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Investigation of the effects on ink colour of lacquer coating applied to the printed substrate in the electrophotographic printing system

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In this study, the effects of the lacquer applied to the printing materials which were printed by electrophotographic printing method on printing quality were investigated. In practice, printing materials with the same weight and different optical properties were used and the study was carried out in three stages. The optical and physical properties of the printing materials used in the first part were determined, in the second part, the printing of these materials by electrophotographic printing method and printability tests were performed. In the third chapter, matte and glossy lacquers were applied to these printed materials and printability tests were repeated. As a result of the study, it was observed that the application of gloss and matte lacquer caused a decrease in the printing density values and also the application of matte lacquer caused a decrease in the gloss values.

Keywords: Lacquer, Gloss, Printing, Paper, Electrophotography.

INTRODUCTION

The facts that technological innovations are increasing rapidly in today's world and the importance given to visually become more and more prominent day by day, as in all sectors, have become significant for the printing industry as well.

While the visual materials to be printed can be produced in the desired color values, not compromising on quality and allure is an important issue in the printing industry today. Innovations and advances in digital printing technologies have opened the door to developments in post-printing processes. There are post-printing applications working compatibly with electrophotographic printing machines[1].

Post-printing processes applied to protect the quality of the printed materials from external influences are very diverse and it is a known fact that these methods affect the print quality of traditionally produced printed materials positively or negatively[2]. Many methods are applied to protect the print quality against external factors such as humidity, sunlight, and heat, and during these processes[3], it is aimed to reflect the maximum amount of its proximity to reality. The most important issue at this stage is the proximity of the printed colors to reality[4].

Although digital printing technologies, which have made great progress in the past, have managed to reflect the maximum realism in the printed media thanks to the color management systems used, there is not enough study related to the effects of post-printing processes on the printing colors[5]. In this study, it is aimed to contribute to overcoming the deficit in this field by revealing the effects of lac printing, which is one of the post-printing applications, on the color quality of the images printed by the electrophotographic printing method.

Lacquer coating, which is one of the surface coating processes after printing, is carried out by transferring liquid lacquers onto the printed substrates[6]. Lacquers are divided into types as oil-based matt or glossy lacquers, water-based (dispersion) matt lacquers, semi-matt-semi-glossy lacquers, glossy lacquers and UV lacquers. Full or partial lacquer (spot lacquer) can be applied to the printed material. In addition, both the front surface and the back surface can be covered with lacquer.

Oil-based lacquers have high viscosity and do not contain pigments[1]. They can be applied in two different ways: matte and glossy. Adhesion properties of oil-based lacquers are strong and do not cause problems such as breakage after coating due to their flexible structures. They are water-resistant and allow partial application. They can be preferred for all types of weights.

Water-based or also called dispersion lacquers, have a fast drying feature and less yellowing properties compared to oil-based lacquers. Due to their fast-drying properties, they enable faster printing and easy stacking. Dispersion lacquers are divided into different types as matte lacquers, semi-matte-semi-gloss lacquers and shiny lacquers. Since they are water-based, they are less harmful to the environment[1].

UV lacquers consist of UV light sensitive and UV light-cured raw materials. UV lacquers are produced as low viscosity or high viscosity. They can be used in all printing systems and can be applied from the ink unit or a separate printing machine to the entire printed area or a specific area. Drying time is low and resistance is higher than dispersion lacquers[7].

In this study, we preferred water-based lacquers. Water-based lacquers can be cleaned with water, high gloss, adhesion on a healthy surface, high resistance to abrasion, fast-drying, etc. has many more advantages. In addition to these advantages, being environmentally friendly and cost-effective compared to other lacquers are the most important factors in choosing water-based lacquers in our study.

MATERIAL AND METHODS

Determination of optical and physical properties of substrates

In practice, materials were printed by using an electrophotographic printing machine. 170 gsm matte and glossy digital printing paper were used as substrates. The surface roughness was measured according to the ISO 8791-4 standard with the L & W PPS Tester, and the weight was determined by a precision scale according to the Tappi T 410 standard. Air permeability was measured with L&W Air Permeance Tester according to Tappi T 460 om-88 standard, and Gloss 60° measurement was made using BYK glossmeter according to ISO 2813 standard. Table 1 shows the optical and physical properties of the printing substrates used. When using paper types, matte papers were shortened to MP, glossy papers to GP, matte lacquer application to ML and gloss lacquer application to GL.

Application of lacquer

In the lacquer application, a laboratory type paper coating machine has been used and its speed is 2 m/min at 21 x 29.7 cm^2. Mayer Rod Number 2 coating rod is used. As the coating material, Sunchemical brand, double-faced gloss lacquer, which can be used in products such as magazines and catalogs, is used. Its viscosity is 32 (Figure 1–2).

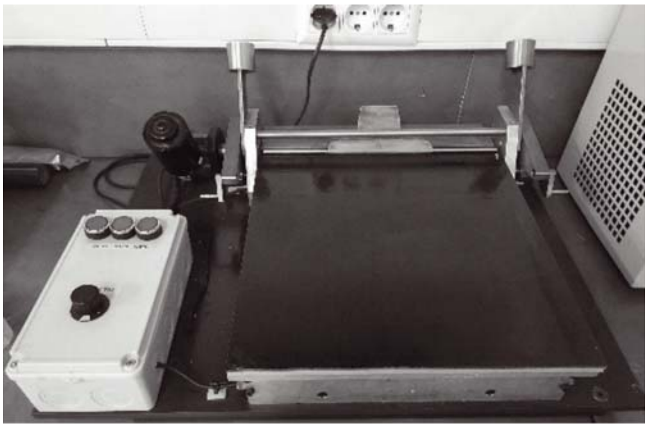


Figure 1. Laboratory paper coating machine

Figure 2. Mayer Rod Number 2 coating bar

Printability

The IT8 7/3 test scale was printed on the test materials. The test scales were measured before and after the lacquer application, using the X-Rite i1Profiler program and color universes were determined. By using BYK glossmeter, gloss values were determined. L*a*b* and density values were measured by X-Rite Exact standard spectrophotometer[8].

RESULTS AND COMMENTS

Print Density

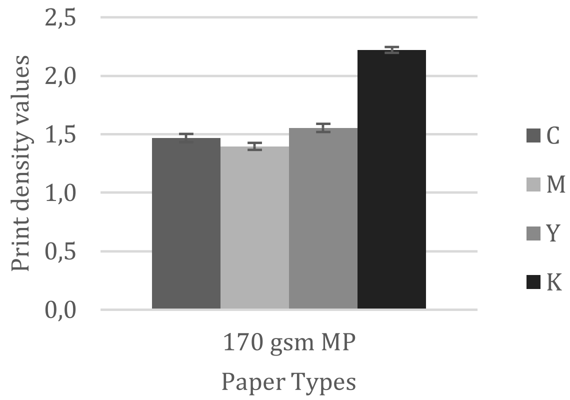
Print density refers to the ink laid on a sheet of paper. The print is the depth density from the substrate or a measure of how dark the print looks after its compression stroke. The more ink density you have, the darker the color. Conversely, less density, less ink, or lighter color comes. Ink density is measured by a machine called a densitometer.

The relationship is explained by the following formula[9]:

$$\text{Density} = \log10\ 1/\text{Reflectance factor} \quad \text{eq1.}$$

Reflectance is calculated by the function: R= Ir/Io.

In Figure 3, before the lacquer application, the printing density values measured over 170 gsm MP and 170 gsm GP are given. At the measured values, it is seen that matte and glossy coated papers have similar print density values.



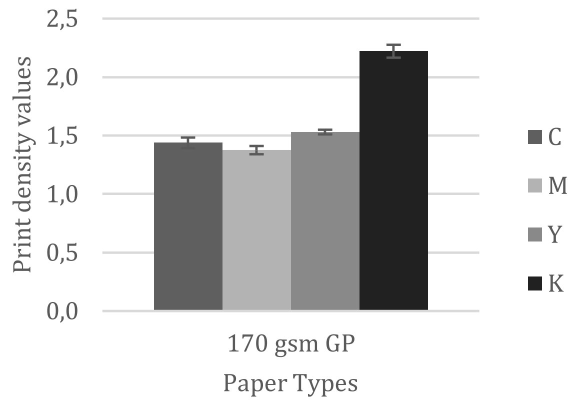


Figure 3. Printing density values before lacquer application

In Figure 4, the printing density values obtained after the application of matte lacquer on 170 gsm matte and 170 gsm glossy coated paper are shown. When these data were compared with the printing density values obtained before the lacquer treatment, it was observed that the printing densities of Cyan (C), Magenta (M),

Table 1. Optical and physical properties of substrates

Test Samples	Smoothness PPS 10 (μm)	Air permeability (ml/min)	Weight (gsm)
Matte Coated Paper	1.8	3.15	170
Glossy Coated Paper	0.8	1.59	170

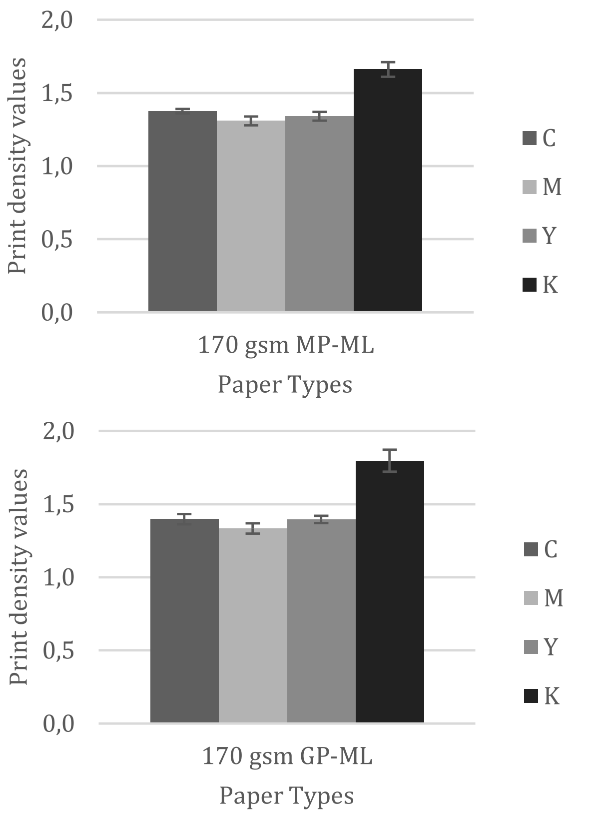


Figure 4. Printing density values after matte lacquer (ML) application

Yellow (Y) and Black (K) colors were decreased. Black was the color with the highest reduction in density.

Figure 5 shows the printing density values obtained after the application of gloss lacquer on 170 gsm matte and 170 gsm glossy coated papers. When these data were compared with the printing density values obtained before the lacquer treatment, it was observed that the printing density of the colors was reduced similar to the application of matte lacquer.

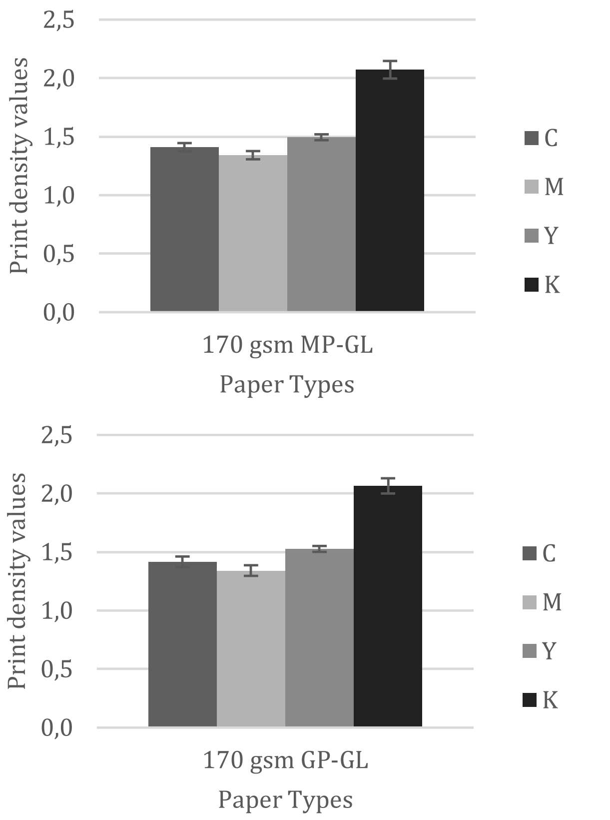


Figure 5. Printing density values after glossy lacquer (GL) application

Print Gloss

Gloss is one of the properties that define the optical properties of the paper surface. The printing gloss value often varies depending on the paper surface characteristics and the ink used[10]. For this reason, smoothness, air permeability and ink components have an important effect on the gloss[11]. The gloss value measured as a reflection value of the light falling on the surface varies depending on the angle of the light falling on the paper surface, the rate of perception of the light reflected from the surface by the people and the type of the incident light[12].

The numerical value resulting from the Gloss measurements is expressed as the Gloss Unit (GU); It is a scale based on measuring the mirror reflection at a specified angle in a highly polished black glass in 100 GU units. The gloss measurement angle changes as it looks different. The gloss obtained varies according to this measured angle[13]. While lower angles give more accurate results for higher gloss (> 70GU); For low gloss (<10GU), the device should be preferred over a higher angle value.

The relationship (Figure 6) is explained by the following formula[11]:

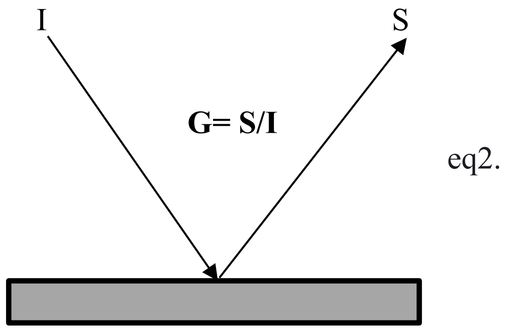


Figure 6. Reflection of incident light on the surface

High printing gloss is obtained when the paper surface is smooth. A smoother surface also increases the printing density by affecting the absorbency of the ink. The increase in the pore volume of the surface causes the ink to spread faster on the surface and therefore lower printing contrast[14].

The difference in gloss between the print gloss and the gloss of the paper is called delta gloss (ΔG)[15] and is calculated according to the formula given (G_{UU}= gloss unprinted, G_{UP}= gloss printed)

$$\Delta G = G_{up} - G_{up} \qquad \text{eq3.}$$

Higher gloss contrast results in glossy and surface smoothness of the paper.

Gloss 60^o values in Figure 7, 170 gsm matte and glossy papers printed using cyan toner, printed and matte lacquer after the application is shown with measurements. When the obtained values were examined, it was found that the printing gloss value obtained after printing was measured higher than the unprinted gloss value on matte paper, but there was a noticeable decrease in this value with matte lacquer application. In the gloss paper measurements, there was no difference between unprinted and printed gloss values, and there was a decrease in gloss value after matte lacquer application. The gloss value obtained is almost the same as the number after matte lacquer application on matte paper.

Gloss 60° values are shown in Figure 8 with measurements of 170 gsm matte and glossy coated papers after printing using cyan toner, unprinted and glossy lacquer application. When the obtained values were examined, it was found that the application of gloss lacquer gave a noticeable increase in gloss values for both matte and glossy paper.

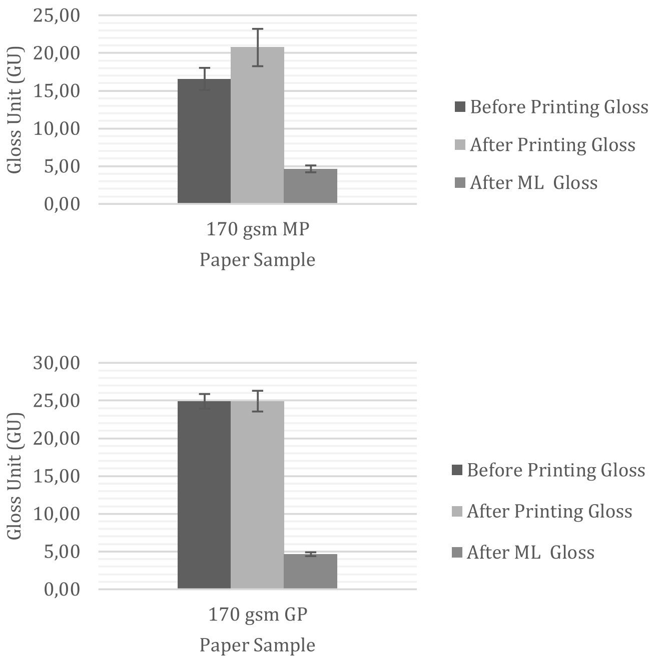


Figure 7. Gloss 60° values for cyan color after matte lacquer (ML) application

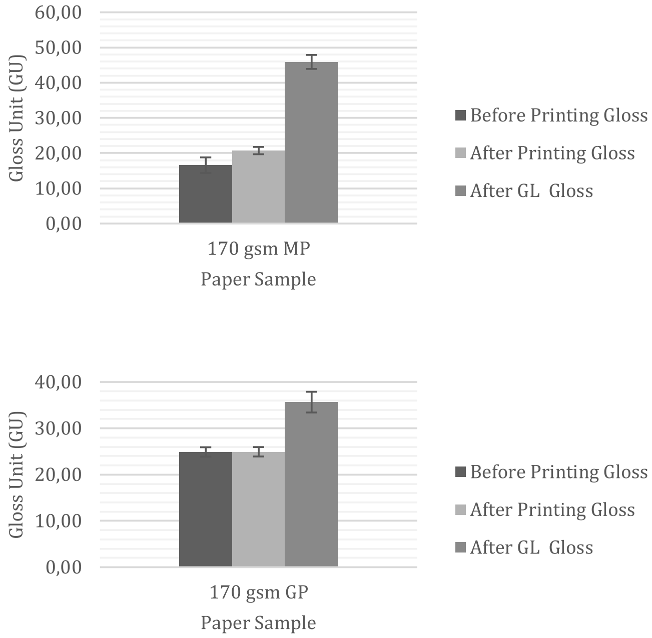


Figure 8. Gloss 60° values for cyan color after Gloss Lacquer (GL) application

Color Distance

Color distance indicates how far two colors in the color space are from each other. CIE L * a * b * calculations are based on the L * a * b * color universe. Using the CIE L * a * b *, the location of the standard color is precisely determined in the L * a * b * color universe with the measurement data. Then a theoretical tolerance sphere is drawn around this color[16]. This sphere indicates the amount of variation acceptable between the standard color and samples. Measurement data, samples remaining inside the sphere are acceptable. If the measurement data is the colors falling outside the sphere, it is unacceptable.

L-axis (from 0 to 100) defines the lightness of the color (dark color has a low L value, light color has a high value), the a-axis (–128 to 128) defines how green or red a color is (low value color greenish, high value reddish), the b-axis (–128 to 128) defines how blue or yellow a color is (low value color bluish, high value yellowish)[17] (Figure 9).

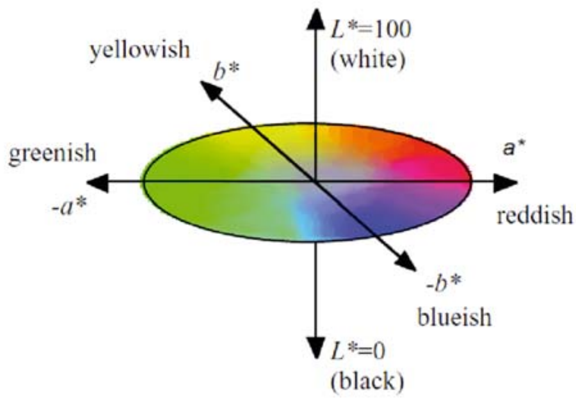


Figure 9. CIE L*a*b* color space[18]

ΔE is calculated using the following equations[19]:

$\Delta L^* = L^*\ \text{actual} - L^*\ \text{target}$ eq4.

$\Delta a^* = a^*\ \text{actual} - a^*\ \text{target}$ eq5.

$\Delta b^* = b^*\ \text{actual} - b^*\ \text{target}$ eq6.

$$\Delta E^* = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad \text{eq7.}$$

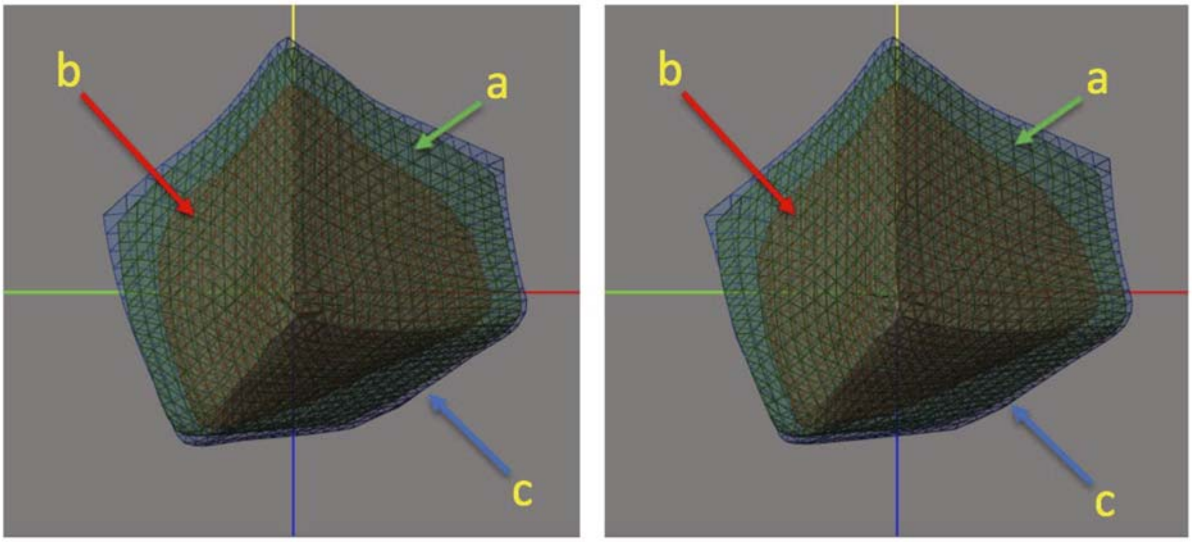
ΔE (margin of error) is used as the unit of measure of color difference. Usually values between 1 and 6 ΔE are accepted as customer tolerance in the reproduction industry. (ΔE) if the difference between colors is greater than 1, this difference can be recognized by the human eye. Differences of up to 2–4 ΔE are not easily distinguishable from the standard color by most observers. In the printing industry, the ΔE standard is preferred to be between 2–3. ΔE values other than these values mean that the desired color value is moved too far.

Table 2 shows the ΔE units obtained by comparing 170 gsm matte and glossy coated papers with values after matte lacquer or gloss lacquer application. When the average ΔE values are examined, it is seen that all values are higher than ΔE 1. The application of bright lacquer made a difference on the color values, but the obtained ΔE values were within acceptable limits. However, the ΔE values measured after matte lacquer application were outside the acceptance limits.

In the graph on the left in Figure 10, the color universes obtained after the application of matte lacquer or gloss lacquer on the matte paper, and the color universes obtained after the application of matte lacquer or gloss lacquer on the glossy paper are shown in the

Table 2. ΔE values after matte lacquer and gloss lacquer application

Paper Samples	170 gsm MP-GL	170 gsm MP-ML	170 gsm GP-GL	170 gsm GP-ML
Average ΔE	2.88	7.48	2.55	7.23
Maximum ΔE	8.81	22.63	9.74	21.91



a: Lacquer-free printing, **b:** Matte lacquer application, **c:** Glossy lacquer application

Figure 10. Color universes after matte and glossy lacquer application

graph on the right. The application of gloss lacquer did not cause much change in the color universes in both paper types, but after the application of matte lacquer, there was a noticeable shrinkage in the color universes.

CONCLUSION

In this study, it has been observed that the application of lacquer coating, one of the protection methods applied to printed materials, has negative effects on the colors of printing. According to the results obtained;

The printing density values measured before the application of lacquer were similar for 170 gsm Matte Coated Paper (MP) and 170 gsm Glossy Coated Paper (GP). Density values measured after matte lacquer and glossy lacquer application decreased.

The gloss values obtained after printing were high on 170 gsm matte paper, but this value decreased after matte lacquer application. The gloss values before and after printing were almost the same on glossy paper, whereas matte lacquer application negatively affected these values. However, the glossy lacquer applied on both matte and glossy paper increased the gloss values considerably. When ΔE values are considered; Although the effect of the application of gloss lacquer on color values, ΔE values were observed to be within acceptable limits for printing. However, the ΔE values obtained after the matt lacquer treatment were found to be above the acceptance limits. Differences in color values occurred.

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