Color Appearance on Synthetic Fabrics Using the Dye Sublimation Digital Textile Printing Method: Exploring the Fiber Composition Effect

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Introduction and background. Color appearance, a human visual perception and a quantifiable physical surface characteristic including brightness, saturation, and hue (Shimo & Smriti, 2015; Vladic et al., 2014), is one of the most important visual features that directly affects the textile appearance and determines the commercial success of textile products (Chae, 2020; Hossain et al., 2016). Brightness and saturation refer to the color lightness or darkness and its intensity or strength, respectively (Adobe, 2022). Previous studies indicated that color brightness and saturation have a significant effect on color appearance and can influence consumer perception and decision-making towards textile product choices (Fortmann-Roe, 2013). The fiber composition of fabrics is one of the factors affecting color appearance of the final textile product because different fibers equip various abilities to uptake or resist the dye (Cotton Incorporated, 2003). Due to the molecular attraction between disperse dye and polyester, polyester fabrics display better ability to absorb the disperse dye than cotton fabrics which cannot be readily dyed due to the lack of affinity with the disperse dye for cellulosic fibers (Pei et al., 2021).

Digital textile printing has been widely used in the fashion industry with a wide range of benefits (e.g., customizable design, high cost-effectiveness, unlimited vertical repeated printing) (Lim & Chapman, 2019; Jennings, 2007). The dye sublimation method has been increasingly adopted in digital textile printing since the mid 1990s and employed in both direct textile printing and transfer textile printing (Xu, 2017). Although previous studies have investigated the effect of fiber compositions on color appearance of fabrics with different disperse dyes (Kim et al., 2011; Pei et al., 2021), little attention was given to examine color appearance on synthetic fabrics with different fiber compositions using the dye sublimation digital textile printing method. Furthermore, traditional color evaluation methods heavily rely on the visual assessment which can be subjective because of human's visual color perception and surrounding visual stimulation (Hinsch & Robinson, 2016). Thus, the purpose of this experimental study was to explore color appearance on synthetic fabrics with different fiber compositions using the dye sublimation digital textile printing method.

Method. An experimental research design, 4 (fabric samples) x 4 (color chips) x 3 (repetition), was used for this study. Four fabric samples consisted of fiber compositions of 100% polyester (S1), 90% polyester +10% cotton (S2), 80% polyester + 20% cotton (S3), and 65% polyester + 35% cotton (S4). Cyan, magenta, yellow, and black color chips were identically placed on each fabric sample based on the CMYK color model for examining color appearance on synthetic fabrics. A circular landmark was added to each color chip for extracting the brightness and saturation values. All color chips, having an identical size of 5" x 5", were first

printed on the transfer papers using an inkjet digital textile printer with dye sublimation inks and then, transferred to each fabric sample with a rotary top feed heat press at 400°F.

The digital image processing technique, a digital image analysis of colored samples with mathematical algorithms for measuring color hue, saturation, and brightness values (Karcher & Richardson, 2003), was applied in this study as an objective method to evaluate color appearance with a digital camera and graphic software. All samples were separately pinned to a white foam board in a dark room to avoid the influence of natural lighting. To provide consistent lighting, two professional photography lights were placed in front of the samples with the neutral light tone. A digital camera was positioned 32" away from the board and captured the digital images of all samples. Adobe Photoshop program was used to manipulate digital images and extract color brightness and saturation values from each sample. SAS 9.4 was then used for statistical analysis at $p < .05$. The *F*-test in ANOVA was performed to determine the significant difference of brightness and saturation among the four samples and the pairwise Tukey adjustment method was chosen to compare brightness and saturation of all four samples.

Results and discussion. The mean color brightness and saturation values of the four samples ranged from 46.08% to 40.25% and 71.41% to 63.58%, respectively. The *F*-test in ANOVA revealed the statistical significance of all four samples in terms of color saturation ($F(3,32) = 84.29$, $p < .0001$) and brightness ($F(3,32) = 5.26$, $p = .0046$). The Tukey's pairwise comparisons resulted these samples into (a) three groups in terms of color saturation, Group 1 = *higher saturation*, Group 2 = *moderate saturation*, and Group 3 = *lower saturation* and (b) two groups for color brightness, Group A = *higher brightness* and Group B = *lower brightness.* Within each group, the mean saturation and brightness values of the samples were not significantly different. For the mean saturation value, Group 1, consisting of S1 and S2, demonstrated *higher saturation* ($M_{S1} = 71.411$; $M_{S2} = 71.25$). Group 2 with S3 exhibited *moderate saturation* ($M_{S3} = 68.08$). Group 3 with S4 represented *lower saturation* ($M_{S4} = 63.58$). In terms of the mean brightness value, Group A, consisting of S1 and S4, demonstrated *higher brightness* ($M_{S1} = 46.08$; $M_{S4} = 44.83$) and Group B with S2, S3, and S4 exhibited *lower brightness* ($M_{S2} = 40.25$; $M_{S3} = 40.91$; $M_{S4} = 44.83$).

The evaluation method of color appearance with the digital image processing technique in this study successfully captured the same color hue in all sample landmarks (cyan 223; magenta 343; yellow 50; black 250), which indicates high consistency of the results. The findings demonstrated the effect of fiber compositions to the color brightness and saturation on synthetic fabrics. Compared to different polyester blend fabrics, S1 with 100% polyester displayed high color brightness and saturation values, supporting the earlier research presenting that dye sublimation inks have an affinity to synthetic polymeric materials and the matrix of those materials enable dye molecules to migrate into polymeric networks effectively (Xu, 2017). This tells that S1 has a better ability to encapsulate dye sublimation inks, which result in a more intense and vibrant color with higher saturation and brightness values.

Conclusion. Using the dye sublimation digital textile printing method and the digital image processing technique, this experimental study examined the effect of different fiber compositions on color appearance of synthetic fabrics. This study presented the potential of

using the digital image processing technique as an alternative method for objectively evaluating color appearance of synthetic fabrics. This study addressed a gap in the literature where no studies examined color appearance on fabrics with different fiber compositions using the dye sublimation ink. The results confirmed the effect of fabrics' fiber compositions on color appearance in the dye sublimation digital textile printing. The findings provide insights and guidelines for academia and industry in terms of selecting appropriate synthetic fabrics for optimizing color appearance when developing textile products with the dye sublimation digital textile printer, which relates to consumers' satisfaction and commercial success of the textile products. This study only focused on the influence of fiber compositions on color appearance of fabrics using the dye sublimation digital textile printer with the transfer textile printing method. In future studies, researchers need to examine the effect of different printing methods regarding color appearance on various fabrics. Although the fiber composition is one of the influencing factors for color appearance, other factors (e.g., fiber variability, yarn density, finishing techniques) also can influence appearance of fabrics in the dye sublimation digital textile printing (Cotton Incorporated, 2003), which urges further research investigation.

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