# The Effect of Spectrophotometer Geometry on the Measured Colors for Textile Samples with Different Textures

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**ABSTRACT**

Spectrophotometers are usually built based on one of these two kinds of geometry; d/8 (diffuse/8) and 45/0. Considering that measured or observed colors depend on the illuminating and viewing conditions, the 45/0 spectrophotometer geometry or d/8 geometry affects the results. In addition, the sample characteristics such as gloss or texture can also influence the measuring results. Therefore, the effect of geometry will be affected by the characteristics of the sample.

In this paper, the effect of spectrophotometer geometry on the result of color measurement is investigated for textile samples with different types of texture. In addition, the effect of texture on the measured colors was compared for two geometries. To this end, 63 polyester samples contained of 9 color centers each of them has 7 different types of texture were used. The spectral reflectance data of the fabrics were measured using two spectrophotometers with different geometry; d/8 and 45/0. Other parameters of the two measuring systems such as the aperture size, laboratory conditions, the sample's direction in front of the spectrophotometer and the number of specimen's layers were equal. The measured values of two instruments were compared. It was shown that the spectrophotometer geometry influences the color coordinates of the samples. The d/8 spectrophotometer with include mode usually gives larger lightness values. $C^*$ and $H^*$ values are affected by the type of spectrophotometer and this effect is dependent on the color center of the sample. In another part of the present study, the color change via the texture difference was evaluated for each of the two geometries, and the obtained results were compared with each other. It was found that the surface texture of the sample influences the measured color from 0.4 to about 4.8 CIEDE2000 (1:1:1) unit for both two types of the spectrophotometer. Moreover, as same as d/8 geometry, the color change via the texture which is measured by 45/0 shows no acceptable correlation with visual assessments.

**Keywords:** spectrophotometer geometry, textile, texture, color

## INTRODUCTION

Spectrophotometers, measure the spectral reflectance and spectral transmittance of the samples through the visible spectrum relative to a particular reference [1-2]. The Viewing angle and the illuminating condition, considerably influence the perceived color [3]. The geometry of a color-measurement instrument is therefore, an important factor in its design [1-3]. Spectrophotometers are usually built based on two kinds of geometry including d/8 and 45/0. Based on the CIE definitions the first number refers to the illumination geometry and the second indicates the observation geometry [4]. The term "d" (diffuse) means that the illuminating or viewing is not directional but is somewhat diffuse, usually by the use of an integrating sphere [4-5].

Although ideally all the instruments in general use, accommodate specimens that are flat [2], the real samples usually do not satisfy this term. For example the textile samples are usually have uneven surface. There are some recommendations for applying each of these two geometries for different applications based on the sample's characteristics such as gloss, texture and also the purpose of measurement like color difference or color appearance [2,5]. Recently, some studies have been published in which the effect of texture on the color and color difference assessments were investigated [6-15]. These studies have been usually done by visual assessment and evaluated the influence of texture on perceived color or color difference in comparison to the instrumental measures. By these experiments it would be possible to enhance the color difference formulae for textured samples.

In our previous research, the effect of texture on the measured colors was visually and instrumentally investigated, in which a d/8 spectrophotometer was used [13]. It was shown that the texture of the sample affects the measured color and this effect is dependent on the color of the sample.

Considering that both the instrumental geometry and surface texture can affect the measured data, it would be of interest to investigate these two factors together. The goal of this paper is to compare the results of two spectrophotometers including d/8 and 45/0 for textile samples with different textures. In addition, the effect of texture on the measured colors of 45/0 spectrophotometer is studied and compared with d/8 geometry.

## EXPERIMENTAL

63 polyester fabrics prepared in the previous research were used [13]. These fabric samples were produced from filament polyester yarn with thread density of 160 denier and nine different colors included green, yellow, blue, red, purple, grey, brown, orange and pink. Each color yarn was knitted with 7 different textures. Visually, the first three textures were almost fine, the textures number 4 and 5 were between fine and coarse types and the last two textures were completely coarse. The applied textures were visually covered fine to completely coarse types. Consequently, the samples were prepared in 9 color groups, each group contains of 7 fabrics with different textures and the same color yarn.

The spectral reflectance data were obtained from two types of spectrophotometers. Once the spectral data were measured with a GretagMacbeth Color Eye 7000A spectrophotometer in a specular component included (SCI) mode, which is an instrument with diffuse/8° geometry. Second time, the spectral data were measured using a HunterLab MiniScanEZ with 45/0 geometry. Other parameters of both measuring systems were adjusted the same, aperture size was set to 1 inch, all the samples were replicated 4 times to be completely opaque and laboratory conditions were also the same. For both instruments, the spectral reflectance values were measured and considered between 400nm and 700nm with 10nm intervals without any ASTM weighting functions. It has been reported that the use of the ASTM weighting functions in the case of non fluorescent reflectance spectra may not greatly affect the results [17].

The color coordinates of the samples were computed using CIE 1964 standard observer (10°) and under illuminant $D_{65}$. It should be noted that, for both measuring instruments each of the 7 textures was measured in the same orientation, as shown in *Figure (1).*

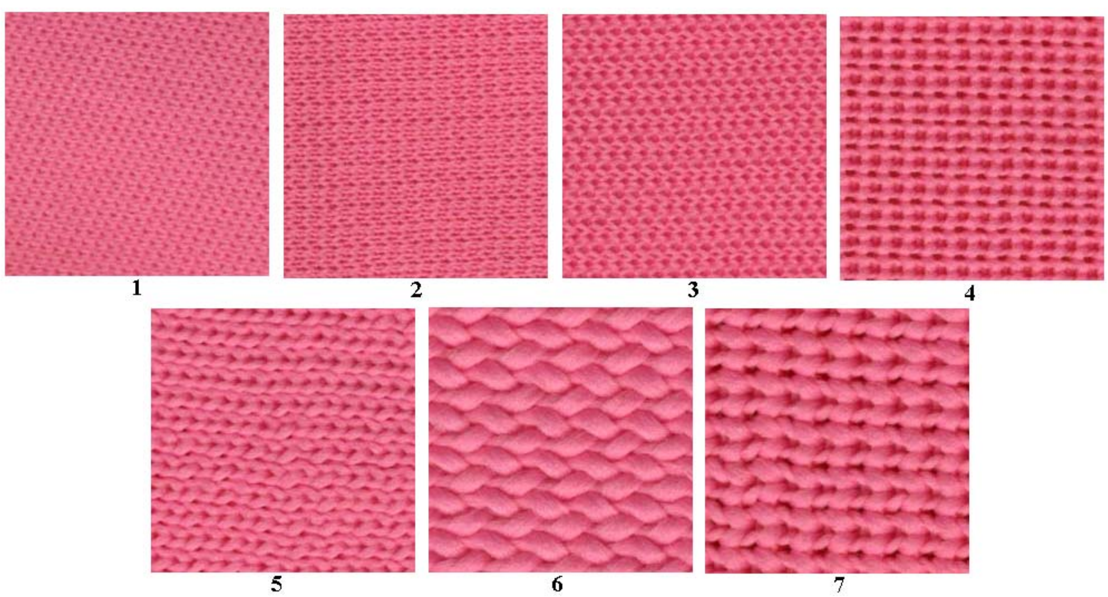


FIGURE 1. The seven texture types of knitted samples. The spectral measurements were carried out in horizontal direction of each texture similar to the image

Moreover, the results of visual assessments for the mentioned samples obtained in the previous research were used [13]. For visual assessment, the color differences between the sample with texture 1 and the other textures had been evaluated for each color centers using the common grey scale method. It had been done by 18 observers including seven men and eleven women who were not color blind according to the Ishihara test. The assessments had been conducted using a ICS-TEXICON light cabinet with 60 lightness value and under the illuminant $D_{65}$. Illuminating/viewing geometry was approximately 45/0.

In the present research, at first the results of two kinds of geometry were compared for the mentioned fabrics. For this purpose, the color difference between the measured values of d/8 and 45/0 spectrophotometer were computed and evaluated for each sample. As declared, the samples are in 9 color groups, each group contains of 7 fabrics with different textures, which were knitted with the same color yarn. So, similar to visual assessment, the color difference between the texture 1 and the other 6 textures in each color group was calculated and considered to see the effect of texture on the color for each of the two geometries. The color difference was computed using the CIEDE2000 (1:1:1) color difference formula [16].

## RESULTS AND DISCUSSION

*Table I* shows the $CIEL^*a^*b^*$ values of the samples under $D_{65}$ and CIE 1964 standard observer while the spectral data were measured using d/8 spectrophotometer. *Table II* shows the corresponding results for 45/0 geometry. To create a proper comparison, the differences between $L^*$, $C^*$ and $H^*$ values of two measuring instruments were computed. The $\Delta C^*$ and $\Delta H^*$ values were weighted for CIEDE2000 (1:1:1) as follows:

$$\Delta C^*_{DE2000} = \Delta C / (S_c \, . k_c) \quad (1)$$

$$\Delta H^*_{DE2000} = \Delta H / (S_h \, . k_h) \quad (2)$$

TABLE I. The color coordinates of the samples while a d/8 spectrophotometer was used for measuring spectral reflectance data. (CIE 1964 standard observer and illuminant $D_{65}$ were applied)

| Color \ Texture No. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Grey | $L^*$ | 60.23 | 57.79 | 56.14 | 58.83 | 58.94 | 60.47 | 56.66 |
| | $a^*$ | -1.33 | -1.51 | -1.71 | -1.58 | -1.94 | -1.65 | -1.66 |
| | $b^*$ | -2.97 | -3.19 | -3.07 | -3.19 | -2.85 | -3.07 | -2.95 |
| Red | $L^*$ | 39.06 | 37.98 | 36.77 | 36.51 | 37.71 | 38.60 | 36.41 |
| | $a^*$ | 55.27 | 54.67 | 55.25 | 54.17 | 54.62 | 55.82 | 54.05 |
| | $b^*$ | 32.71 | 32.21 | 33.76 | 32.85 | 32.92 | 34.18 | 33.05 |
| Orange | $L^*$ | 55.52 | 54.23 | 53.12 | 51.89 | 53.76 | 54.42 | 52.03 |
| | $a^*$ | 43.57 | 44.45 | 45.77 | 44.74 | 44.93 | 44.22 | 43.99 |
| | $b^*$ | 55.41 | 55.45 | 56.86 | 55.89 | 57.81 | 57.45 | 55.79 |
| Brown | $L^*$ | 28.97 | 27.88 | 25.18 | 25.43 | 26.54 | 27.07 | 25.33 |
| | $a^*$ | 7.49 | 7.10 | 7.20 | 7.07 | 7.31 | 7.68 | 7.24 |
| | $b^*$ | 9.18 | 8.58 | 9.08 | 9.05 | 9.48 | 10.15 | 9.41 |
| Yellow | $L^*$ | 89.92 | 89.20 | 89.14 | 89.02 | 89.19 | 88.85 | 87.98 |
| | $a^*$ | -5.78 | -5.70 | -5.85 | -5.26 | -5.21 | -5.40 | -5.17 |
| | $b^*$ | 52.03 | 53.71 | 52.02 | 52.01 | 51.18 | 48.44 | 50.49 |
| Green | $L^*$ | 36.56 | 35.75 | 34.10 | 34.15 | 35.30 | 35.65 | 34.00 |
| | $a^*$ | -27.42 | -26.35 | -26.73 | -26.50 | -27.13 | -28.30 | -27.10 |
| | $b^*$ | 24.90 | 23.73 | 24.17 | 24.25 | 24.93 | 25.74 | 24.70 |
| Blue | $L^*$ | 70.51 | 69.36 | 69.55 | 68.87 | 70.55 | 70.81 | 69.60 |
| | $a^*$ | -6.18 | -6.06 | -6.28 | -6.33 | -6.34 | -6.72 | -6.26 |
| | $b^*$ | -25.36 | -25.94 | -25.46 | -24.69 | -24.11 | -23.21 | -24.46 |
| Purple | $L^*$ | 39.35 | 38.50 | 36.28 | 36.09 | 37.71 | 38.68 | 36.55 |
| | $a^*$ | 36.20 | 35.79 | 36.45 | 35.63 | 36.29 | 37.70 | 35.97 |
| | $b^*$ | -23.29 | -23.02 | -23.09 | -22.70 | -23.57 | -24.58 | -23.41 |
| Pink | $L^*$ | 64.94 | 63.66 | 61.78 | 61.28 | 62.49 | 64.49 | 61.69 |
| | $a^*$ | 48.44 | 49.21 | 51.09 | 49.87 | 49.80 | 48.60 | 48.94 |
| | $b^*$ | -3.52 | -3.14 | -2.57 | -2.28 | -2.74 | -4.14 | -3.15 |

TABLE II. The color coordinates of the samples while a 45/0 spectrophotometer was used for measuring spectral reflectance data. (CIE 1964 standard observer and illuminant $D_{65}$ were applied)

| Texture No. / Color | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Grey | $L^*$ | 59.82 | 56.89 | 54.59 | 55.37 | 58.94 | 59.88 | 56.33 |
| | $a^*$ | -1.72 | -1.95 | -2.13 | -1.83 | -2.00 | -2.02 | -1.87 |
| | $b^*$ | -1.49 | -1.99 | -2.22 | -2.14 | -1.99 | -1.60 | -2.17 |
| Red | $L^*$ | 38.32 | 37.29 | 35.55 | 35.58 | 37.52 | 37.77 | 36.05 |
| | $a^*$ | 55.83 | 55.03 | 55.33 | 53.98 | 55.10 | 55.51 | 54.41 |
| | $b^*$ | 34.05 | 33.49 | 34.69 | 33.04 | 33.77 | 34.44 | 33.82 |
| Orange | $L^*$ | 54.91 | 53.47 | 51.56 | 50.91 | 53.34 | 54.23 | 51.04 |
| | $a^*$ | 44.37 | 45.47 | 46.96 | 45.77 | 45.13 | 44.92 | 44.59 |
| | $b^*$ | 56.72 | 56.52 | 57.42 | 56.15 | 57.60 | 58.13 | 55.80 |
| Brown | $L^*$ | 28.15 | 26.84 | 23.62 | 24.18 | 25.40 | 25.28 | 24.36 |
| | $a^*$ | 7.40 | 7.03 | 6.88 | 6.92 | 7.17 | 7.43 | 7.04 |
| | $b^*$ | 10.29 | 9.52 | 9.48 | 9.43 | 10.10 | 10.52 | 9.82 |
| Yellow | $L^*$ | 89.26 | 88.25 | 87.91 | 87.97 | 88.37 | 87.57 | 85.69 |
| | $a^*$ | -6.02 | -5.96 | -6.09 | -5.47 | -5.60 | -5.82 | -5.23 |
| | $b^*$ | 52.35 | 54.34 | 52.72 | 53.34 | 51.73 | 49.10 | 51.39 |
| Green | $L^*$ | 33.71 | 34.62 | 32.18 | 32.70 | 35.34 | 35.88 | 34.12 |
| | $a^*$ | -27.15 | -27.17 | -26.70 | -26.75 | -28.19 | -28.99 | -27.59 |
| | $b^*$ | 24.16 | 24.24 | 23.85 | 23.97 | 25.44 | 25.89 | 24.69 |
| Blue | $L^*$ | 70.29 | 68.09 | 69.46 | 68.37 | 69.38 | 69.50 | 68.17 |
| | $a^*$ | -7.11 | -7.01 | -7.11 | -7.00 | -7.20 | -7.32 | -6.96 |
| | $b^*$ | -23.53 | -25.05 | -23.54 | -24.06 | -23.44 | -22.12 | -23.23 |
| Purple | $L^*$ | 38.87 | 37.17 | 34.63 | 35.53 | 37.77 | 38.35 | 36.20 |
| | $a^*$ | 36.54 | 35.38 | 36.10 | 35.02 | 36.60 | 37.43 | 35.71 |
| | $b^*$ | -24.77 | -23.51 | -23.89 | -23.55 | -24.91 | -25.66 | -24.19 |
| Pink | $L^*$ | 64.34 | 62.54 | 60.78 | 60.44 | 62.86 | 63.29 | 60.37 |
| | $a^*$ | 48.77 | 50.36 | 52.04 | 51.46 | 50.23 | 48.78 | 49.98 |
| | $b^*$ | -2.85 | -2.06 | -1.78 | -1.37 | -2.35 | -3.42 | -1.97 |

The resulted from bar-lines are plotted in *Figure 2* to 4. As illustrated in *Figure 2*, the $L^*$ values of d/8 are more than the comparable values of 45/0 for almost all the samples with different textures and colors. A two-way Anova test with 0.95 confidences level was performed to investigate the effect of the texture and color center of the samples statistically. The P-values of 0.093 and 0.573 were obtained for texture and color, respectively. Considering that the obtained P-values are more than 0.05, the effect of spectrophotometer geometry on the lightness values of the textile samples is not statistically affected by the texture and color center of the sample with 0.95 confidences level.

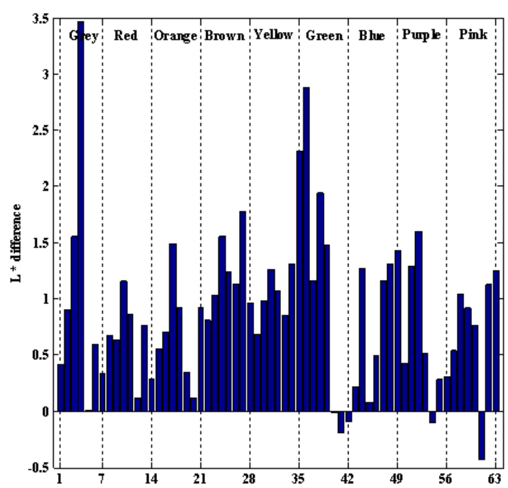


FIGURE 2. The $L^*$ difference between d/8 and 45/0 measurements.

The bar-lines of the chroma differences show that except grey, blue and some of the green samples for the other 6 color centers, 45/0 is usually reported larger C* value. The obtained P-values of texture and color were 0.450 and 0.000 respectively, which indicates that the effect of spectrophotometer geometry on the chroma values is statistically related to the color center of the samples.

It can be seen from *Figure 4* that the 45/0 geometry can cause a positive shift in hue angle for grey, orange, yellow, blue and purple samples compared to d/8. For the other color centers it might cause a negative shift. In addition, the obtained P-values of texture and color were 0.810 and 0.000 respectively, which indicates that the effect of spectrophotometer geometry on the hue values is statistically related to the color of the samples.

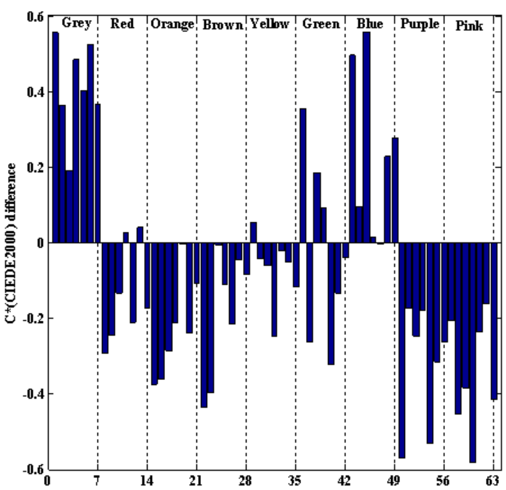


FIGURE 3. The $C^*$ difference between d/8 and 45/0 measurements.

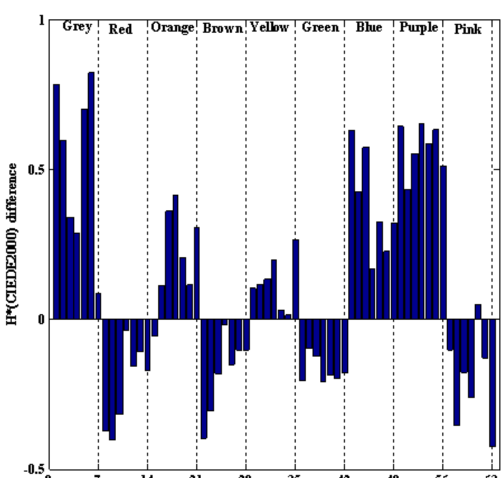


FIGURE 4. The $H^*$ difference between d/8 and 45/0 measurements.

Consequently, the spectrophotometer geometry influences the color coordinates of the textile samples with different textures. The d/8 geometry totally lead to higher $L^*$ values. It might be because of that the surface characteristics such as gloss and texture usually influences the lightness of the samples. Whereas the spectrophotometers are designed for flat samples, it is expected that the spectrophotometers' geometry show the most variations on the lightness, for the samples with different textures. Although, the lightness values are changed higher than chroma and hue measures, the chromaticity of the samples are also changed because of the instrument’s geometry.

*Table III* gives the color difference between the d/8 and 45/0 measures. It is illustrated that the geometry of the spectrophotometer influences the measured colors of texture samples. There exists 0.2 to about 3.2 units of CIEDE2000 (1:1:1) color difference between two measuring geometries. It seems that the color of the samples may influence the effect of geometry on the color measurement. As shown in this table, the largest difference between two measuring status can be seen for grey samples followed by green ones. To be able to see whether this effect is statistically significant or not, a two-way Anova test with 0.95 confidences level was performed. The P-values of 0.162 and 0.359 were found for texture and color respectively. Therefore, however, the spectrophotometer geometry influences the spectral measurements, the texture and the color center of the samples has no statistically significant effect on the geometry effect. It is maybe because of that the major effect of spectrophotometer geometry is on the lightness values and it was shown that the $L^*$ differences between d/8 and 45/0 is not statistically related to the texture and color of the samples.

TABLE III. The color difference [CIEDE2000 (1:1:1)] between the measured values of d/8 and 45/0 geometries.

| Texture / Color | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **Mean** | *std* | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Grey | 1.03 | 1.08 | 1.52 | 3.23 | 3.00 | 1.11 | 0.49 | **1.64** | *1.06* | 0.49 | 3.23 |
| Red | 0.75 | 0.72 | 1.03 | 0.72 | 0.28 | 0.66 | 0.34 | **0.64** | *0.26* | 0.28 | 1.03 |
| Orange | 0.64 | 0.77 | 1.54 | 1.02 | 0.39 | 0.29 | 0.98 | **0.81** | *0.42* | 0.29 | 1.54 |
| Brown | 0.85 | 0.92 | 1.15 | 0.91 | 0.88 | 1.32 | 0.71 | **0.96** | *0.20* | 0.71 | 1.32 |
| Yellow | 0.45 | 0.63 | 0.81 | 0.75 | 0.54 | 0.84 | 1.52 | **0.79** | *0.35* | 0.45 | 1.52 |
| Green | 2.41 | 1.00 | 1.58 | 1.21 | 0.37 | 0.29 | 0.20 | **1.01** | *0.81* | 0.20 | 2.41 |
| Blue | 0.82 | 1.09 | 0.80 | 0.42 | 0.96 | 1.06 | 1.20 | **0.91** | *0.26* | 0.42 | 1.20 |
| Purple | 0.94 | 1.19 | 1.46 | 0.80 | 0.79 | 0.75 | 0.63 | **0.94** | *0.29* | 0.63 | 1.46 |
| Pink | 0.50 | 1.05 | 0.90 | 0.92 | 0.44 | 0.96 | 1.24 | **0.86** | *0.29* | 0.44 | 1.24 |
| **Mean** | **0.93** | **0.94** | **1.20** | **1.11** | **0.85** | **0.81** | **0.81** | | | | |
| *Std.* | *0.58* | *0.19* | *0.33* | *0.83* | *0.84* | *0.35* | *0.45* | | | | |
| Min | 0.45 | 0.63 | 0.80 | 0.42 | 0.28 | 0.29 | 0.20 | | | | |
| Max | 2.41 | 1.19 | 1.58 | 3.23 | 3.00 | 1.32 | 1.52 | | | | |

The effect of texture on the measured color of d/8 spectrophotometer was discussed in the previous study [13]. *Table IV* shows the color difference between the first texture and the other 6 textures for each of the 9 color centers while d/8 spectrophotometer was applied. As discussed in the previous research, texture influences the spectrophotometer measurements based on d/8 geometry and the effect of texture on the measured colors depends on the type of texture and the color of the sample.

*Table V* gives the same investigation for 45/0 geometry. As indicated, the sample texture influences the measured colors with 45/0 spectrophotometer. It makes usually between 1 to about 5 units of CIEDE2000 (1:1:1) color difference. It seems that similar to d/8, the effect of texture on the measured color with 45/0 is also dependent on the color and the type of texture. For more surveys, two-way Anova test with 0.95 confidence level was applied. The P-values of 0.000 and 0.002 were resulted for texture and color respectively. Therefore, the effect of texture on the measured colors with 45/0 spectrophotometer depends on the texture and the color of the samples. It can be seen that the largest effect of texture on the measured colors with 45/0 was obtained for orange, brown, pink and grey samples sequentially. Similar results can be seen for d/8 geometry with a bit difference in sample ranking, in this situation the grey samples show the biggest color changes followed by orange, brown and pink. Furthermore, textures 3, 4 and 7 have the largest effect on the measured colors with 45/0. The similar results can be observed for d/8 geometry; however, the color difference caused by texture 3 and 4 is almost more than texture 7. Considering that texture 3 and 4 have the middle level of coarseness, it seems that the structure or the type of texture is more effective than the coarseness of the texture.

Another comparison was applied between 45/0 and d/8 geometries in which the color change via the texture variation was discussed. To do that a pair comparison T-Test was performed between the computed values of *Table IV and V*. The P-value of 0.032 was obtained with 0.95 confidence level, which shows that the color change by the texture difference is statistically dependent on the spectrophotometer geometry with 0.95 confidence level.

TABLE IV. The color difference [CIEDE2000 (1:1:1)] between the texture 1 and the other 6 textures in each color groups. The used spectrophotometer is d/8.

| Texture / Color | 2 | 3 | 4 | 5 | 6 | 7 | **Mean** | *std* | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|
| Grey | 2.69 | 4.86 | 4.10 | 0.97 | 0.43 | 3.22 | **2.71** | *1.74* | 0.43 | 4.86 |
| Red | 0.92 | 2.38 | 2.37 | 0.71 | 0.55 | 1.98 | **1.48** | *0.85* | 0.55 | 2.38 |
| Orange | 1.50 | 3.42 | 4.00 | 1.53 | 0.77 | 3.80 | **2.50** | *1.39* | 0.77 | 4.00 |
| Brown | 1.14 | 3.41 | 3.01 | 2.07 | 2.14 | 2.84 | **2.43** | *0.82* | 1.14 | 3.41 |
| Yellow | 0.88 | 0.87 | 0.96 | 0.64 | 1.47 | 2.36 | **1.20** | *0.63* | 0.64 | 2.36 |
| Green | 0.74 | 1.25 | 0.83 | 1.47 | 2.01 | 0.42 | **1.12** | *0.58* | 0.42 | 2.01 |
| Blue | 1.89 | 0.64 | 1.52 | 0.71 | 1.00 | 1.66 | **1.24** | *0.53* | 0.64 | 1.89 |
| Purple | 1.58 | 3.59 | 2.91 | 0.95 | 0.62 | 2.30 | **1.99** | *1.15* | 0.62 | 3.59 |
| Pink | 1.65 | 3.25 | 3.53 | 1.36 | 0.93 | 3.44 | **2.36** | *1.17* | 0.93 | 3.53 |
| **Mean** | **1.44** | **2.63** | **2.58** | **1.16** | **1.10** | **2.45** | | | | |
| *Std.* | *0.61* | *1.44* | *1.24* | *0.48* | *0.63* | *1.03* | | | | |
| Min | 0.74 | 0.64 | 0.83 | 0.64 | 0.43 | 0.42 | | | | |
| Max | 2.69 | 4.86 | 4.10 | 2.07 | 2.14 | 3.80 | | | | |

TABLE V. The color difference [CIEDe2000 (1:1:1)] between the texture 1 and the other 6 textures in each color groups. The used spectrophotometer is 45/0.

| Texture / Color | 2 | 3 | 4 | 5 | 6 | 7 | **Mean** | *std* | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|
| Grey | 2.20 | 3.73 | 1.29 | 1.21 | 0.48 | 3.24 | **2.02** | *1.26* | 0.48 | 3.73 |
| Red | 0.95 | 2.02 | 2.22 | 1.21 | 0.75 | 2.33 | **1.58** | *0.69* | 0.75 | 2.33 |
| Orange | 1.30 | 2.43 | 3.54 | 1.82 | 1.22 | 3.37 | **2.28** | *1.01* | 1.22 | 3.54 |
| Brown | 0.98 | 2.85 | 2.68 | 1.86 | 1.58 | 2.74 | **2.11** | *0.76* | 0.98 | 2.85 |
| Yellow | 0.68 | 0.50 | 0.66 | 0.62 | 1.29 | 1.35 | **0.85** | *0.37* | 0.50 | 1.35 |
| Green | 0.90 | 2.07 | 2.04 | 1.06 | 0.88 | 2.12 | **1.51** | *0.62* | 0.88 | 2.12 |
| Blue | 0.94 | 0.74 | 1.32 | 0.65 | 1.28 | 0.84 | **0.96** | *0.28* | 0.65 | 1.32 |
| Purple | 0.75 | 2.62 | 2.79 | 1.42 | 0.90 | 2.40 | **1.81** | *0.90* | 0.75 | 2.79 |
| Pink | 1.12 | 2.85 | 3.21 | 2.15 | 0.52 | 2.75 | **2.10** | *1.07* | 0.52 | 3.21 |
| **Mean** | **1.09** | **2.20** | **2.20** | **1.33** | **0.99** | **2.35** | | | | |
| *Std.* | *0.45* | *1.03* | *0.96* | *0.53* | *0.38* | *0.83* | | | | |
| Min | 0.68 | 0.50 | 0.66 | 0.62 | 0.48 | 0.84 | | | | |
| Max | 2.20 | 3.73 | 3.54 | 2.15 | 1.58 | 3.37 | | | | |

In the previous study, the correlation between the instrumental and visual color change via the texture variations was investigated for d/8 spectrophotometer. To be able to compare d/8 with 45/0 geometry and, to see that whether the 45/0 geometry has a better correlation with visual results, the same research has been accomplished for 45/0 measures. As indicated in *Figure 5 and 6*, there is almost no significant difference between the d/8 and 45/0 spectrophotometer in correlation of visual and instrumental color changes via the texture differences. Furthermore, this part of computations was repeated using CIEDE2000 (1:1:2) to see whether a better correlation was obtained. The results showed no significant difference. The correlation coefficient values between the visual assessments and the instruments' measurements were 0.62 and 0.59 for d/8 and 45/0 respectively.

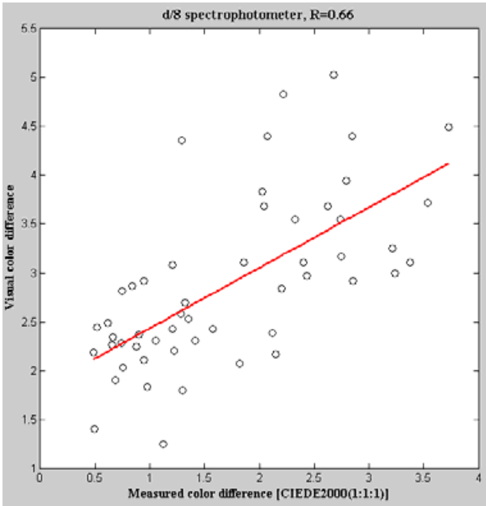


FIGURE 5. The correlation between the measured and visual color differences via the texture change while the spectrophotometer geometry is d/8.

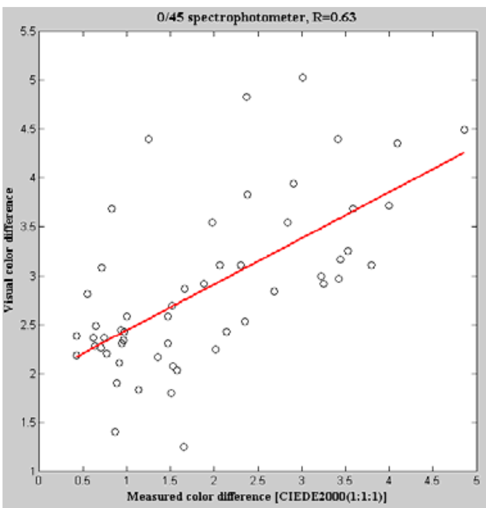


FIGURE 6. The correlation between the measured and visual color differences via the texture change while the spectrophotometer geometry is 45/0.

## CONCLUSION

Spectrophotometers might have different geometry, which can influence the color measurement results. Moreover, the visual and instrumental color assessment is affected by the texture of the samples. In the present study, the effect of spectrophotometer geometry on the color measurement of textile samples including different kinds of texture, were investigated. It was shown that there is an average of 1 unit of CIEDE2000 (1:1:1) color difference between d/8 and 45/0 geometry, which can sometimes reach to about 3 units. In addition this difference is not statistically related to the type of texture and color center of the samples. Moreover, the most differences between the measured values of these two spectrophotometers are in lightness values. Although the total color difference between two geometries does not depend on the texture and color of the samples, the differences between $C^*$ and $H^*$ values of two instrumental measures depend on the color center of the samples when they are evaluated separately. In addition, the d/8 geometry gives almost higher $L^*$ values.

In the other part of this research, the effect of texture on the measured colors with 45/0 spectrophotometer was investigated and in comparison to previous research for d/8 geometry. It was shown that the texture of the sample can affect the measured color by 45/0 geometry similar to d/8. In addition this effect depends on the color center of the samples. The texture affects the color values of both two measuring geometries; however, this effect shows differences between two statuses statistically. Also, the effect of texture on the instrumental assessments of color for both two geometries shows almost the same correlation with visual assessments.

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