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Original Article

Comparative Study on the Characteristics of Different Terry Fabrics Dyed with Reactive Dye

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Abstract - *The goal of this research is to compare the quality characteristics of four distinct terry towel fabric samples, such as Flat Back Terry, Both Side Terry, Zero Twist Terry, and Sheared Terry reactive dyed samples. In this work, the focus was on dyeing terry towel fabric with reactive dyes in three different shades: orange, green, and gold. After evaluating the color difference, fastness to washing, Rubbing, and Perspiration (acid/alkaline) was assessed, and the individual shades were compared among different terry fabric samples. It was found that the results of different types of terry towel fabrics and other parameters were almost similar in terms of shades.*

Keywords - *Flat Back Terry, Both Side Terry, Zero Twist Terry, SHEARED Terry.*

1. Introduction

Terry fabrics are widely used in applications like bath towels due to their excellent water absorbency. These pile fabrics can be produced through either weaving or knitting techniques [1-2]. Terry woven fabric has a distinctive construction, consisting of a base fabric made of basic warp and weft threads, along with a looped pile attached to it. This pile is created using a separate warp system. The loop pile structure is the key element that determines both the overall design and the performance characteristics of terry fabric. The appearance, texture, and functional properties of the fabric can be tailored by selecting different raw materials, yarn types, and methods of attaching the pile to the base fabric [3-4].

Since the structural variations of woven terry fabrics are relatively limited, examining their comfort properties can provide new insights into this area. Towels represent the most common application of terry-woven fabrics in water-related uses. Consumers prefer bathrobes and towels that feel comfortable and fresh, are lightweight and soft, dry quickly by efficiently transferring moisture from the body, and maintain a hygienic feel with a natural texture. As a result, comfort—a key characteristic for textile products—becomes an essential requirement for terry fabrics intended for use in water-related applications. The terry towels are textiles with loop structures on one or both sides that frequently cover the entire surface, always anticipating greater softness and absorption for the user. The towel's pile affects its capability to absorb water, as well as other qualities, including the intended quality, weight, and other factors influenced by the loop's length. Terry towel fabrics can be regarded as a specialty textile product because they require a specific weaving technique and have a distinct construction compared to regular fabrics. It is formed with loop pile on one or both sides, often the entire surface. There are various terry towel fabrics, such as flat back, both sides, zero twist, and sheared terry, among others. The pore and capillary structure within and between cotton fibers is particularly well-suited for this function. Among the essential qualities of woven terry towels is their wet strength, since these textiles tend to stay damp more frequently than other household fabrics [5-11].

In this article, four different types of terry towel fabric samples such as: Flat Back Terry, Both Side Terry, Zero Twist Terry, and Sheared Terry were dyed with reactive dyes in four different shades, for example: Orange (0.32%), Green (1.25%), and Gold (1.42%) were compared and found out the variation in shade and fastness to wash, rubbing, light and perspiration were not remarkably changed or altered.

2. Materials and Methods

2.1. Materials

Four distinct terry towel fabric samples, including flat back terry, both-side terry, zero-twist terry, and sheared terry fabric samples, were selected. These samples were made of cotton yarn and weighed 400 GSM (Grams per square meter). The terry towel fabric samples were dyed with reactive dyes (Avitera and Bodactive) in different combinations. The shades, such as Orange (0.32%), Green (1.25%), and Gold (1.42%), were dyed. The recipe for dyeing the samples is shown in Table 1.

Table 1. The dyeing recipe of the samples

Orange	Green	Gold
Avitera light Blue SE 0.0066% Avitera light Red SE 0.158% Avitera gold SE 0.156% Total Shade 0.32 %	Avitera light Blue SE 0.026% Bodactive T/Blue BNC 0.033% Bodactive yellow C4-GL 1.2% Total Shade 1.25 %	Avitera light Blue SE 0.00105% Avitera Gold SE 0.06% Bodactive Yellow C4-GL 1.36% Total Shade 1.42%

2.2. Laboratory Dyeing Procedure for Terry Fabric Samples

The dyeing pots of the laboratory dyeing machine were filled with 10 gm samples of four terry towel fabrics, including flat-back terry, both-side terry, zero-twist terry, and sheared terry bleached fabric samples. Salt, leveling agent, water, and a color solution prepared according to the instructions were previously added to the dyeing pots. After 20 minutes of dyeing at 60°C, soda ash was added to the samples. Once more, the dyeing process was carried out for 40 minutes at the same temperature. Following a rinse, wash, and neutralization with acetic acid, the samples were then soaped at 90 °C for 10 minutes. They were subsequently washed and dried.

2.3. Methodology of Color Difference (DE) Evaluation

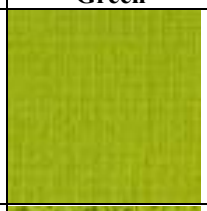
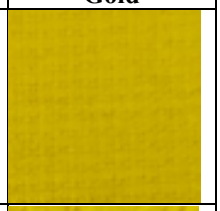
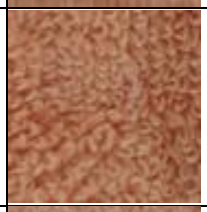
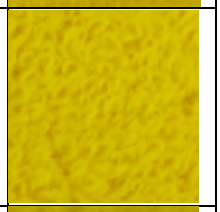
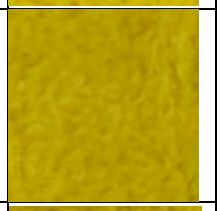
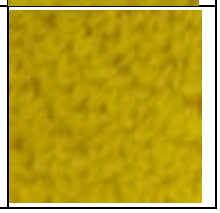
The Spectrophotometer X-Rite Color iMatch (version 7.4) was used to assess the color Difference (DE) of the samples. The color differences of the samples were measured using the CIE (International Commission on Illumination) L*a*b* color system, which was employed to evaluate color deviations by means of ΔE or DE values. Color deviation in the above-mentioned system is represented by the shortest distance in the CIE L*a*b* co-ordinate space from the position of the standard color with which it is compared.

The comparison was performed using spectrophotometric evaluation with light sources D65, TL84, and F02. The Lightness (DL*), Saturation (DC*), Hue (DH), CIE lab value for references (Da* and Db*), and Total color Deviations (DE) were evaluated using both side terry fabric samples as the standard.

The three coordinates of CIELAB represent the lightness of the color. L* = 0 yields black, and L* = 100 indicates diffuse white. A* Negative values indicate green, while positive values indicate red. B* negative values indicate blue, and positive values indicate yellow. DE was calculated using equation (1).

$$DE = [(DL^*)^2 + (Da^*)^2 + (Db^*)^2]^{1/2} \quad (1)$$

Table 2. Comparative shade difference among the samples

Samples	Orange	Green	Gold
Flat Back Terry (flat side)			
Zero Twist Terry			
Sheard Terry			
Both sides Terry			

2.4. Color Fastness to Wash

The ISO 105 C06:2010 technique was used to test color fastness to washing. Single test of 10 cm ×4 cm with 1 g/L sodium perborate solution and 4 g/L European Color Fastness Establishment (ECE) reference detergent in a machine wash at 40 °C.

2.5. Color Fastness to Rubbing

This test is proposed to evaluate the amount of color that may transfer from the surface of a colorful fabric to a specific test cloth when it is rubbed (both dry and wet), using ISO 10512:2016 as the method.

2.6. Color fastness to perspiration

Acid and alkaline sweat color fastness was evaluated using the ISO 105 E04:2013 method to assess the reactive dyed terry towel fabric samples.

3. Results and Discussion

3.1. Comparison of Shade

Table 2 displays the optical images of four different samples of terry fabric dyed with reactive dyes in three different shades.

3.2. Color Difference (DE) evaluation

3.2.1. Orange Shade

Table 3 displays the spectrophotometric evaluation of orange shade of reactive dyed flat back terry, sheared terry, and zero twist terry fabric samples as compared to both side terry fabric sample dyed with the same recipe. It should be noted that the side terry fabric has been used as the standard sample.

Table 3. Spectrophotometric evaluation of orange shade

Samples	Ill-obs	DL*	Da*	Db*	Dc*	DH*
Flat Back Terry	D65	0.97	0.96	0.01	0.69	-0.67
	TL84	1.04	0.97	0.10	0.72	-0.65
	F02	1.03	0.77	0.10	0.51	-0.58
Sheared Terry	D65	1.60	-0.52	-1.02	-1.08	-0.37
	TL84	1.54	-0.45	-1.14	-1.15	-0.42
	F02	1.61	-0.32	-1.01	-1.02	-0.30
Zero Twist Terry	D65	2.96	-1.64	-1.20	-2.01	0.29
	TL84	2.83	-1.48	-1.42	-2.05	0.19
	F02	3.01	-1.14	-1.10	-1.54	0.34

The comparison of the orange shade of different terry fabric samples under various light sources has been graphically displayed in Figure 1. It is observed that the lightness DL* values of the flat back terry sample were 0.97, 1.04, and 1.03 in the corresponding illuminants D65, TL84, and F02, respectively. It indicates that the sample is lighter than its corresponding standard sample. Similarly, the CIE lab value for reference Da* values was 0.96, 0.97, and 0.77 under the same illuminants, respectively. It specifies that the sample is more red than the standard sample. Likewise, the CIE lab value for reference Db* values were 0.01, 0.10, and 0.12. It indicates that the sample was more yellow than the standard samples. The Chroma differences Dc* values were 0.69, 0.72, and 0.51. It designates that the sample is more saturated than the standard sample. The difference in hue DH was -0.67, -0.65, and -0.58.

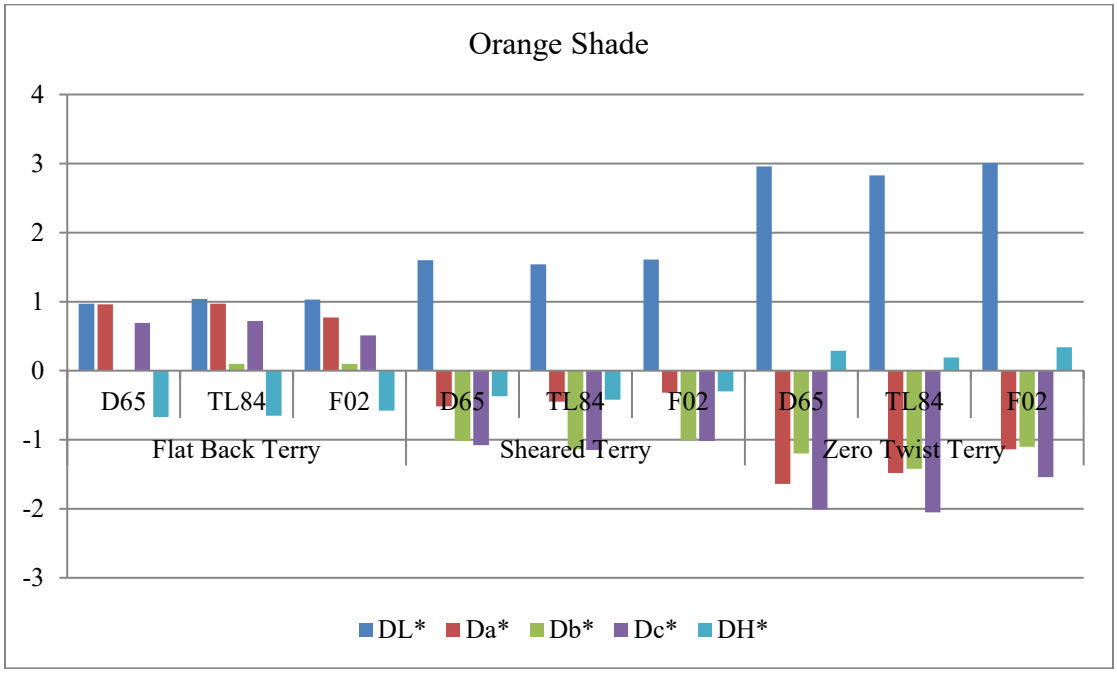


Fig. 1 Graphical representation of the comparison of the orange shade of reactive dyed different terry samples under different light sources

Figure 1 also shows that the lightness DL* values of the Sheared Terry sample were 1.60, 1.54, and 1.61 in corresponding illuminants D65, TL84, and F02, respectively. It indicates that the sample is lighter than its corresponding standard sample. Similarly, the CIE lab value for reference Da* values was -0.52, -0.45, and -0.32 in the same illuminants, respectively. It specifies that the sample is greener than the standard sample. Likewise, CIE lab value for reference Db* values were -1.02, -1.14, and -1.01. It indicates that the sample was bluish than the standard. The Chroma differences Dc* values were -1.08, -1.15, and -1.02. It designates that the sample is less saturated than the standard sample. The differences in hue DH were -0.37, -0.42, and -0.30 in the corresponding illuminants, respectively.

Again, it is also evident from Figure 1 that the lightness DL* values of the zero-twist terry fabric sample were 2.96, 2.83, and 3.01 in the corresponding illuminants D65, TL84, and F02, respectively. It indicates that the sample is lighter than its corresponding standard sample. Similarly, the CIE lab value for reference Da* values were -1.16, -1.48, and -1.14. It specifies that the sample is greener than the standard. Likewise, CIE lab value for reference Db* values were -1.20, -1.42, and -1.10. It indicates that the sample was bluish than the standard. The Chroma differences Dc* values were -2.01, -2.05, and -1.54. It designates that the sample is less saturated than the standard. The difference in hue DH was 0.29, 0.19, and 0.34 in the corresponding illuminants, respectively.

3.2.2. Green Shade

Table 4 displays the spectrophotometric evaluation of the green shade of reactive dyed Flat Back Terry, Sheared Terry, and Zero Twist Terry fabric samples as compared to both side terry fabric samples dyed with the same recipe.

Table 4. Spectrophotometric evaluation of green shade

Samples	Ill-obs	DL*	Da*	Db*	Dc*	DH*
Flat back terry	D65	0.56	0.90	-0.04	-0.35	-0.84
	TL84	0.65	0.71	0.13	-0.07	-0.72
	F02	0.63	0.63	0.16	0.00	-0.65
Sheared terry	D65	-0.33	-0.24	1.96	1.93	-0.45
	TL84	-0.29	-0.29	2.11	2.11	-0.30
	F02	-0.29	-0.19	2.09	2.07	-0.32
Zero twist terry	D65	0.93	0.48	1.44	1.19	-0.78
	TL84	0.95	0.63	1.59	1.36	-1.03
	F02	0.97	0.40	1.64	1.50	-0.78

Fig 2 shows a graphic comparison of the green shade of various terry cloth samples under several lighting conditions. According to Figure 2, the lightness DL* values of the flat back terry sample were 0.56, 0.65, and 0.63 for the matching illuminants D65, TL84, and F02, respectively. It indicates that the sample is lighter than the standard. Likewise, the CIE lab values for reference Da* values were 0.90, 0.71, and 0.63, respectively. The sample is more reddish than usual. Similarly, the reference Db* values' CIE lab values were 0.04, 0.13, and 0.16. It suggests that compared to typical samples, the sample was more yellowish. The chroma differences Dc* values were -0.35, -0.07, and -0.01. It describes that the sample is less saturated than the standard sample. The differences in hue DH were -0.84, -0.72, and -0.65 in the corresponding illuminants, respectively.

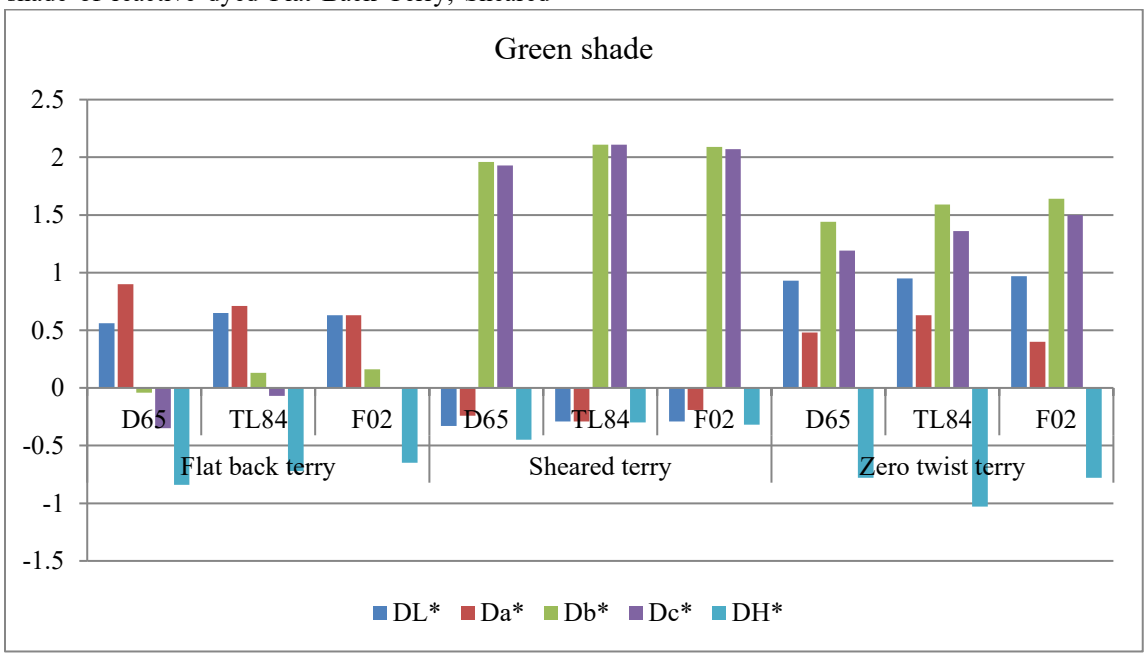


Fig 2 Graphical representation of comparison of the green shade of reactive dyed different terry samples under different light sources

According to Figure 2, the Sheared Terry sample's lightness DL* values were -0.33, -0.29, and -0.29 in the associated illuminants D65, TL84, and F02, respectively. It shows that the sample is darker than the standard. Likewise, the CIE lab values for reference Da* values were -0.24, -0.29, and -0.19, respectively. It states that the sample is greener than the standard. Similarly, the reference Db* values were 1.96, 2.11, and 2.09. It suggests that compared to the standard, the sample was more yellowish. The chroma differences Dc* values were 1.93, 2.11, and 2.07. It indicates that, compared to the standard, the sample is more saturated. The hue DH differences were -0.45, -0.30, and -0.32, respectively.

The Zero Twist Terry sample's lightness DL* values were again determined from Figure 2, with values of 0.93, 0.95, and 0.97 for comparable illuminants D65, TL84, and F02, respectively. In comparison to its comparable standard sample, it signifies that the sample is lighter. The CIE lab values for reference Da* values in the same illuminants were likewise 0.48, 0.63, and 0.40, respectively. The sample was more reddish compared to the standard. For reference, the Db* values were 1.44, 1.59, and 1.64. The sample was more yellowish than the standard, according to this. Under identical illumination conditions, the chroma differences Dc* values were 1.19, 1.36, and 1.50. In comparison to the standard sample, it indicates that the sample is more saturated. The hue DH differences were -0.94, -1.03, and -0.78.

3.2.3. Gold Shade

Table 5 displays the spectrophotometric evaluation of orange shade of reactive dyed flat back terry, sheared terry, and zero twist terry fabric samples as compared to both side terry fabric sample dyed with the same recipe.

Table 5. Spectrophotometric evaluation of gold shade

Samples	Ill-obs	DL*	Da*	Db*	Dc*	DH*
Flat back terry	D65	-0.39	-0.56	-0.02	-0.03	0.56
	TL84	-0.44	-0.36	-0.04	-0.04	0.35
	F02	-0.47	-0.34	-0.04	-0.04	0.34
Sheared terry	D65	0.72	-1.42	1.10	1.09	1.43
	TL84	0.63	-0.90	1.11	1.11	0.90
	F02	0.60	-0.87	1.06	1.07	0.86
Zero twist terry	D65	-0.69	-0.69	0.79	0.80	0.70
	TL84	-0.74	-0.49	0.83	0.82	0.49
	F02	-0.76	-0.44	0.79	0.79	0.43

In Figure 3, the gold shade of various terry cloth samples under various light sources is graphically compared by similar illuminants D65, TL84, and F02; the flat back terry sample's lightness DL* values were -0.39, -0.44, and -0.47, respectively, as shown in Figure 3. It shows that compared to the equivalent standard sample, the sample is darker. Likewise, the CIE lab values for reference Da* values in the same illuminants were -0.56, -0.36, and -0.34 in that order. In comparison to the standard, it is greener. For reference, the DB* values, the CIE lab values were -0.02, -0.04, and -0.06. The sample was more bluish than the typical sample, according to this. The Dc* values for chroma differences under the same illumination were -0.03, -0.04, and -0.04. It designates that the sample is less saturated or duller than the standard sample. The difference in hue DH was 0.56, 0.35, and 0.34 by corresponding illuminants, respectively, which indicates a minor hue difference from the standard.

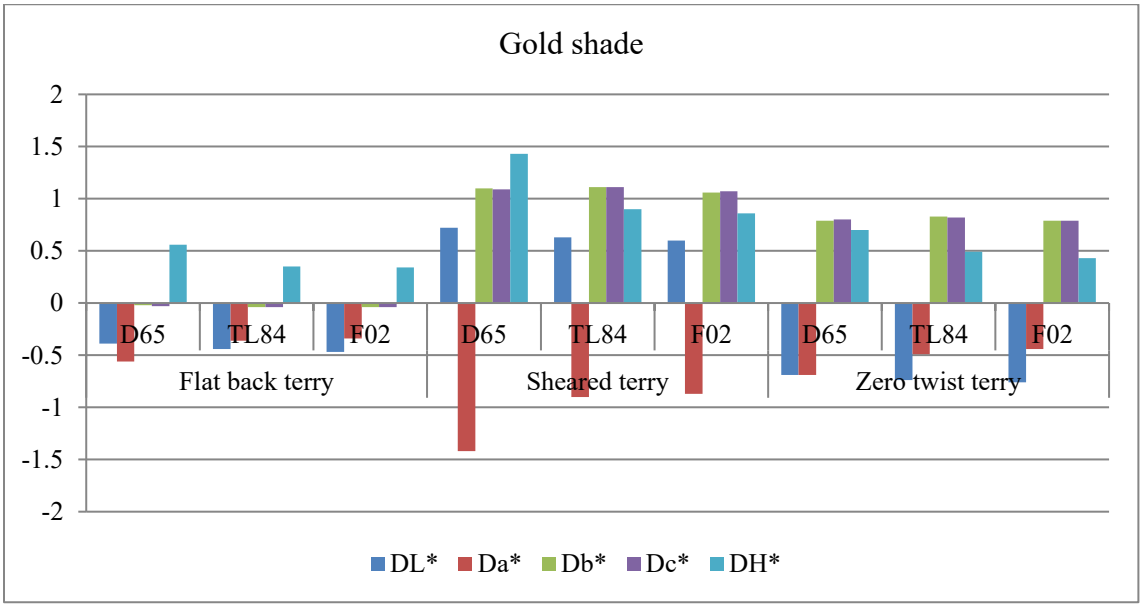


Fig. 3 Graphical representation of comparison of gold shade of reactive dyed different terry samples under different light sources

The Sheared Terry sample's lightness DL* values, as displayed in Figure 3, were 0.72, 0.63, and 0.60 in the associated illuminants D65, TL84, and F02, respectively. It signifies that the sample is lighter than the standard. In the same illuminants, the CIE lab values for reference Da* values were -1.42, -0.90, and -0.87, respectively. It makes clear that the sample is greener than a typical sample.

Similarly, reference Db* values had CIE lab values of 1.10, 1.11, and 1.06. It shows that the sample is yellower than the typical sample. Under the same illumination conditions, the chroma differences Dc* values were 1.09, 1.11, and 1.07. It indicates that the sample is more saturated than the typical sample. The hue DH differences were 1.43, 0.90, and 0.86, respectively. Compared to the reference sample, it shows a slight hue change.

Figure 3 also displays the lightness DL* values of the zero twist terry sample, which were -0.69, -0.74, and -0.76 by corresponding illuminants D65, TL84, and F02, respectively. It indicates that the sample is darker than its corresponding standard sample. Similarly, CIE lab value for reference Da* values were -0.69, -0.49, and -0.44. It specifies that the sample is greener than the standard sample.

Likewise, the CIE lab value for reference Db* values were 0.79, 0.83, and 0.79. It indicates that the sample was bluer than the standard. The Chroma differences Dc* values were 0.80, 0.82, and 0.79. It designates that the sample is more saturated or brighter than the standard sample. The difference in hue DH was 0.70, 0.49, and 0.43. It indicates a minor hue difference from the standard.

3.2. Total Color Difference (DE) Evaluation

Table 6 displays the total color difference of different shades of Flat Back Terry, Sheared Terry, and Zero Twist Terry fabric samples as compared to Both Side Terry fabric samples.

Table 6. Total color difference of different shades of different terry fabric samples

Samples	Ill-obs.	Total color difference (DE)		
		Orange	Green	Gold
Flat back terry	D65	0.86	0.49	0.34
	TL84	0.87	0.44	0.24
	F02	0.87	0.41	0.24
Sheared terry	D65	0.91	0.71	0.89
	TL84	0.91	0.74	0.62
	F02	0.90	0.73	0.59
Zero twist terry	D65	1.56	0.72	0.52
	TL84	1.46	0.78	0.45
	F02	1.49	0.75	0.43

From Figure 4, it is evident that the total color Difference (DE) values of different terry towel fabric samples in various shades, such as orange, green, and gold, under different light sources, including D65, TL84, and F02, are presented. DE values of all the shades, such as orange, green, and gold, in flat back terry fabric samples were very close compared to those of both side terry fabric samples, as the color difference was less than 1. Similarly, all the shades, such as orange, green, and gold, of the Sheared Terry fabric samples were very close to each other compared to the side terry fabric samples, as the color difference was less than 1.

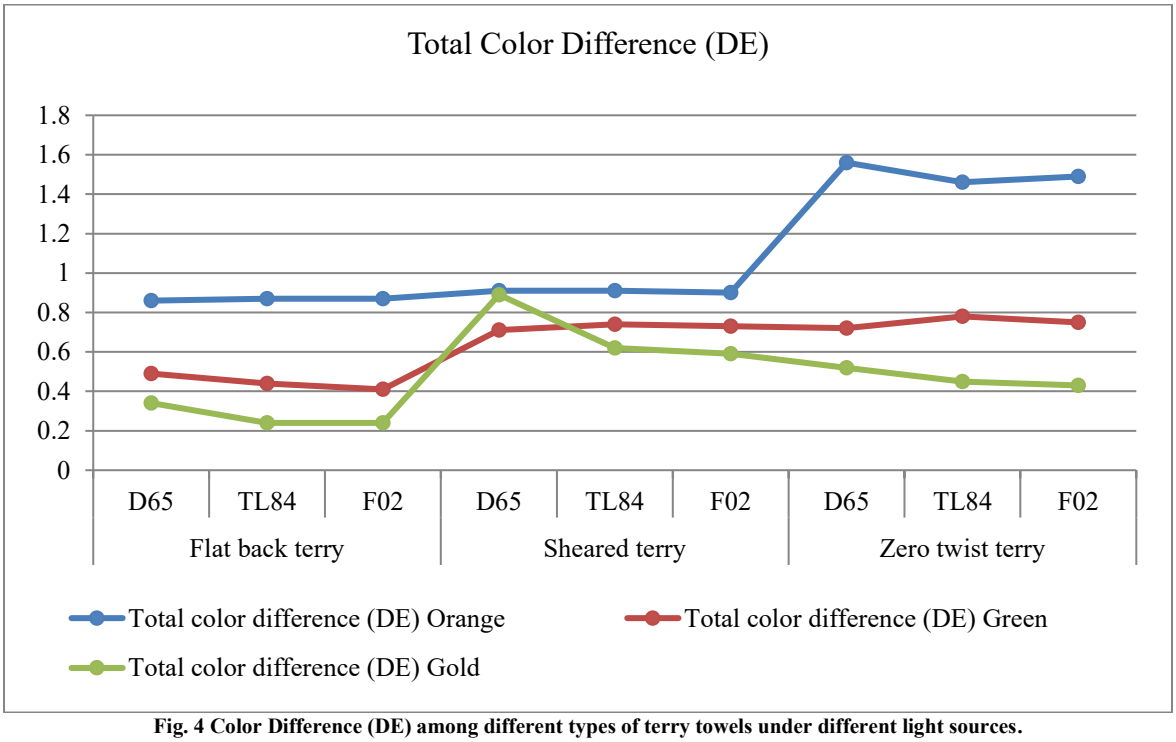


Fig. 4 Color Difference (DE) among different types of terry towels under different light sources.

Again, the color difference of green and gold shades of zero twist fabric samples was matched with both side terry fabric samples, but the orange shade of zero twist terry fabric samples was 1.56, 1.46, and 1.49 under three different light sources. It indicates that the difference is beyond the limit as compared to both side terry fabric samples.

3.3. Color Fastness to Wash

Table 7 indicates the variation in color and staining on multifiber fabric owing to washing on reactive dyed different types of terry towel fabric, such as: Flat back terry, both side terry, zero twist terry, and sheared terry fabric samples. The rating of color change of washed fabric samples was 4 for all the fabric samples and the staining on different fibers like acetate, cotton, nylon, polyester, acrylic and wool for all the samples of different shades was 4-5, which indicates the very good wash fastness except the green and gold shade in terms of staining on cotton and wool fiber, the grey scale rating was 4, which indicates also good results.

Table 7. Color fastness to wash

Shade	Color change	Staining on					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Orange	4	4-5	4-5	4-5	4-5	4-5	4-5
Green	4	4-5	4	4-5	4-5	4-5	4
Gold	4	4-5	4	4-5	4-5	4-5	4

3.4. Color Fastness to Perspiration

The acidic and alkaline solutions for the sweating test results on reactive dyed different types of terry towel fabric, for example: Flat back terry, both side terry, zero twist terry, and sheared terry fabric samples are displayed in Table 8. The color change rating of orange, green, and gold shades of all the samples was 4, which indicates good results, and in terms of staining in all the multifiber fabrics, the rating was 4-5 for acetate, nylon, polyester, acrylic, and wool fiber, which indicates very good results. But the rating of the orange shade for cotton fiber is 4-5. The green and gold shades show the staining on cotton 4, which also indicates a good result.

Table 8. Results of the perspiration test

Shade		Color change	Staining on					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Orange	Acid	4	4-5	4-5	4-5	4-5	4-5	4-5
	Alkali	4	4-5	4-5	4-5	4-5	4-5	4-5
Green	Acid	4	4-5	4	4-5	4-5	4-5	4-5
	Alkali	4	4-5	4	4-5	4-5	4-5	4-5
Gold	Acid	4	4-5	4	4-5	4-5	4-5	4-5
	Alkali	4	4-5	4	4-5	4-5	4-5	4-5

Table 9. Results of Rubbing Fastness

Rubbing Condition	Orange	Green	Gold
Dry	4-5	4-5	4-5
Wet	4	4	4

3.5. Color Fastness to Rubbing

The rubbing fastness results of the reactive dyed different types of terry towel fabric, for example: Flat Back Terry, Both Side Terry, Zero Twist Terry, and Sheared Terry, are observed in Table 9. The rubbing fastness result revealed that the grey scale rating for dry Rubbing was 4-5, and wet rubbing rating was 4, which indicates that the color fastness to rubbing results for all types of samples was very good.

4. Conclusion

From the above discussion, it can be inferred that the reactive dyed shades like orange, green, and gold, of various terry towel fabric samples, including Flat Back Terry, Both Side Terry, Zero Twist Terry, and Sheared Terry fabric samples, were nearly identical in terms of quality parameters. Lastly, it can be said that the color difference, wash, rubbing, and perspiration fastness of different shades of different terry fabrics are similar regardless of the variations in structures of the various terry fabric samples.

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