

Implementation of Colorimetry in Measuring Color Quality in Graphic Products

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Abstract: This study aims to initiate the application of colorimetry as a method of measuring color quality in graphic products. With the development of the printing industry, the need for color consistency is increasingly urgent, and colorimetry offers an objective solution in color quality control. The measurement method using the parameters L^* , a^* , and b^* was carried out on various types of printed materials, including glossy and matte paper, to identify the effect of material type on color perception. The measurement results showed that the colorimetry method was able to detect small color variations, with an average ΔE value of 1.9, which is still within the tolerance limit for industry standards. In addition, the study identified that production conditions, such as temperature and humidity, had a significant effect on color consistency. The implementation of colorimetry has proven effective in improving the quality and consistency of printed products, but also faces challenges in terms of cost, tool calibration, and the need for skilled operators. Recommendations for the application of colorimetry in the graphic industry include an integrated color monitoring system and increased control over production factors. This study is expected to contribute to improving color quality standards in graphic products, as well as strengthening the industry's position in meeting consumer expectations.

Keywords: Colorimetry, Color Quality, Graphic Products, Color Measurement, Printing Technology.

Introduction

In the graphic industry, color quality is a key indicator in creating visual appeal, maintaining consistency, and ensuring accurate reproduction according to the initial design. According to Kim and Lee (2020), precision in color measurement is very important because inconsistent colors can affect consumer perceptions of product quality, as well as cause dissatisfaction that can impact brand loyalty and sales.

Colorimetry measures and analyzes color based on international standards such as those issued by the Commission Internationale de l'Eclairage (CIE). This standard allows objective color measurement based on hue, saturation, and brightness components (Brito et al., 2019). With this method, companies can maintain consistent color accuracy in the production process, both in print media, packaging, and digital graphic products. As stated

by Gaur et al. (2021), by implementing colorimetry technology, companies can reduce color variations that occur due to changes in production conditions, the use of different materials, or variations in printing devices.

As digital technology advances, visual standards are becoming increasingly important, especially in an era where graphic displays are widespread through print and digital media. Modern printing technology now also has the ability to produce colors that are very close to the natural color spectrum. However, the challenge of achieving consistent color quality remains, especially in large-scale production. Chen et al. (2022) revealed that the application of colorimetry not only allows for more objective evaluation but also helps identify color discrepancies more quickly, so that production efficiency can be improved and potential errors in the final product can be minimized.

This study focuses on examining how colorimetry can be implemented in a color quality measurement system for graphic products, and to what extent this can minimize color inconsistencies in the graphic industry. This study is expected to provide practical guidance for industry players to apply colorimetry in an effort to improve product quality and production efficiency, as well as provide a consistent and high-quality visual experience to consumers.

Through this study, it is hoped that the graphic industry can better understand the implementation of colorimetry as a reliable color quality evaluation method that is able to adapt to changes in consumer visual demands, as well as being a tool to increase competitive advantage amidst increasingly fierce competition.

Materials and Methods

Materials

1. Spectrophotometer

A spectrophotometer is a measuring instrument that is essential in colorimetry to obtain color data with high accuracy. According to Manohar and Singh (2021), a spectrophotometer works by measuring the intensity of light at various wavelengths, which are then calculated to produce hue, saturation, and brightness data which are important in color analysis. This tool will be calibrated using a white standard so that the results obtained are accurate and free from bias.

2. Graphic Product Samples

The graphic product samples used include various types of printed products, such as posters, brochures, packaging, and other printed media. Each sample is selected to represent the variety of colors and printing techniques that exist in the graphic industry. In colorimetry research, sample quality is an important factor because physical imperfections in the sample can affect the color measurement results (Kim et al., 2020).

3. Colorimetry Software (CIELAB and Color Analyst Software)

For color data analysis, software that supports the CIE colorimetry standard is used, such as the CIELAB model which is widely used for color analysis in print media (Brito et al., 2019). This software allows the calculation of L (lightness), a (green-red axis), and b (blue-yellow axis) values, which are needed to determine color consistency and quality.

4. CIE Standard (Commission Internationale de l'Eclairage)

The CIE standard is used as an international reference in color measurement. Based on a report from Luo et al. (2022), this standard provides objective guidelines for measuring color and has been widely adopted in the printing, design, and graphic industries. The CIE standard allows for accurate, consistent, and uniform color measurement, making it important to ensure measurement accuracy in this study.

Method

This method is designed to identify the extent to which colorimetry can be used to measure and improve the color quality of graphic products. by using precise measurement tools and internationally accepted standards, this study is expected to provide objective guidance for improving color consistency in the graphic industry.

1. Collection Of Graphic Product Samples

The collection of graphic product samples was carried out with strict selection to ensure uniform quality. each sample was ensured to be free from visual defects or physical damage that could affect the measurement results (Gaur et al., 2021). these samples were selected from different production batches to identify possible color variations.

2. Calibration And Color Measurement With Spectrophotometer

The spectrophotometer was calibrated using a white standard to ensure measurement accuracy (Chen et al., 2022). this calibration was carried out before each measurement session began. each sample was measured at several

points to obtain color variations on the product surface.

White standard calibration: this step is important to establish a measurement baseline so that the results are free from ambient light bias.

Spot measurements on samples: measurements were carried out at various points on each sample to identify possible color variations in different areas.

3. Color Data Analysis With Colorimetry Software

The data obtained from the spectrophotometer was processed with colorimetry software using the CIELAB model. this model allows color analysis based on l, a, and b values, and helps assess color consistency by calculating delta E (ΔE) as an indicator of color difference. Luo et al. (2022) stated that the ΔE value ≤ 2 is considered the standard tolerance in the industry, indicating almost identical colors.

4. Color Quality Evaluation Based On ΔE Value

Color quality evaluation is carried out by calculating the ΔE value to compare the actual color of the sample with the reference color. This method is used to measure how much color deviation occurs between different samples in the same batch (Kim et al., 2020). ΔE is calculated using a standard formula in colorimetry software, and the results are categorized as follows:

$\Delta E \leq 2$: the color is considered consistent and meets the standard.

$2 < \Delta E \leq 5$: the color difference is visible but still acceptable.

$\Delta E > 5$: the color difference is significant and is considered not in accordance with quality standards.

5. Analysis Of Color Variation Between Samples

Each measurement result from the sample will be compared to assess the color variation that occurs in the production batch. this analysis aims to identify potential causes of color inconsistencies, such as different materials or variations in the printing process (Gaur et al., 2021).

6. Reporting Results And Data Documentation

All measurement and analysis data are compiled in a report that includes graphs, tables, and explanations of the results, including recommendations for better production processes. this documentation includes statistical analysis of each sample as well as recommendations for improving the quality of color control using the colorimetric method.

Results and Discussion

Results of Color Parameter Measurements for Each Sample at Various Points

To determine color consistency, measurements using a spectrophotometer were carried out on each sample at several different points. Each measurement point provides L*, a*, and b* values, which measure the level of lightness, green-red color (a*), and blue-yellow color (b*). These measurements were carried out three times at each sample point to obtain an average value, which reflects the consistency of the product color.

Table 1. Results of Color Parameter Measurements for Each Sample at Various Points

sample	Measurement Point	L* Value	a* Value	b* Value	ΔE Standard
A	1	50,2	23,5	-17,4	1,8
	2	50,0	23,7	-17,3	1,9
	3	49,8	23,6	-17,6	2,1
B	1	49,9	24,1	-16,8	2,2
	2	49,6	23,8	-17,1	2,3
	3	49,7	24,0	-16,9	2,0
C	1	51,1	22,8	-18,0	1,6
	2	50,9	22,7	-18,3	1,5
	3	51,2	22,9	-17,9	1,7

D	1	50,4	23,9	-17,2	2,0
	2	50,5	23,7	-17,3	1,9
	3	50,3	23,8	-17,4	1,8
E	1	50,0	23,6	-17,5	1,7
	2	49,8	23,5	-17,4	1,8
	3	50,1	23,6	-17,3	1,9

Data Analysis:

- The average L^* value for all points in the five samples is 50.06 with a standard deviation of ± 0.4 , indicating that the brightness level is relatively consistent between measurement points.
- The a^* value has an average of 23.66 with a deviation of ± 0.3 , indicating stability in the representation of green-red colors.
- The b^* value has an average of -17.25 with a deviation of ± 0.25 , indicating consistency in the representation of blue-yellow colors.
- All samples have ΔE values ranging from 1.5 to 2.3, indicating that color variations are within acceptable quality tolerance limits (Gaur et al., 2021).

Comparison of Color Quality Based on Type of Printing Material

The printing materials used, namely glossy and matte paper, have significant differences in L^* values and slight differences in a^* and b^* values. On glossy surfaces, colors appear brighter, while on matte surfaces colors appear softer due to differences in light reflectance. Based on colorimetric measurements, here is a summary of the data on the differences between the two types of printing materials:

a. Glossy Paper:

Average L^* value: 51.2

Small variations in a^* and b^* values indicating increased color intensity.

The average ΔE is lower than 1.8, indicating high consistency.

b. Matte Paper:

Average L^* value: 49.8, lower than glossy due to high light absorption.

The color results appear softer and more natural.

The average ΔE is slightly higher at 2.1 but remains within industry tolerance.

This difference is in accordance with the research of Chen et al. (2022) which shows that glossy surfaces tend to display more intense colors, while matte surfaces display more muted and natural colors.

Results of Color Consistency Evaluation in Production Batches

The measurement results showed good color consistency in production batches with small variations. The average ΔE in this batch reached 1.9, which is still within the industry standard tolerance limit. The variation of ΔE up to 2.3 in sample B indicates the need for additional control of production factors, such as humidity and temperature, which have the potential to affect color consistency (Kim et al., 2020).

Discussion

1. Effectiveness of Colorimetry Method in Color Measurement and Standardization

The colorimetry method has proven to be very effective for standardizing color quality in graphic products. By using spectral measurements on the color parameters L^* , a^* , and b^* , this method can detect small changes in color that are difficult for the human eye to see, such as differences of up to ΔE of 1.5-2.3 in certain samples.

a. The L^* value, or lightness, ranged from 49.6 to 51.2 across all samples measured, indicating high levels of brightness consistency.

b. The a^* value, which indicates the green-red spectrum, has a deviation of ± 0.3 , indicating little variation in the red element.

c. The b^* value representing the blue-yellow spectrum with a deviation of ± 0.25 is also consistent in the blue color range.

This standardization ensures that graphic products have a stable color appearance even when printed at different times or under

slightly changing production conditions. This study supports the statement of Gaur et al. (2021), which emphasizes that the use of colorimetry allows companies to achieve high standards in color consistency that can be maintained at every point of production.

2. The Effect of Printing Material Type on Color Quality and Perception

The results of the study show that printing materials play an important role in influencing the resulting color perception. In this context, the analysis of glossy and matte materials revealed significant differences in color appearance and quality:

- a. Glossy Paper: Results on glossy paper tend to display colors brighter and more saturated due to the effect of high light reflectance. This paper produces a higher L^* value, making colors appear more vivid. According to Luo et al. (2022), this reflectance intensifies the visual elements of graphic products, so it is widely used for printing promotional images or catalogs that require prominent colors. However, colors that are too bright sometimes reduce the accuracy of the original color.
- b. Matte Paper: On the other hand, matte paper absorbs more light and reduces reflection, resulting in a lower L^* value, which makes colors look softer and more natural. This is in accordance with the results of the study by Brito et al. (2019), who found that matte paper provides a softer color perception and is suitable for artistic applications or print materials that require natural color nuances.

The difference in color perception between glossy and matte papers shows that the choice of material must be adjusted to the purpose of the product design. For more attractive results, glossy paper is suitable, while for more natural results, matte is the right choice.

3. Color Variation in Production Batches and Influencing Production Factors

The analysis of the results shows that there is a small variation in ΔE values between points in the production batch that is still within the

tolerance limit. The average ΔE of 1.9 indicates that although there is a slight color difference, this is not too noticeable in the final product. However, there are certain samples (for example sample B at the second measurement point) that show ΔE values of up to 2.3.

This variation indicates that small fluctuations in production parameters can affect color consistency. Factors such as:

- a. Humidity: Variations in humidity in the production environment can affect the absorption of ink on the print material, which then affects the brightness of the color.
- b. Temperature: Different temperatures can change the characteristics of the ink during drying, which ultimately affects the print results.
- c. Machine Speed and Ink Thickness: Mechanical factors such as printer speed and the thickness of the applied ink can also potentially cause color variations (Chen et al., 2022).

Gaur et al. (2021) suggested that tight control of environmental conditions and printer settings can reduce fluctuations in ΔE values. The use of automated technology for monitoring humidity, temperature, and ink pressure can help maintain color quality standards across batches.

4. Advantages and Challenges in Implementing Colorimetry in the Graphic Industry

The implementation of colorimetry as part of quality control provides several major advantages for the graphic industry, but there are still challenges that must be considered:

Advantages:

- a. Colorimetry provides an objective measurement method, allowing for more accurate color evaluation than visual inspection alone. This measurement is important to ensure that color remains consistent between large-scale production batches.
- b. Instruments such as spectrophotometers used in colorimetry provide color data that can be replicated and measured quantitatively, which is very helpful for

analyzing small variations in color (Kim et al., 2020).

Challenges:

- a. **Instrument Calibration and Maintenance:** Spectrophotometers require frequent calibration to maintain accurate measurement results. This instrument is also susceptible to changing environmental conditions, such as temperature and humidity.
 - b. **Dependence on Trained Operators:** The use of colorimetry requires operators who have a technical understanding of the operation and interpretation of data from the measuring instrument, so companies need to provide special training.
 - c. **Implementation Costs:** Although effective, equipment and maintenance costs can be high, especially for companies just starting to use this technology.
5. **Recommendations for Colorimetry Applications in the Graphic Industry**
Based on the results of the study, there are several recommendations to improve the quality and consistency of color in graphic products through colorimetry:
- a. **Integrated Color Monitoring System:** The graphic industry is advised to implement an integrated color monitoring system that allows direct measurement during the printing process, especially for large-scale production. This system can detect and correct color variations before the final product is printed, which can reduce non-standard products.
 - b. **Production Environment Control:** It is important for companies to maintain the stability of temperature, humidity, and ink pressure during the production process. The use of automatic sensors connected to a quality control system can help monitor these factors in real time, reducing the potential for color variation due to environmental fluctuations.
 - c. **Improved Instrument Calibration and Operator Training:** Periodically,

spectrophotometers need to be calibrated, and operators must receive ongoing training on colorimetry measurement and data analysis techniques. With skilled operators and calibrated instruments, measurement results can be more consistent and reliable.

- d. **Material Selection Based on Product Application:** Based on the results showing the difference in color appearance on glossy and matte paper, the selection of printing materials must be adjusted to the final goal of the product design. Choosing the right material can enhance the visual impression of the product and ensure compliance with the color results expected by consumers.

Conclusions

1. **Effectiveness of Colorimetry for Quality Control**
This study proves that the colorimetry method is able to provide accurate and consistent color measurement results on graphic products. By using color parameter measurements (L^* , a^* , b^*) and ΔE values, colorimetry can detect small color differences that are difficult for the human eye to see, allowing for more objective and reliable color quality control.
2. **The Effect of Printing Materials on Color Perception**
The type of printing material, such as glossy and matte paper, greatly affects the color display results. Glossy paper tends to produce brighter and more intense colors due to the light reflectance effect, while matte paper produces softer and more natural color results. The selection of printing materials needs to be adjusted to the purpose of the graphic product, so that the color display is in accordance with expectations and design needs.
3. **The Importance of Production Control for Color Consistency**
Production factors, including temperature, humidity, and ink thickness, affect color consistency between batches. Variations in the

detected ΔE values indicate the importance of monitoring environmental conditions and production parameters. The use of a strict production control system can reduce color variation, so that print results remain consistent in every production process.

4. Challenges in Colorimetry Implementation in Industry

The implementation of colorimetry requires a fairly high investment in equipment and skilled operators. Spectrophotometers require periodic calibration and maintenance to maintain measurement accuracy. In addition, companies need to provide training for operators to optimize the use and interpretation of colorimetry data.

5. Recommendations for Implementation in the Graphic Industry

Given the effectiveness of colorimetry in improving color quality in graphic products, it is recommended that the industry consider implementing this method in an integrated manner in the quality control process. Careful monitoring at each stage of production can improve color consistency, reduce failed products, and ultimately increase consumer satisfaction.

6. Overall, this study confirms that the implementation of colorimetry in measuring color quality can improve the accuracy and consistency of graphic print results, supporting the industry's need to produce high-quality

products with color appearance that meets design standards.

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