has begun to be consumed more rationally, and an important industrial sector with high added value, subject to trade, has been formed. Moreover, cellulose-based decor paper applications/lamination on wood-based composite surfaces have developed and become very popular products in worldwide (Shmulsky and Jones 2019, Akbulut and Ayrılmış 2024). But besides quality and cost considerations, it is important to ensure harmony between the wooden materials to be used in the decor paper lamination process, such as board-decor paper-resin-glue (Aksu 2009, Muğla 2010).

Many researchers have explained that the application of synthetic resin impregnated α-cellulose based decor papers on wooden composite materials via lamination method has many advantages (Aksu 2009, Muğla 2010, Beglen 2024). In general, these decor papers can be produced and applied on desired material surfaces more economically with the desired color, pattern and abrasion resistance than many other surface coating methods (Aksu 2009, Muğla 2010, Akbulut and Ayrılmış 2024). It has even been supposed that, because of technological developments, the synthetic resin impregnated α-cellulose based decor paper laminated wood-based composites surface show very aesthetic appearance, with various lust/shiny look which cannot be easily distinguished from natural wood veneers (Nemli 2003, Aksu 2009, Ross 2010, Akbulut and Ayrılmış 2024, Beglen 2024, Sahin et al. 2024). However, one of the important considerations for lamination is to be base decor paper, that must have good enough properties for impregnation and following lamination process, regarding resistance against stress with desired chemical interactions.

As it is known, cellulose is a natural polymer consisting of a straight, long chain and numerous hydroglycopyranose units. Each β-D-glucopyranose unit in the structure of cellulose contains three free hydroxyl groups, two of which are secondary (OH-2 and OH-3) and one is the primary hydroxyl group (Young 2008). Therefore, those specific properties of cellulose are particularly important in both providing strength and to adhering surface treatment chemicals (impregnation resins) to the sheet structure (Fengel and Wegener 2011). Regarding cellulose properties, α-cellulose properties in sheet structure (paper) found to be suitable for decor paper manufacturing and following multi-stage synthetic resin impregnation at various temperatures and thermal lamination at high temperatures (> 100 ^{0}C). Moreover, the synthetic resin properties must be certain characteristics such as colorless, hardened with heat (thermoset) without deformation and must be resistant to particularly household agents. Regarding those issues, urea-formaldehyde and melamine-formaldehyde resins are commonly used alone or together by preparing certain formulations for desired effects. It has been proposed by Akbulut and Ayrılmış (2024) that the hot-pressing conditions during decor paper lamination process are one of the key parameter for on the performance properties of the laminated products. It was also investigated physical, mechanical, other surface related properties with antibacterial performance against *Escherichia Coli* bacteria for melamine formaldehyde resin impregnated α-cellulose based decor paper applied board surfaces. Furthermore, it was found to be those surfaces show acceptable desired properties against selected biophsicochemical factors (Beglen 2024).

This study investigated three types of α-cellulose-based white decor paper, which each has three different grammage, laminated particleboard surfaces which is subjected to five different type agents applied according to TS EN 14323 standard, to evaluate optical performance and qualities with using instrumental numeric evaluations.

MATERIAL AND METHODS

The material of this study is the three different white tone, each type has three different grammage, melamine formaldehyde impregnated decor paper laminated particleboards. A total of 90 samples (ten samples for each condition in each decor paper grammage) were prepared according to the standard of TS EN 14323, and conditioned at 20 ºC and 65% relative humidity. The small samples were subjected to; water vapor, coffee, water, ethyl alcohol and acetone treatment according to TS EN 14323 standard, to numerical assesment of stability of surfaces against discolorations. The optical properties of CIE C* (Chromacity), chromacity difference (ΔC), h^0 (hue) and CIE XYZ tristimulus and yellowness index were selected for surface color changes. Color analysis in the study was measured automatically with the help of X-Rite 962 (Grand Rapids, Michigan) spectrophotometer. The spectrometric measurements can help to describe the laminated surface colors and all the peculiarities on the surface of materials. Hence, the spectrophotometer measurements ertified the color properties of substrates. The numerical representation color value can be obtained by the cylindrical values: of the C* saturation and the hue angle on the colour circle around the lightness axis in the CIE $L^*C^*h^0$ representation. However, depending on the color value the h angle can move its value around the colour circle from 0^0 and 359^0 from red to violet -red following the trigonometric direction. A positive sign indicates a counterclockwise change of hue, a negative sign a clockwise change. The hue and chromacity (C*) could be calculated with equations 1 and 2 correponding color coordinates of a* and b*.

$$C_{ab} = \sqrt{a^2 + b^2} \qquad (1)$$

$$h_{ab} = a\tan(b/a) \qquad (2)$$

Where: a and b* are color coordinates*

The CIE XYZ color space was defined by CIE (Commission Internationale de l'Éclairage) in 1931, which is widely used color descriptions in material science. However, it is an additive-scheme color space and generally called “tristimulus color space”. In this method, the three primary colours are non-monochromatic with a dominant wavelength of:

- in the blue part 465 nm (Z stimuli),
- in the yellow-green 545 nm (Y stimuli)
- in the red part 640 nm (X stimuli)

The yellowness index WI is calculated from the following equations:

$$WI = Y + 800\,(xn - x) + 1700\,(yn - y) \qquad (3)$$

Where, WI is the yellowness index, Y the tristimulus value and xn, yn the chromaticity coordinates

However, one of the most commonly used apparatus to measure surface luster/shiny is glossmeter, which measures the ratio of specular reflection to diffuse reflection in angles, 60° with respect to the surface. Gloss properties of the samples were determined in accordance with the ASTM D 523 standard using the Pacific Scientific, Glossgard II 60° gloss meter device (Lansing, MI), measuring at 60°.

Some code numbers, are used throughout the study given in Tables and Figures, are established to represent treatment conditions. These are: A, B and C: the type of laminated decor paper, 80-, 90 and 110: the grammage of laminated decor paper on particleboard surfaces, 0: control, I: water vapor treatment, II: coffee treatment, III: water treatment, IV: alcohol treatment and V: Acetone treatment.

The data obtained in the study were statistically evaluated. IBM SPSS version 22.0 was used to analyse the data (SPSS 2013). One-way ANOVA was made for the study data. The results obtained were compared using the Duncan test. As a result of the analysis, the groups in each table were compared among themselves. The letters in parentheses in the tables represent the differences between the groups. Analyses were performed at 95% confidence level.

RESULTS AND DISCUSSIONS

Chromaticity or color purity is an objective specification of a color regardless of its luminance. It has consisted of two color parameters (CIE a* and b*) often specified as hue (h). For the controls, there is marginally differences between those decor papers which A-types has the chromacity values at around 2.20 (± 0.5), C-types has the chromacity values at around 4.10 (± 1.0) and B-types has the chromacity values at around 6.90 (± 1.0). However, the surface treatments appeared to marginal impact for changes <± 1.0 point in all paper types and grammages, regardless of treatments. On the other hand, we calculated those changes from counterpart controls, and given in Figure 1, comparatively. It could be seen that there is both way changes in either increase (+%) or decrease (-%) chromacity. But it is worth to note that the considerably differences, which might be perceived by human (> 10.0 point) were found with alcohol (A_{80IV}: 17.90%) and acetone (A_{80V}: 21.41%) treated A-type 80 gr/cm^2 decor paper laminated samples and acetone treated (C_{90V}: -10.29%) C- type 90 gr/cm^2 decor paper laminated samples while rest of show lower chromacity changes in either or decrease regarding counterpart controls, regardless of treatment conditions, type of laminated decor papers.

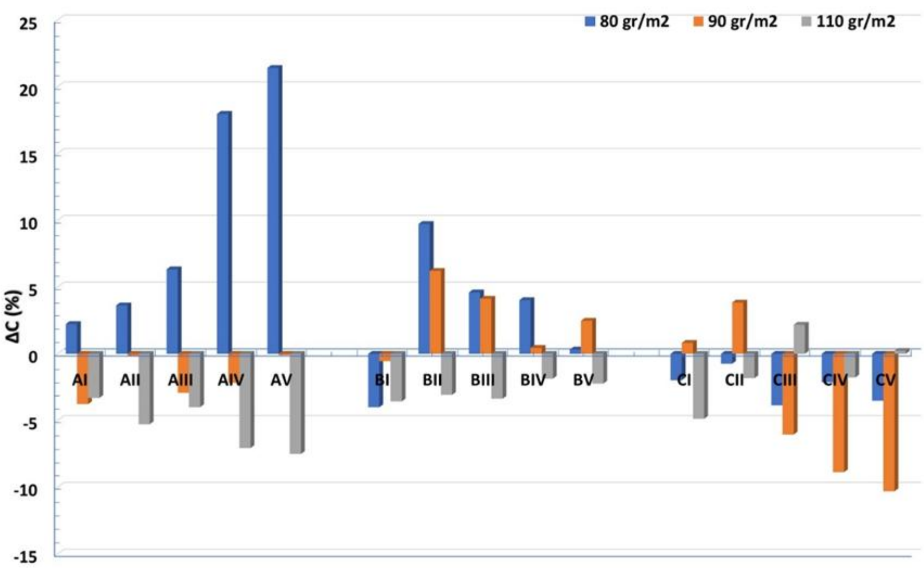

Figure 1. The chromacity difference (ΔC %) of samples

In color theory, hue is one of the main parameter to define color. Typically, it refers to corresponding to an angular position around a color space coordinate diagram. Colors with the same hue could be distinguished with adjectives referring to their lightness or colorfulness. Therefore, besides color coordinate parameters, it is usually used with other color parameters, especially chroma (saturation or purity) to evaluate exact color properties. For example, light yellow, pastel yellow, vivid yellow all might have similar hue value but different chroma properties. In our study, although all three paper types regarded as white color, there is considerably hue roughly marked all measured hue values on color space, and shown in Figure 2, in order to roughly indicate hue differences for five different surface agent treatments. It could be realized that very low and negligible hue differences after surface treatments with all agents, which could not be visually perceived.

differences among samples. Initially, A-types of papers hue value was found to be at around 120^0 (± 5.0), B-type of papers hue value was found to be at around 84^0 (± 2.0), and C-types of papers was found to be at around 102^0 (± 2.0). Those values clearly indicate some level differences among decor paper samples, regarding white color properties. Like chromacity properties, except sample treated with alcohol and acetone in 80 gr/cm^2, A-type paper which show Δh_{80IV}: 5.11^0 and Δh_{A80V}: 5.16^0 differences from counterpart controls, rest of the samples show only marginally changes in terms of hue, for all treatment conditions (<± 3.0 degrees). We have

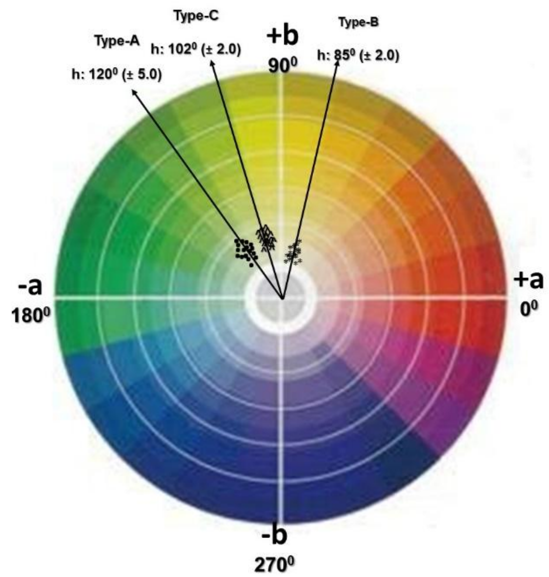

Figure 2. The hue (angle) properties of samples

Gloss is an optical property which indicates how well a surface reflects light in a specular (mirror-like) direction, which specifies how shiny the appearance of an object is perceived by an observer. It is one of the important parameters that are used to describe the visual appearance of materials. Table 1 shows the gloss properties of controls and samples, which is after five different surface treatments. It is notable that A- and B-type decor papers are classified as high-gloss (>100 Gu) while C-type decor paper is low-gloss (<20 Gu), although their other color properties are similar to each other. It is noticeable that almost all A- and B-type decor paper coated samples show similar, or some level lowering surface gloss properties compare to counterpart controls. For A-type (high gloss) decor papers, the lowest gloss value of 98.66 Gu with coffee treatment, followed by 100.48 Gu with water vapor treatment in 110 gr/cm2 decor papers. For B-type (high gloss) decor papers, the lowest gloss value of 88.40 Gu was found with water vapor treatment in 90 gr/cm2 followed by 101.98 Gu with ethyl alcohol treatment in 80 gr/cm2 decor papers. For C-type (low gloss) decor papers, the lowest gloss value of 14.60 Gu was found with acetone treatment in 90 gr/cm2. Interestingly, surface treated all C-type 110 gr/cm2 decor paper surfaces show some level higher gloss values than counterpart control samples, which is the highest gloss value of 21.18 Gu was found with water vapor treated sample.

Table 1. Gloss properties of samples

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

	80 gr/cm^2			90 gr/ cm^2			110 gr/ cm^2		
Samples	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
0	108.82(f) (1.08)	108.06(f) (0.98)	17.32(e) (0.33)	108.98(b) (0.61)	110.76(f) (0.45)	15.52(f) (2.16)	107.84(f) (2.10)	107.2(d) (1.33)	17.77(a) (0.44)
I	101.96(a) (1.39)	104.72(e) (1.75)	17.56(f) (0.18)	106.5(a) (1.11)	88.4(a) (9.57)	15.16(d) (2.43)	100.48(b) (1.85)	104.86(b) (1.61)	21.18(f) (0.13)
II	106.3(e) (0.76)	103.72(b) (2.29)	16.88(c) (0.16)	109.16(c) (0.34)	104.8(c) (1.03)	14.88(b) (0.16)	98.66(a) (3.36)	102.68(a) (1.23)	19.6(b) (0.39)
III	105.92(d) (0.43)	104.7(d) (0.73)	17.12(d) (0.08)	109.18(d) (1.48)	105.44(d) (0.87)	15.32(e) (1.02)	107.16(d) (0.40)	106.52(c) (0.84)	19.94(d) (0.19)
IV	104.8(c) (1.93)	101.98(a) (1.03)	16.7(b) (0.36)	110.66(f) (0.44)	106.78(e) (0.83)	14.9(c) (0.62)	107.76(e) (0.57)	107.58(f) (0.93)	19.95(e) (0.15)
V	103.8(b) (1.51)	104.6(c) (0.80)	16.6(a) (0.39)	109.44(e) (0.85)	104.64(b) (1.21)	14.60(a) (0.39)	107.0(c) (0.63)	107.5(e) (0.68)	19.90(c) (0.27)

For surface colors, yellowness is an important colorimetric characteristic, as a whiter appearance is always associated with cleanness, freedom from contaminants, and good quality (Wei et al. 2017). Yellowness index (WI) is generally used for measuring any near-white materials, which is a number that represents how white that sample is. Table 2 shows the white color change of three different type within each has three different grammages of samples after five different agent treatments. Initially, it appears to B-type has the highest yellowness values (WI_{B0}: 9.70 to 10.48) followed by C-type (WI_{C0}: 5.23-6.03) and A-type (WI_{A0}: 2.17-2.33). The surface treatments impact on white color changes either increase or decrease compared to controls. The lowest WI value of 1.98 (metric) was found with water treated A-type 90 gr/cm^2 sample (WI_{A90III}: 2.18), WI: 4.50 (metric) was found with acetone treated C-type 90 gr/cm^2 sample (WI_{C90V}: 4.50), and WI: 9.35 (metric) was found with water vapor treated B-type 110 gr/cm^2 sample (WI_{B110I}: 9.35), in that order. However, all those values indicated negligible yellowness changes for all conditions, regardless of type of- or grammage of laminated papers. Therefore, it could be reasonably to suggest that the White color properties of samples have not changed considerably with selected surface treatment agents.

Table 2. Yellowness (Index) properties of samples

	80 gr			**90 gr**			**110 gr**		
Samples	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
0	2.17(a) (0.18)	10.31(b) (0.15)	5.55(f) (0.25)	2.18(f) (0.24)	10.48(c) (0.09)	5.23(c) (0.22)	2.33(f) (0.15)	9.70(f) (0.18)	6.03(e) (0.23)
I	2.26(b) (0.12)	9.86(a) (0.47)	5.42(e) (0.10)	1.99(b) (0.08)	10.37(a) (0.10)	5.41(e) (0.12)	2.24(e) (0.13)	9.35(a) (0.10)	5.66(a) (0.11)
II	2.30(c) (0.10)	11.32(f) (0.11)	5.50(a) (0.03)	2.11(e) (0.13)	11.08(f) (0.30)	5.46(f) (0.06)	2.14(c) (0.12)	9.40(c) (0.06)	5.87(c) (0.12)
III	2.43(d) (0.04)	10.78(e) (0.30)	5.28(b) (0.12)	1.98(a) (0.06)	10.86(e) (0.19)	5.0(b) (0.35)	2.19(d) (0.04)	9.37(b) (0.16)	6.15(f) (0.07)
IV	2.85(e) (0.19)	10.72(d) (0.14)	5.40(d) (0.15)	2.02(c) (0.10)	10.46(b) (0.19)	5.30(d) (0.14)	2.05(b) (0.09)	9.52(e) (0.20)	5.86(b) (0.05)
V	2.96(f) (0.42)	10.33(c) (0.19)	5.30(c) (0.21)	2.09(d) (0.12)	10.68(d) (0.17)	4.50(a) (0.50)	2.02(a) (0.12)	9.48(d) (0.15)	6.0(d) (0.12)

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

Visual appearance of laminated wooden products are very important characteristics, and numerous efforts have been made to quantify it in woodworking industry, since it is an indication of the quality of the wooden products (Jonsson et al. 2008, Muğla 2010, de Morais and Pereira 2015, Bhatta et al. 2017, Miao et al. 2024, Beglen 2024). However, the appearance of an object, like decor paper coated wooden products, is the result of complex interactions between light, surface, and the perception of the observer. Therefore, it is very difficult to describe or determine with one single method the appearance of wooden substrates. In this context, there are various methods and instruments to quantify different appearance components, which can be numerical measurements are suggestive with or without visual perceptions.

In Table 3, the red sitmuli (X) values of samples laminated with three different types of white decor papers which each has three different grammages which subjected to five different surface treatment agents are shown in comparatively. Like other optical properties presented above, a similar trend was also observed with X stimuli, very low range changes were usually observed compare to counterpart controls. The highest X stimuli was found in A-type 90 gr/cm^2 water treated sample (XA_{90III}: 86.14), while the lowest X sitmuli value of X_{B0110}: 78.26 (metric) with B-type 110 gr/cm^2 control decor paper laminated sample.

Table 3. X stimuli properties of samples

	80 gr			**90 gr**			**110 gr**		
Samples	A	B	C	A	B	C	A	B	C
0	82.61(a) (0.35)	79.82(a) (0.21)	81.77(a) (0.20)	82.40(a) (0.30)	79.69(a) (0.18)	81.94(e) (0.16)	81.58(a) (0.27)	78.26(a) (0.46)	82.53(a) (0.39)
I	83.55(f) (0.11)	80.53(f) (0.22)	82.31(b) (0.18)	84.42(e) (2.18)	80.58(b) (0.40)	82.29(f) (0.16)	82.96(f) (0.21)	78.35(c) (0.25)	83.25(b) (0.27)
II	82.74(c) (0.08)	79.92(b) (0.21)	82.54(e) (0.13)	83.07(d) (0.09)	80.62(c) (0.14)	81.74(d) (1.17)	82.22(c) (0.17)	78.34(b) (0.08)	83.52(c) (0.09)
III	82.91(d) (0.17)	80.18(e) (0.12)	82.41(c) (0.18)	86.14(f) (4.67)	80.73(d) (0.21)	81.61(c) (1.97)	82.28(d) (0.15)	78.45(e) (0.28)	83.8(e) (0.15)
IV	82.91(d) (0.15)	80.06(c) (0.10)	82.41(c) (0.29)	82.89(c) (0.22)	80.89(e) (0.17)	81.21(a) (1.16)	82.18(b) (0.20)	78.44(d) (0.25)	83.25(b) (0.09)
V	82.65(b) (0.32)	80.07(d) (0.31)	82.47(d) (0.31)	82.79(b) (0.25)	80.95(f) (0.20)	81.27(b) (1.03)	82.29(e) (0.29)	78.55(f) (0.08)	83.55(d) (0.38)

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

In Table 4, the yellow stimuli (Y) values also show marginal changes after surface treatments. Initially around 3.0 units differences among control samples, the grammage appear to not influence the Y stimuli values in all three type decor papers. However, the highest Y stimuli value of 88.93 (metric) was found with coffee treated 110 gr/cm^2 decor paper laminate sample Y_{C110II}: 88.93 (metric) while the lowest Y stimuli value of Y_{B110}: 82.17 (metric) with B-type 110 gr/cm^2 control decor paper laminated sample.

Table 4. Y stimuli properties of sample

	80 gr			90 gr			110 gr		
Samples	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
0	87.72(a) (0.36)	83.94(a) (0.21)	86.69(a) (0.21)	87.48(a) (0.34)	83.05(a) (0.19)	86.96(e) (0.15)	86.63(a) (0.31)	82.17(a) (0.48)	87.57(a) (0.41)
I	88.71(f) (0.13)	84.59(e) (0.18)	87.26(b) (0.19)	88.57(f) (0.21)	84.49(b) (0.49)	87.25(f) (0.17)	88.07(f) (0.22)	82.45(d) (0.39)	88.36(b) (0.29)
II	87.86(c) (0.09)	85.81(f) (4.32)	87.50(f) (0.13)	88.21(e) (0.09)	86.52(e) (4.54)	86.50(d) (1.50)	87.29(c) (0.17)	82.37(b) (0.23)	88.93(f) (0.09)
III	88.01(d) (0.19)	84.24(d) (0.11)	87.37(c) (0.18)	88.08(d) (0.20)	84.63(c) (0.21)	86.37(b) (1.41)	87.36(d) (0.15)	82.46(e) (0.28)	88.70(e) (0.16)
IV	88.04(e) (0.15)	84.07(b) (0.10)	87.39(d) (0.29)	88.03(c) (0.24)	84.84(d) (0.16)	86.39(c) (1.50)	87.27(b) (0.18)	82.38(c) (0.25)	88.37(c) (0.09)
V	87.77(b) (0.33)	84.15(c) (0.30)	87.44(e) (0.31)	87.92(b) (0.26)	86.90(f) (4.42)	86.24(a) (1.22)	87.38(e) (0.31)	82.50(f) (0.08)	88.69(d) (0.40)

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

In Table 5, the initial blue stimuli (Z) values appeared to be considerably different among three different types of white decor papers. The A-types decor papers have the highest Z values of, in range of Z_{A0}: 90.11-91.41 (metric) followed by C-type decor papers in range of Z_{C0}: 87.34-87.89, and B-type decor papers in range of X_{B0}: 79.47-80.34. However, the grammage seems to not be influenced the Z stimuli, which is marginally in the similar values noted. Moreover, surface treatments have only marginally influenced on Z stimuli values in all five different surface agent treated samples.

Table 5. Z stimuli properties of samples

	80 gr			90 gr			110 gr		
Samples	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
0	91.41(c) (0.29)	80.34(b) (0.10)	87.34(a) (0.36)	91.14(a) (0.37)	80.18(a) (0.20)	87.89(e) (0.10)	90.11(a) (0.44)	79.42(a) (0.54)	87.79(a) (0.35)
I	92.36(f) (0.18)	81.60(f) (0.55)	88.05(b) (0.22)	92.46(f) (0.17)	81.07(c) (0.46)	88.01(f) (0.18)	91.70(f) (0.28)	79.79(c) (0.30)	88.92(c) (0.28)
II	91.43(d) (0.09)	79.56(a) (0.29)	88.21(d) (0.14)	91.97(b) (0.21)	82.47(f) (4.59)	87.61(d) (0.96)	90.99(b) (0.22)	79.79(c) (0.06)	89.08(f) (0.19)
III	91.48(e) (0.20)	80.45(c) (0.26)	88.28(e) (0.22)	91.95(e) (0.16)	80.78(b) (0.29)	85.68(a) (2.55)	91.02(c) (0.15)	79.90(d) (0.10)	89.04(e) (0.18)
IV	91.11(b) (0.27)	80.57(d) (0.18)	88.18(c) (0.42)	91.87(d) (0.16)	81.32(e) (0.14)	87.38(c) (1.20)	91.04(d) (0.13)	79.59(b) (0.65)	88.74(b) (0.13)
V	90.73(a) (0.70)	80.75(e) (0.24)	88.32(f) (0.37)	91.69(c) (0.18)	81.20(d) (0.21)	86.72(b) (1.59)	91.18(e) (0.22)	79.94(e) (0.19)	88.93(d) (0.34)

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

In order to evaluate all tristimulus changes (%) from controls, the measured values were subtracted from counterpart control samples and plotted in Figure 3a for 80 gr/cm^2 decor papers, in Figure 3b for 90 gr/cm^2 decor papers, and Figure 3c for 110 gr/cm^2 decor papers, in that order. It appeared to there is only marginally tristimulus changes (<± 3.0%) in 80 gr/cm^2 decor paper laminated samples after five different surface treatments. The highest changes either increase or decrease were noted with B-tye decor paper laminated surfaces for Y and Z stimulus, which are treated with coffee (Y_{B80II}: 2.24%; Z_{B80II}: -1.26%). However, more aggressive tristimulus changes were observed (%) in 90 gr/cm^2 decor paper laminated samples. The highest stimuli change value of X_{A90I}: 4.51% was found with A-type water treated sample, followed by Y_{B90I}: 3.40% with B-type water treated sample, and X_{A90I}: 2.44% with A-type water vapor treated sample, while rest of show only marginally changes (<± 1.5%), regardless of treatment conditions and lamination types. In 110 gr/cm^2 decor paper laminated samples, the highest stimuli changes were found with water vapor treated A-type of decor paper samples (X_{A110I}: 1.68%; Y_{A110I}: 1.66%, Z_{A110I}: 1.76%). The water treated C-type decor paper sample has also shown X stimuli changes of $X_{C110III}$: 1.56%, while rest of samples show <1.5% tristimulus changes.

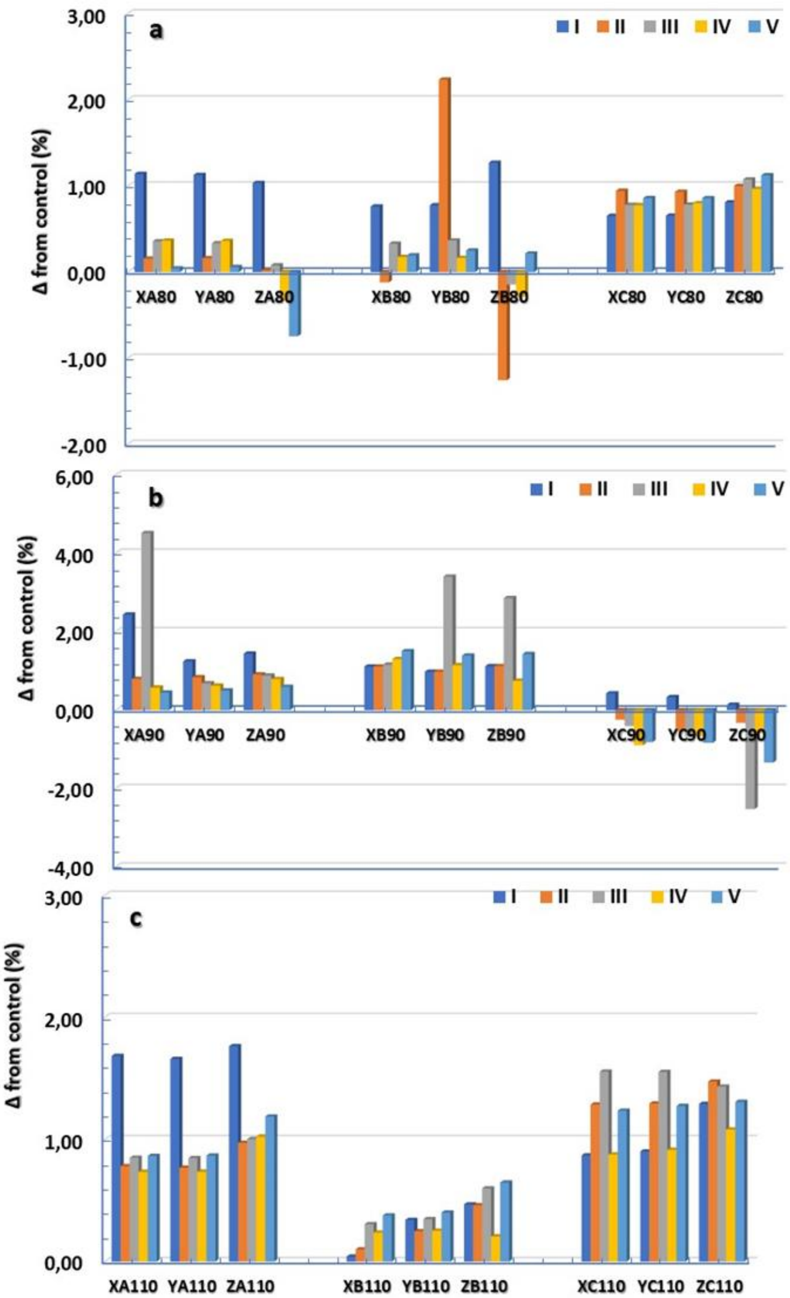

Figure 3. The trisitmulus differences (ΔXYZ, %) from controls (a: 80 gr/cm2 decor paper laminated, b: 90 gr/cm2 decor paper laminated, c: 110 gr/cm2 decor paper laminated)

CONCLUSIONS

There are numerous studies in the field of optical behaviors of material surfaces with different textures, and also different methods to investigate surface properties. However, most of the investigations have described the relationship between color and perception in a qualitative approach rather than quantitative. The cost-effective decor paper lamination techniques are one of the selective parameter that could be evaluated together with expected performance characteristics in laminated composite characteristics. In this sense, the properties of the decor paper used in the lamination process with the preparation of the appropriate formulations for the decor paper impregnation process, decor paper-composite board lamination methods and the expected performance from those products are some of the important study subjects of the forest products industry.

In this study, the relation between surface color changes of three different types and each has three different gramamages decor paper laminated particleboard surfaces were evaluated after standard five different surface agent treatments. However, the perception of color is not simple, considering it is affected by the environment in the field of view of the observer. In this case, color perception can change by any changes in the spectral distribution or relative position of the light source, the object, or the observer. The results of this study indicate that the instrumental measurements of color (CIE XYZ), gloss and other optical properties (WI) are closely correlated to the visual perceptions in most cases. However, some level differences exist between the visual and instrumental color measurements, indicating a necessity for a more accurate measurement. Regarding this context, spectrophotometers are very sophisticated and accurate instruments could be utilized in changes in optical properties of visually important products, such as furniture and laminated wooden products.

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