The Scientific Temper (2024) Vol. 15 (1): 1755-1758
E-ISSN: 2231-6396, ISSN: 0976-8653
Doi: 10.58414/SCIENTIFICTEMPER.2024.15.1.24
https://scientifictemper.com/

RESEARCH ARTICLE

Comparative study of color difference on coated and uncoated paper in digital printing

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Abstract

Digital printing is most prominent printing approach that facilitates numerous advantages. Coated and uncoated media are the most commonly used substrates for conventional and digital printing. The coated and uncoated paper media exhibit different surface characteristics and behave according to print quality. So, evaluating and comparing print quality attributes on these paper substrates is necessary. The color difference is the significant mismatch and evaluation of the accuracy of color while printing. Hence, understanding color differences on coated and uncoated media is crucial aspect. This present analysis is to carry out a comparative study of color differences in digital printing on coated and uncoated paper.

Keywords: Color difference, Digital Printing, Coated Paper, Uncoated Paper, HP Indigo.

Introduction

Digital printing offers many advantages over conventional printing approaches, including its flexible and versatile nature. The greatest advantages lie in these masterless technologies (Rossitza Sardjeva, 2013), which has eliminated many intermediate steps required for conventional printing (Coppel *et al*., 2014). Such printing methodologies offers digitized data printing in one complete cycle required for getting one impression which consists of imaging, inking, applying toner, fixing and cleaning process (Metcalf & Wright, 1957). Although despite of such a sophisticated approach color variation is also observed during printing, known as color difference (Jangra *et al*., 2023). This color difference is denoted by ΔE, providing a significant mismatch while evaluating print quality. The importance of finding out the accuracy of printing cannot be ignored. This is a standard measurement approach based on CIE L*a*b* Space (Cinko & Becerir, 2019) and used for quantification of color difference (Kendal *et al*., 2013) either printed or digital screen (Burns, 1997). This method was developed by the CIE acronym for Commission Internationale de'Eclairage (Fairchild, 2013), an International Commission on Illumination.

*CIE L*a*b* Color Space*

This model, also known as the CIE lab color model, was developed in 1976 by CIE. This uniform color model (Wei *et al*., 2017) deals with all the applications based on subtractive color mixing. As the name suggests, this model consists of three dimensions (shown in Figure 1: CIE L*a*b* Color Model) namely L (Value: 0 to 100, 0: Black and 100: White), a* (-100: Green to +100: Red, also called Red-Green axis) and b* (-100: Blue to +100: Yellow, also called Yellow-Blue axis) for representation and quantification of color.

Finding ΔE

ΔE termed as delta E or color difference calculated ("Precise Color Communication," n.d.) on the colorimetric values of ΔL (difference in lightness), Δa* (difference between printed color and standard color on a-axis) and Δb* (difference between printed color and standard color on b-axis) as shown:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

ΔE Equation (Courtesy of http://zschuessler.github.io/DeltaE/learn/)

ΔE or color difference value ranges from zero to one hundred, which means the least color difference to highly distorted. Lower color difference (Roy Choudhury, 2015) value represents higher accuracy and higher indicates the level of mismatch.

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How to cite this article: Jangra, V., Kumar, P., Vandana. (2024). Comparative study of color difference on coated and uncoated paper in digital printing. The Scientific Temper, **15**(1):1755-1758.

Doi: 10.58414/SCIENTIFICTEMPER.2024.15.1.24

Source of support: Nil

Conflict of interest: None.

Received: 08/01/2024 **Accepted:** 28/01/2024 **Published** : 15/03/2024

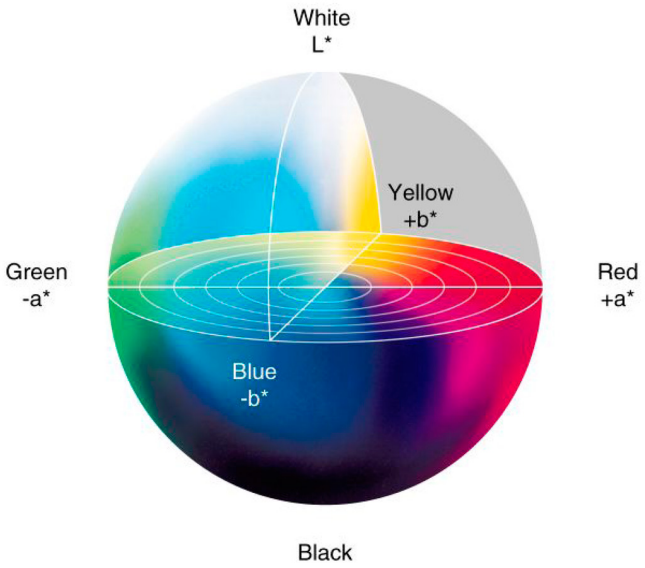

Figure 1: CIE L*a*b* color model (Image courtesy:www.mdpi.com)

Objectives of Study

Coated and uncoated paper substrates are commonly used for numerous applications. In order to compare the color difference exhibited on these media, this study was carried out on HP Indigo digital print engine. Key objective is to find ΔE value and draw comparative analysis on coated and uncoated paper.

Research Methodology

Color differences (ΔE Value) is common aspect to differentiate significant mis match. In order to find the color difference on coated and uncoated media, a master chart (test chart) was developed by incorporating numerous technical elements from printing perspective. HP Indigo digital print engine was used for printing on coated and uncoated media. Royal Matt paper as coated paper and super print paper as uncoated media were used as substrate. After calibrating the printing engine and maintaining the optimum surrounding (press standard) conditions the printing on both (coated and uncoated media) was done. In order to carryout colorimetric measurement, x-Rite i1 Pro Spectro-densitometer was used under standard lighting conditions after proper calibration. The data for primary (R, G, B) and process (C, M, Y, K) colors were recorded for further analysis.

Data Analysis

For identifying color difference (ΔE Value) in digital printing for primary (R, G, B) and process (C, M, Y, K) color, HP indigo digital print engine was used and media included coated and uncoated paper. The analysis of data is represented as below:

Color difference of cyan color

The finding of ΔE value on coated and uncoated paper using HP Indigo digital print engine are represented in Figure 2. During observation, the range of ΔE value on coated paper and uncoated paper were found in the range of 2.67 to 4.02 and 5.96 to 7.26, respectively. It was observed that the color difference value for uncoated paper, i.e., super print paper substrate, was higher than coated paper, i.e., royal matt paper.

Color difference of magenta color

HP Indigo results for ΔE value for magenta color on coated paper and uncoated paper are depicted in Figure 3. Observation revealed that ΔE values in coated paper are higher than uncoated paper and were found in the range 6.83 to 7.96 and 4.96 to 6.7, respectively. Although the difference between the range on coated and uncoated paper is less in case of magenta color.

Color difference of yellow color

The ΔE values of yellow color on coated and uncoated paper using HP Indigo digital print engine is represented in Figure 4. The finding revealed that ΔE values on royal matt paper (coated paper) were higher than super print (uncoated paper). The range observed for coated paper and uncoated paper was 13.81 to 15.21 and 4.89 to 7.17, respectively.

Color difference of black color

Figure 5 represents the color differences exhibited by HP Indigo digital print engine for black color on royal matt paper (coated paper) and super print (uncoated paper). The range of color difference observed was 2.03 to 3.75 and 0.44 to 1.3 for coated and uncoated paper, respectively. Less color difference for black color was exhibited by uncoated paper in the case of black color. Also, haphazard behavior was observed in case of black color.

Color difference of red color

The reference observation of color difference for red color on coated and uncoated paper found that more color difference was exhibited in case of uncoated, i.e., super print paper, as depicted in Figure 6. The range for ΔE value on coated and uncoated paper was found 4.06 to 5.7 and 11.12 to 13.77, respectively. However, a linear line was observed on both paper substrates without much variation.

Color difference of green color

The results of ΔE value for green color on royal matt paper (coated paper) and super print (uncoated paper) using HP indigo digital print engine are presented in Figure 7. The range of ΔE value was found 9.55 to 13.18 on super print paper and behaviour for green color was non-uniform with lot of variations at different points. Although ΔE value on coated paper was in 6.57 to 8.62 and, uniform movement was observed.

Color difference of blue color

Observations of ΔE value on royal matt paper (coated paper) and super print (uncoated paper) using HP indigo digital

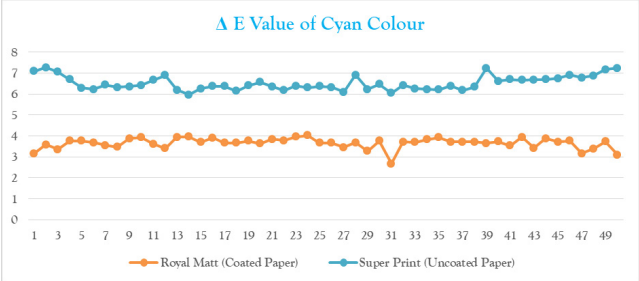

Figure 2: Cyan color on coated (Royal Matt) and uncoated paper (Super Print)

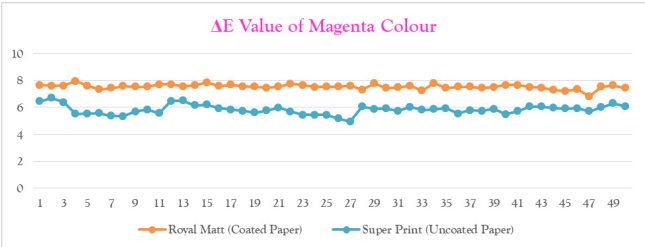

Figure 3: Magenta color on coated (Royal Matt) and uncoated paper (Super Print)

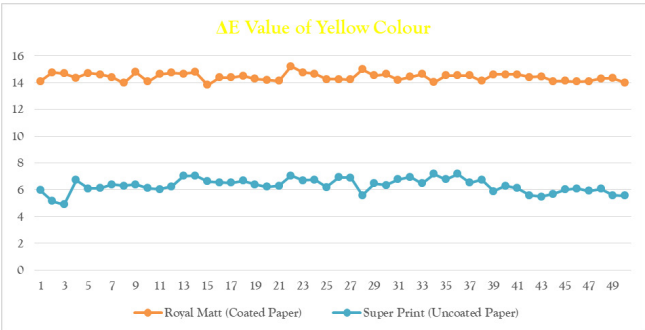

Figure 4: Yellow color on coated (Royal Matt) and uncoated paper (Super Print)

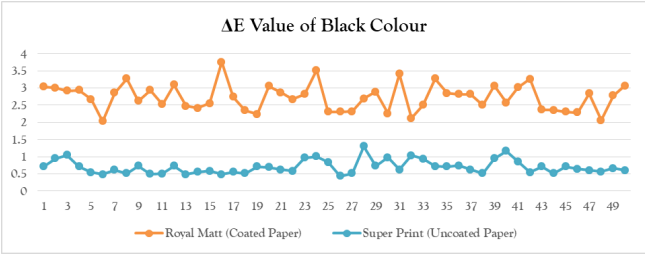

Figure 5: Black color on coated (Royal Matt) and uncoated paper (Super Print)

print engine are presented in Figure 8. The range of color difference for blue color was found 3.55 to 5.92 and 10.84 to 14.19 on coated and uncoated paper, respectively. The behavior on coated paper was uniform and non-uniform on uncoated paper.

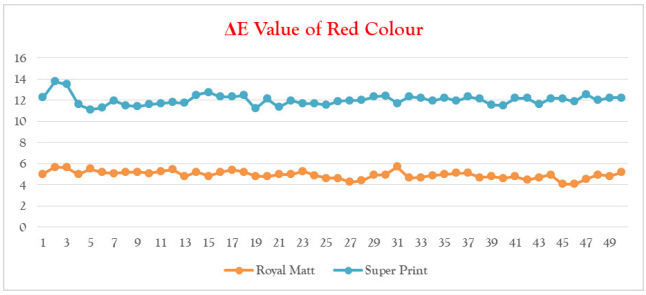

Figure 6: Red color on coated (Royal Matt) and uncoated paper (Super Print)

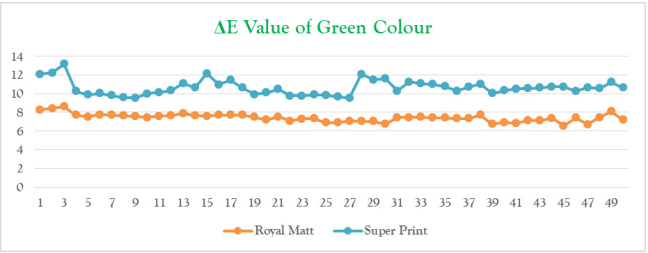

Figure 7: Green color on coated (Royal Matt) and uncoated paper (Super Print)

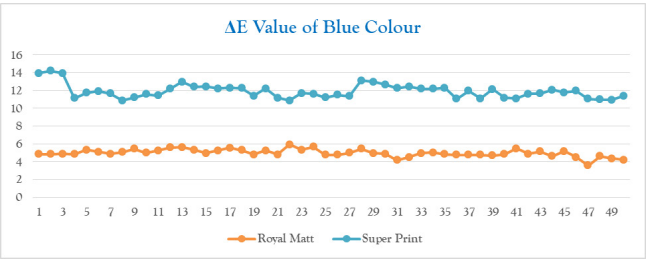

Figure 8: Blue color on coated (Royal Matt) and uncoated paper (Super Print)

Table 1: Summary of color difference (ΔE Value) using HP indigo print engine

ΔE value		*Royal matt*	*Super print*
Cyan	Mini.	2.67	5.96
	Max.	4.02	7.26
Magenta	Mini.	6.83	4.96
	Max.	7.96	6.7
Yellow	Mini.	13.81	4.89
	Max.	15.21	7.17
Black	Mini.	2.03	1.10
	Max.	3.75	2.58
Red	Mini.	4.06	11.12
	Max.	5.7	13.77
Green	Mini.	6.57	9.55
	Max.	8.62	13.18
Blue	Mini.	3.55	10.84
	Max.	5.92	14.19

Observation and Discussion

A study on color gamut and quality parameter was explored on electrophotographical digital printing systems (Spiridonov *et al*., 2022) using different media (Coated and Uncoated Paper) for study and observed HP indigo showed a greater color range on coated paper. A similar study was also carried out for analyzing the parameter determining the effect of coated and Uncoated on print quality (Sesli *et al*., 2023) using cold set offset printing where the difference range of ΔE Values were reported from 1 (Eye cannot distinguish) to 5 (not very distinguished, but acceptable). Research work carried out by authors was further in-depth expansion, particularly on color difference (ΔE Value) on coated and uncoated media, which will be highly beneficial for large scale as well as medium-scale digital printers for minimizing color difference on abovesaid media during printing of similar jobs on different media. The findings of color difference, i.e., ΔE value on royal matt paper (coated paper) and super print (uncoated paper) using HP Indigo digital print engine, are summarized in Table 1.

Commercial printing requires CMYK Printing. However, here, seven color were considered, i.e., CMYK+RGB (Ink Trapping) for an in-depth study of color difference on different media, considering the wider acceptability of printing jobs. This may be very helpful for maintaining print quality for printing jobs and brand protection for packaging applications.

Conclusion

Analysis of data reflected the range and behavior of color differences exhibited on royal matt paper (coated paper) and super print (uncoated paper) using HP Indigo digital print engine. During observation, the color difference values for primary (R, G, B) and process (C, M, Y, K) colors demonstrated by HP Indigo were repeated again and again. Royal matt, i.e., coated paper, exhibited the lowest ΔE value for cyan, red, green and blue colors. On the other hand, for magenta, yellow and black colors demonstrated the the lowest ΔE value on uncoated (super print) media. The behavior of green and blue colors on super print paper was non-uniform with lot of variations at different points.

Acknowledgment

The authors thank the Department of Printing Technology, GJUS&T, Hisar for providing the required infrastructure and facilities for research work. Also, I would like to Mr. Amit Sharma (MD, Harper Collins) and Mr. Ishant Kalkal (RSG Solutions) for their technical support during this study. Special thanks to those who helped directly or indirectly during this experimental research activity.

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