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Spectrometer Analysis of Dyeing Behavior of Cotton and Polyester Fabric Using Direct, Reactive, and Dispersive Dyes

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SPECTROMETER ANAYLSIS OF DYEING BEHAVIOR OF COTTON AND POLYESTER FABRIC USING DIRECT, REACTIVE, AND DISPERSE DYES

By

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Spectrometer Analysis of Dyeing Behavior of Cotton and Polyester Fabric Using Direct, Reactive, and Disperse Dyes

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Maria Langton

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Abstract

Color is one the most significant factors for textile fabrics. In addition, color is very important for marketability of textile fabrics. Colorfastness refers to dyes that do not shift hue or fade when exposed to light and other environmental factors and that do not bleed onto other fabrics or materials during storage, processing, use, or care. This study focuses on the use of three different types of dye, disperse, reactive, and direct, on two most commonly used fabrics, cotton and polyester. The fabrics will go under testing to see how much dye is released into the wash by looking at the L, A, B values from the CIELAB spectrometer. The methods done in this study will conclude if the tested fabrics absorb the dyes, making the textiles marketable.

1 Introduction

Color is the sensation created in the brain by the message stimulated by the impact of radiation of a particular wavelength on the nerves of the eye. The human eye can see within the visible wavelengths that range from four hundred to seven hundred nanometers. The eye can see color by three main process sequences. The first sequence is the spectral power distribution of illuminant between wavelengths at four hundred to seven hundred nanometers, which reflects red, yellow, and blue color. Next is the diffuse reflection from an opaque surface, such as textiles. Finally, the last sequence is the spectral response curve of the color receptor in the human eye.

Color is made up of elements in order to see wavelengths. There are three attributes that contribute to the elements of color, as well as describing dyed fabrics. The first attribute of color is called hue. Hue is the quality that distinguishes one color from another ranging from red through orange, yellow, green, blue, indigo and violet, as determined by the dominant wavelength of the light (Subhas, 2010). The next attribute of color is value. Value tells the lightness and/or darkness of a colored surface. However, value does not always correspond to the amount of light that is being reflected. Value is measured on a scale from zero to ten, where zero represents absolute black and ten represents absolute white, which doesn't exist in reality. Finally, the last attribute of color is chroma. Chroma is the strength of the color and is also measured and designated to a number. The term intensity, saturation, and purity are sometimes used in place of chroma. When chroma is high, color will be very right. High chroma does not consist of white, gray, or black.

Color measurement is the process of assigning numerical values to a color, which is done to aid color matching and shade sorting. Color measurement can be done by the trained human eye or with instruments that evaluates the color in three or more dimensions. Many different instruments and systems are used in this process. Color matching is the process of developing a formula to a color swatch or when coordinating fabrics that are desired. Shade sorting is the process of grouping fabrics together by color (Kadolph, 2007, p. 383)

A colorant is a chemical compound that is added to a substance in order to change a color. There are two general colorants that can be added to textiles, pigments and dyes. Most colored textiles are done by dye or pigment mixtures rather than a single dye or pigment. However, there are major differences between these coloring substances and the ways that they are done on fabrics.

Pigments can change the color of reflected or transmitted light by the wavelength selective absorption. Many materials absorb certain wavelengths of light due to pigments. Since pigments are insoluble particles, they can hold onto the surface of fabrics by a binding agent that are diffused into the fiber structure by heat or catalyst. The binding agent acts like glue and holes the pigment to the fiber. There are specific binders for certain fiber contents in fabrics as well as the performance expectations for the fabric. Binders can be used to produce soft and flexible fabrics; ideally binders should not interfere with the color of the pigment or with the fabrics hand and function. However, pigments are not permanent and create problems in textiles such as stiffness, crocking, and fading (Kadolph, 2007, p. 383). Pigment solutions can be added in liquid or paste form and are sometimes called pigment dyes.

The other colorant is dye. Dyes are organic compounds composed of a chromosphore, the colored portion of the dye molecule, and an auxochrome which makes the dye soluble and is a site for bonding to the fiber. The biggest difference between dyes and pigments is that pigments are not soluble in their application medium and contain no available water solubilizing groups (Kadolph, 2007, p. 356). Dyes, however, are molecules that can be dissolved in water, also known as hydrophilic, and form transparent solutions so that they will penetrate into the fiber. Any undissolved particles of dye remain on the outside of the fiber, where they can bleed and are sensitive to surface abrasion. Dyes have great color strength, where pigments have lower color strengths. Most dyes bond chemically with the fiber and are found in the inner part of the fiber, rather than the surface where pigments are found. Dyes can be used in either solutions or pastes. There are several classes of dye that are determined by the chemical nature of the dyes. Dyes are mainly selective based on the chemical properties of the textile material. Among these classes of dyes include acid dye, azoic dye, basic dye, direct dye, disperse dye, vat dye, reactive dye, sulfur dye, and others (Subhas, 2010). This study discusses direct, disperse, and reactive dyes that are commonly used for cotton and polyester fabrics.

2 Literature Research

2.1 Direct Dyes

Direct dyes are anionic dyes substantive to cellulose when applied from an aqueous bath containing electrolytes, like sodium chloride (NaCl). There are more than two hundred direct dyes listed in Buyers Guide of AATCC (American Association of Textile Chemist and Colorist). Over eight hundred commercial products are available from different manufacturers. Wash fastness properties of these dyes are not so good, however, that can be improved using an after treatment. These after treatments improve washing fastness, but can have adverse effect or light fastness. Direct dyes are one of the simplest classes of dyes to use and they are water soluble. It is a low cost dye and used in less expensive products (Kadolph, 2007, p. 356). One example of the simplest form of direct dyes is shown in the Figure 1.0 below.

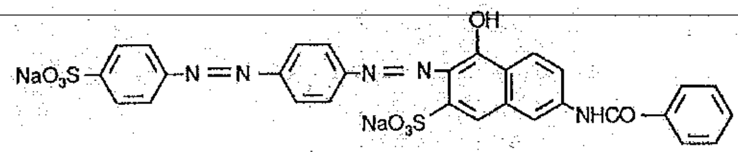


Figure 1

The figure shown is a C.I. Direct Red 81 (Kadolph, 2007, p. 354). This direct dye shows two azo groups, three benzene rings, one naphthalene residue, four aromatic rings in all, two sodium sulfonate groups with one hydroxyl, and one amino group.

2.2 Reactive Dyes

Reactive dyes were introduced in 1956, the first dyes cellulose which would react with the cellulose molecules to form covalent dye-fiber bonds. Reactive dyes generally have very high fastness. In reactive dyes the dye molecules or ions do not lose all their solubilizing groups after diffusion into the fibers, but under the dye appropriate conditions, they may react and attach themselves by covalent chemical bonds to the much larger fiber molecules, to form new colored derivatives of the fiber. The small part of the solubilizing groups is inadequate to cause the larger newly formed fiber-dye molecules to dissolve in water. This characteristic causes high wash fastness. There are generally four features for typical reactive dyes:

1. The chromophoric grouping, contributing to color and much of the substantively for cellulose.
2. The reactive system, enabling the dye to react with the hydroxyl groups in cellulose.
3. A bridging group that links the reactive system to the chromospheres.
4. One or more solubilizing groups, usually sulphonic acid substituents are attached to the Chromophoric grouping.

An example Anthraquinonoid – C.I. Reactive Blue 4 is shown below in Figure 2.0: (Aspland, 1997, p. 131)

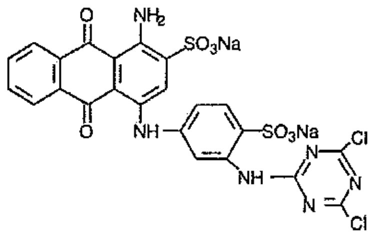


Figure 2

The reactive dye molecules tend to be larger, linier, and somewhat less brightly colored then acid dye molecules. Reactive dyes all rely on many of the same chromphonic groups such as acid and direct dyes for their color, although the azo chromophore –N=N, is by far the most important (Aspland, 1997, p. 131). Within reactive dyes, covalent bonds are created. The covalent bonds uniform the molecules, enable the dyes to react with the cellulose, and create a bridging group that links the reactive system. With Covalent bonds, both atoms donate an electron to the bond and the resulting pair of electrons is shared between them (Aspland, 1997, p. 107). Because of this, the bonds share a lot of energy which requires even more energy to tear them apart.

2.3 Disperse Dyes

Disperse dyes are insoluble dyes, are nonionic, and have very limited solubility in water at room temperature and have substantively for one or more hydrophobic fibers (Aspland, 1997, p. 193). Therefore, disperse dyes are only suitable for dyeing polyester and nylon fibers. There are two methods used for dyeing the polyester fibers and they are carrier dyeing and thermosol process (Subhas, 2010).

Polyester is a hydrophobic fiber having high crystalinity that reduces dye diffusion within the fiber structure. Generally accepted as describing for disperse dyeing is aqueous phase transfer of dyes to the hydrophobic fiber. A small amount of the disperse dye forms an aqueous solution with initially at first, the greater proportion of the dye in dispersion in the dye bath. Monomolecular dye is absorbed on the surface of the fiber from the aqueous dye solution. As dye molecules diffuse from the surface to the interior of the fiber through amorphous regions, the dye particles from the bulk dispersion dissolve in the depleted aqueous dye solution which is then replenished with monomolecules that can be further absorbed onto the fibers surface. This process can be accelerated by raising the temperature of the fiber, which causes swelling of the fiber and the amorphous region moves to allow the dye molecule to enter the fiber structure. The temperature during dyeing must be raised above the Tg (glass transition temperature) of the fiber (Subhas, 2010). This process is illustrated in Figure 3.0 below (Burkinshaw, 1995, p. 9)

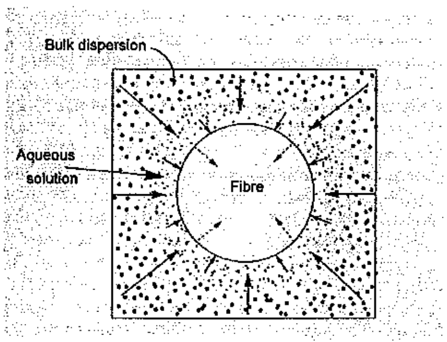


Figure 3

However, since disperse dyes have such limited solubility in water, some particles in the disperse dye may still be occluded on the fibers surface after the dyeing phase is complete. If this occurs, the last state of the total dyeing process may need to be one where surface dye is removed (Aspland, 1997, pp. 194-195). The result of having excess dye on the outside of fiber's surface includes reduced wet-fastness, wash-fastness, sublimation, dry-cleaning fastness, and a more dull color shade (Aspland, 1997, pp. 194-195). To remove the unwanted dye from the fabric, a procedure called reduction clearing is used. Reduction clearing uses a bath of about two grams per liter of both caustic soda and sodium dithionite, and about one gram per liter of a stable surfactant (Aspland, 1997, pp. 194-195).

2.4 CIELAB Color System

The most common color measuring system for textiles that is used in the United States is CIELAB color system. The international Commission on Illumination (called CIE) completed the first phase of CIELAB in 1931 (Systems, 2010, pp. 2-7). Initially, CIELAB was developed as an objective, color, and evaluation method using a light source, a sample, and an observer. This viewing method was equivalent to what the human eye would see from a distance. However in 1965 the Commission made two changes to the CIEBLAB system. The Commission's developed a ten-degree observer and artificial daylight. In 1976, the Commissions latest version of the CIELAB system was created. Currently, the CIELAB system uses tristimulus values, which are artificial interpretations of what the human eye sees (Systems, 2010, pp. 2-7)The CIELAB system compares a sample to a standard and makes a numerical determination based on the apparent color difference. These color differences are given a value and is plotted on a chart that is shown on a computer screen. The chart or area that CIELAB system recognizes is called the "color space". This theoretical space can be thought of as a three-dimensional cylinder with an axis running through the center from top to bottom (Systems, 2010, pp. 2-7). CIELAB Color System values are designated as L,a, and b representing the three attributes of color. The "L" scale represents the lightness of the sample, which is based on the percentage of light reflectance

(Systems, 2010, pp. 2-7). The "L" scale is a ratio scale ranging from zero (black) to one hundred (white). The "L" value is the vertical axis running through the center. The "A" scale is an interval scale that ranges from negative infinity (-∞) green to positive infinity (+∞) red. When a sample is placed under the CIELAB spectrometer, the "A" scale doesn't mean that the sample is red or green, it simply means that the sample has red and green shading. The "A" value is represented by the horizontal plane on the chart. The "B" scale ranges from negative (-∞) blue to positive infinity (+∞) yellow. Again, when blue and yellow shades read on the Spectrometer, it doesn't mean the sample is blue or yellow, it merely means there are blue and yellow shades in the sample. The "B" value is represented on the vertical plane on the chart. Any color can be distinctly designated by L,a,b. Using the spectrometer before and after washing out each fabric sample, will help determine how much dye was absorbed in the fabric's fibers or how much dye did not get absorbed. Figure 4.0 below shows the CIELAB chart with all the L, A, B values.

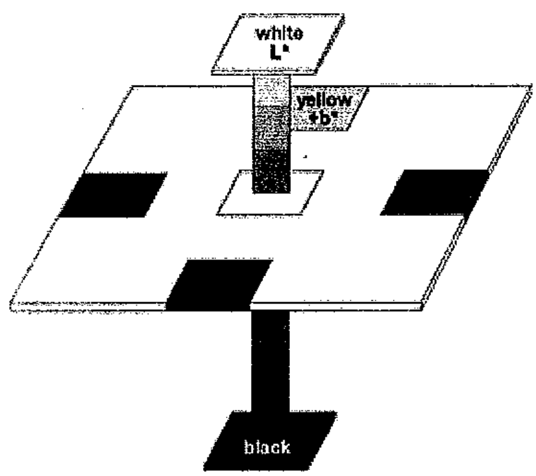


Figure 4

2.5 Kubelka-Munk

Kubelka-Munk function K/S is widely accepted as the dye depth indicator of textile fabrics.

Kubelka-Munk remains among the most accessible mathematical description for the diffuse reflection process (Subhas, 2010). The formula for Kubelka-Munk's function is K/S = $\frac{(1-R)}{2R}$, where R is equal to the degree of reflectance, K is equal to the absorption of light, and S is equal to light scattering. The R value of the dyed fabric was measured on a color-eye spectrophotometer at a wavelength of minimum reflectance. The depth of the color increases with dyeing time initially after certain period of time the rate of increase starts decreasing and thus equilibrium is reached and therefore the dye is completed.

3 Methodology

The methodology of this study is to use direct, disperse, and reactive dyes on the appropriate fabric for the dye molecules to absorb or diffuse into the fabric's fiber structure. Therefore, polyester fabric will be used for disperse dyes and cotton fabric will be used for direct and reactive dyes. Each fabric sample will be immersed in the appropriate dye bath for a certain period of time. After each fabric is dyed, they will be placed under the CIELAB spectrometer to determine the L, a, b values. Once each fabric is evaluated three times, they will be placed in a washing machine that is used for home laundering. After washing, the samples will be placed under the CIELAB spectrometer again. The objective is to evaluate both sets of L, a, b values to determine how much dye is released into the washer, or in other words, how much dye remained on the fabrics surface and not in the fabric's fibers (color-fastness). After evaluating the L, a, b readings the Kubelka-Munk mathematical function and L, a, b value graphs will be used to further assist in determining the amount of dye that is released in the wash.

3.1 Dyeing Process

Depending on the fiber content, fabric weight, and penetration needed, there are different methods in applying the dye on textiles. The methods tend to involve one of three ways of combining the dye bath with the textile. The textile is circulated in a dye bath, the dye bath is circulated around the textile, or both textile and dye bath are circulated around each other (Kadolph, 2007, p. 391).

Dyeing is the collective name given to the processes whereby colors are dissolved, transported to the fiber surface and, as individual molecules or ions, diffused into the fibers to have substantively (Aspland, 1997, p. 354). The soluble molecules or ions pass from an external phase, outside the fiber, and into he internal or fiber phase. This may be followed by further process steps to ensure the resistance of the soluble, diffusible ions to easy removal from the fiber by water, the solvent (Aspland, 1997, p. 354).

The dye process describes the environment created for the introduction of dye by hot water, steam, or dry heat. For textile dyeing, creating a dye bath with dye and other auxiliary chemicals is mandatory. The transfer of color or potentially color chemicals species from the dye bath takes place onto the fabrics surface through sorption. Then diffusion of the color occurs from the surface into the fibers structure. It can vary significantly as to what happens prior to transfer and after diffusion depending on the application properties of the dye processes required for the color chemicals. The colored chemicals should be at the finest state of subdivision, which should be in the form of molecules or ions in solutions. Most dyes are in the form of water soluble sodium salts, but exceptions are basic dyes and disperse dyes. The anions transfer and diffusion processes take place from aqueous solutions in bath containing electrolytes, which depends on there being some level of attraction, called substantively, between the color bearing dye bath anions the non-ionic cellulose fibers. The most likely cause of substantively appears to be the combination of relatively weak secondary attractions including van der Waals forces and h-bonding.

Dyes are mainly selective based on the chemical properties of the textile material, as stated above. For each type of fabric the amount of dye that has been attached to the textile will be determined. For this study, polyester and cotton fabrics will be used, therefore reactive and direct dye will be used for the cotton samples and disperse dye will be used for the polyester samples. Each fabric sample will be dyed at five different time segments. The first fabric sample will be immersed in the dye bath for five minutes, the second sample at ten minutes, third sample at fifteen minutes, fourth sample at twenty minutes, and the last sample at twenty five minutes. After each sample (five polyester and five cotton samples) complete the allotted time needed, they will be washed. For each type of dye, a different procedure is done in order for the dye to penetrate into the textiles fibers.

Reactive or fiber-reactive dyes, combined chemically with the textile's fiber. Therefore, the characteristics of reactive dyes are bright shades, good light-fastness, good wash-fastness, and sensitivity to chlorine bleach. Five of the ten cotton samples were immersed in a reactive dye bath for this study. Below is the dyeing process that was followed (Chipot, 2010).

1. Cut and weigh 100% cotton fabric sample, 3x3 inch square.
2. Wash and scour the fabric with 0.05g soda ash and two drops of Synthrapol at 60-70°C for 15 minutes
3. Mix 5.5mL distilled water at room temperature with 0.165g dye
4. Add to 110mL distilled water room temperature
5. Add 10g salt and 0.077g Metaphos, dissolve
6. Add fabric and stir for 10-15minutes
7. Mix 5.5mL distilled water and 0.716g Dye Activator at 35°C
8. Remove fabric and add activator solution to dye bath, mix well.
9. Return fabric for 60 minutes, stirring every five minutes.
10. Allow dye bath to cool and remove the fabric and rinse well with warm water. Let fabric air dry.
11. Repeat until all five samples are done in time segments of five, ten, fifteen, twenty, and twenty five minutes.

Disperse dyes are known for being a commercially significant dye class. The dye particles disperse in water, which allows a good color range. The characteristics for disperse dyes are fair to excellent light-fastness and wash-fastness, however, blues and violets on acetate fume fade. All five polyester samples were immersed in a dye bath with disperse dye for this study. Below is the dyeing process that was followed (Chipot, 2010).

1. Cut and weigh 100% polyester fabric sample, 3x3 inch square.
2. Wash and scour the fabric with 0.05g soda ash and two drops of Synthrapol at 60-70˚C for 15 minutes
3. While fabric is washing, prepare the dye and dye bath.
4. Dissolve 0.25g dye into 9mL of boiling distilled water. Cool to room temperature and filter through two layers of nylon.
5. Dilute Dye Carrier NSC by adding 1mL of Carrier to 9mL boiling water.
6. Prepare dye bath by adding the following ingredients, stir well after adding each
    a. 330 mL Distilled water
    b. 0.15g citric acid crystals
    c. 6 drops of Synthrapol
    d. Dissolved dye mix
    e. Diluted dye carrier
7. Rinse fabric, squeeze, and put in dye bath
8. Bring dye bath rapidly to a boil, stirring constantly. Keep boiling for 30-45 minutes.
9. While dye bath is simmering, prepare a second bath of distilled water at 82˚C.
10. Remove the fabric from dye bath and immediately plunge into second pot to rinse the fabric

11. Discard the dye bath and refill with 70˚C distilled water. Add 2 drops of Synthrapol and stir for 5-10 minutes to wash the fabric.
12. Rinse well with hot water, air dry.
13. Repeat until all five samples are done in time segments of five, ten, fifteen, twenty, and twenty five minutes.

Direct dyes are a commercially significant dye class since they have a complete color range. Direct dyes have good colorfastness to light, however direct dyes have poor wash-fastness. The remaining five cotton samples were immersed in a dye bath with direct dye for this study. Below is the dyeing process that was followed (Chipot, 2010).

1. Cut and weigh 100% cotton fabric sample, 3x3 in square.
2. Wash and scour the fabric with 0.05g soda ash and two drops of Synthrapol at 60-70˚C for 15 minutes
3. Rinse fabric well
4. Heat up 200mL distilled water to 50˚C
    a. Add 0.1g direct dye powder
    b. Add 0.8g salt
    c. Add 2 drops Synthrapol
    d. Dissolve these ingredients
    e. Add fabric
5. Bring temperature up to 95˚C and stir for 30 minutes.
6. Allow dye bath to cool and remove the fabric and rinse well with warm water. Let fabric air dry.

7. Repeat until all five samples are done in time segments of five, ten, fifteen, twenty, and twenty five minutes.

3.2: Color Measurement Process

After air drying the fabric samples, each will be analyzed under the CIELAB system spectrometer. Each dye has five different samples. Each sample will be read on the spectrometer and then recorded in a table three different times. The process to use the CIELAB system spectrometer is as follows (Chipot, 2010):

1. Turn spectrometer on.
2. Turn on computer attached to the spectrometer.
3. Open up Easy Match QC Software.
4. Standardize by pressing STANDARDIZE icon.
5. Calibrate spectrometer by following directions given on screen using the black glass and white tile.
6. Press NEW JOB icon and name file.
7. Place sample under spectrometer.
8. Click READ STANDARD icon, name standard
9. Record given L, A, B values on data sheet in the Easy Match QC Software.
10. Repeat two times to have a total of three measurements for L, A, and B values.
11. Repeat until all fabric samples are read three times, for each time segment, and for each dye type.

The spectrometer will determine the L, a, b values for each sample. Once all of the samples have been read, an average of the three L, a, b values will be determined for graphing. This information will be needed when re-reading the fabric samples after being washed.

3.3: Washing Process

According to AATCC, there are certain washing procedures that need to take place for the testing of the fabric samples (AATCC, 2012). For this study, an automatic washer and tumbler dryer was used that were stacked on top of each other. Frigidaire is the brand of the washer and dryer that was used. The laundering machine is a heavy duty extra large capacity. The machine has two speed combinations and has a ¾ HP motor. Only one type of dye with the five samples was washed at a time. No mixtures of dyed fabrics were placed in the washing machine at the same time. The procedure that was used to wash all the fabric samples is as follows:

1. Select five samples of either disperse, reactive, or direct dye fabrics
2. Place the five samples in the washing machine
3. Set the washer knob representing the type of fabric to "colors"
4. Set the washer knob representing the water temperature to "hot-cold"
5. Set the washer knob representing the size of the load to "small"
6. Add thirty grams of Ultra Tide concentrated soap into the wash
7. Press "start"

Once the washing is complete, the next step is to dry the fabric samples. The procedure that was used to dry the fabric samples is as follows:

1. Move all the washed fabric samples into the dryer.
2. Do not place a dryer sheet in the dyer.

3. Set the dryer knob representing the heat to "normal".
4. Press "start".
5. Once the fabric samples are dry, place them back under the spectrometer to be evaluated.
6. Repeat this procedure until all fabric samples are washed and dried.

3.4: Re-Reading L, A, B Values

After each fabric sample is washed and dried, the samples are placed under the CIELAB for a second round of readings. The procedure is the same as the first round of L, A, B readings. The steps are as followed:

1. Turn spectrometer on.
2. Turn on computer attached to the spectrometer.
3. Open up Easy Match QC Software.
4. Standardize by pressing STANDARDIZE icon.
5. Calibrate spectrometer by following directions given on screen using the black glass and white tile.
6. Press NEW JOB icon and name file.
7. Place sample under spectrometer.
8. Click READ STANDARD icon, name standard.
9. Record given L, A, B values on data sheet in the Easy Match QC Software.
10. Repeat two times to have a total of three measurements for L, A, and B values.
11. Repeat until all fabric samples are read three times, for each time segment, and for each dye type.
12. Record all data from before washing and after washing into a Table. Each type of dye and sample will have a separate table.

4 Research Data

4.1 Sample L, a, b Values of Dyed and Washed Fabrics

Tables 1 through 15 show the fabrics L, a, b values for each type of dyed fabric. It is seen in Tables 1 through 15 the values of the fabric dyed before and after washing. An average of three readings was needed for each type of fabric. Tables 1 through 15 illustrate all the L values for five different fabrics because they were dyed with disperse dye for 10, 15, 20, 25, and 30 minutes. Similarly, all the other dyes (direct and reactive) was used to develop similar data for the different appropriate fabrics

Table 1 Disperse Dye Sample One 10 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	63.84	63.83	63.84
A	26.29	26.25	26.27
B	6.22	6.23	6.25
WASHED	Reading One	Reading Two	Reading Three
L	63.77	63.77	63.78
A	24.33	24.32	24.32
B	5.83	5.84	5.78

K/S Dyed: 1.68 **K/S Washed:** 1.84

Table 2 Disperse Dye Sample Two 15 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	60.37	60.37	60.14
A	31.66	31.67	31.5
B	10.32	10.32	10.19
WASHED	Reading One	Reading Two	Reading Three
L	60.82	60.8	60.79
A	30.41	30.39	30.41
B	10.58	10.59	10.6

K/S Dyed: 1.85 **K/S Washed**: 1.84

Table 3 Disperse Dye Sample Three 20 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	58.28	58.2	58.21
A	33.47	33.38	33.43
B	12.15	12.17	12.15
WASHED	Reading One	Reading Two	Reading Three
L	58.56	58.55	58.54
A	32.43	32.4	32.42
B	12.11	12.13	12.14

K/S Dyed: 2.11 **K/S Washed**: 2.08

Table 4 Disperse Dye Sample Four 25 Minutes and K/S Values

DYED	Reading One	Reading Two	Reading Three
L	56.2	56.21	56.21
A	34.34	34.32	34.37
B	13.1	13.17	13.16
WASHED	Reading One	Reading Two	Reading Three
L	56.74	56.76	56.76
A	33.44	33.4	33.38
B	13.6	13.6	13.62

K/S Dyed: 2.46 **K/S Washed:** 2.35

Table 5 Disperse Dye Sample Five 30 Minutes and K/S Values

DYED	Reading One	Reading Two	Reading Three
L	56.2	56.21	56.21
A	34.34	34.32	34.37
B	13.1	13.17	13.16
WASHED	Reading One	Reading Two	Reading Three
L	56.74	56.76	56.76
A	33.44	33.4	33.38
B	13.6	13.6	13.62

Table 6 Reactive Dye Sample One 10 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	81.86	81.47	81.64
A	-14.19	-13.83	-13.91
B	46.24	46.29	46.47
WASHED	Reading One	Reading Two	Reading Three
L	81.24	81.33	81.33
A	-12.86	-13.37	-13.36
B	45.93	51.49	51.52

K/S Dyed: .70 **K/S Washed:** .70

Table 7 Reactive Dye Sample Two 15 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	81.63	81.59	81.61
A	-14.14	-14.12	-14.11
B	50.98	54.03	51.07
WASHED	Reading One	Reading Two	Reading Three
L	81.16	81.33	81.33
A	-13.28	-13.37	-13.36
B	51.13	51.49	51.52

K/S Dyed: .68 **K/S Washed:** .70

Table 8 Reactive Dye Sample Three 20 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	81.38	81.39	81.39
A	-14.2	-14.12	-14.15
B	53.29	54.28	53.3
WASHED	Reading One	Reading Two	Reading Three
L	81.35	81.54	81.53
A	-13.45	-13.35	-13.37
B	53.9	53.08	53.1

K/S Washed: .70 **K/S Dyed:** .66

Table 9 Reactive Dye Sample Four 25 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	81.63	81.62	81.63
A	-14.36	-14.35	-14.15
B	56.43	56.4	53.3
WASHED	Reading One	Reading Two	Reading Three
L	81.04	81.04	81.03
A	-13.5	-13.47	-13.47
B	56.54	56.49	56.54

K/S Dyed: .66 **K/S Washed:** .69

Table 10 Reactive Dye Sample Five 30 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	81.4	81.38	81.37
A	-14.25	-14.36	-14.23
B	58.04	58.12	58.01
WASHED	Reading One	Reading Two	Reading Three
L	81.06	81.06	81.06
A	-12.99	-12.99	-13
B	58.1	58.04	58.08

K/S Dyed: .67 **K/S Washed:** .66

Table 11 Direct Dye Sample One 10 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	62.98	62.95	62.99
A	4.34	4.36	4.46
B	-29.62	-29.6	-29.93
WASHED	Reading One	Reading Two	Reading Three
L	66.65	66.62	66.62
A	5.9	5.82	5.8
B	-24.73	-24.47	-24.99

K/S Dyed: 6.59 **K/S Washed:** 4.25

Table 12 Direct Dye Sample Two 15 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	63.1	63.1	63.1
A	4.56	4.56	4.55
B	-29.37	-29.4	-29.4
WASHED	Reading One	Reading Two	Reading Three
L	64.79	64.81	64.79
A	6.39	5.82	6.38
B	-25	-25.04	-25.01

K/S Dyed: 6.42 **K/S Washed**: 4.87

Table 13 Direct Dye Sample Three 20 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	61.61	61.6	61.61
A	5.43	5.41	5.42
B	-30.97	-30.95	-30.94
WASHED	Reading One	Reading Two	Reading Three
L	62.09	62.09	64.1
A	6.87	6.63	6.94
B	-26.64	-26.63	-26.67

K/S Dyed: 7.27 **K/S Washed**: 6.05

Table 14 Direct Dye Sample Four 25 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	59.83	59.83	59.83
A	5.85	5.89	5.85
B	-30.86	-30.86	-30.9
WASHED	Reading One	Reading Two	Reading Three
L	62.76	64.08	64.11
A	6.61	6.63	6.7
B	-26.27	-26.26	-26.52

K/S Dyed: 8.09 **K/S Washed:** 5.25

Table 15 Direct Dye Sample Five 30 Minutes and K/S Values:

DYED	Reading One	Reading Two	Reading Three
L	58.82	58.85	58.84
A	5.72	5.74	5.73
B	-30.89	-30.99	-30.89
WASHED	Reading One	Reading Two	Reading Three
L	61.76	61.74	61.72
A	7.19	7.08	7.13
B	-27.12	-26.88	-26.87

K/S Dyed: 8.72 K/S **Washed:** 6.21

4.2 Figures Representing L, a, b Values of Dyed and Washed Fabrics

The collected data for the L, a, b values are presented in figure 5 through 13 for all the dyes and different fabrics before and after washing. It was further examined if there was a significant difference in the L, a, b values between washed and unwashed fabrics. Figure 5 shows the L value samples for before and after washing of fabrics dyed with disperse color. A total of three readings for each value were taken and their average was reported. The relationship between dye value (L-value) and the dyeing time were plotted in Figures 5 through 13 for each dye type. This gives an indication of dyeing rate.

Figure 5 Disperse Dyes "L" Value

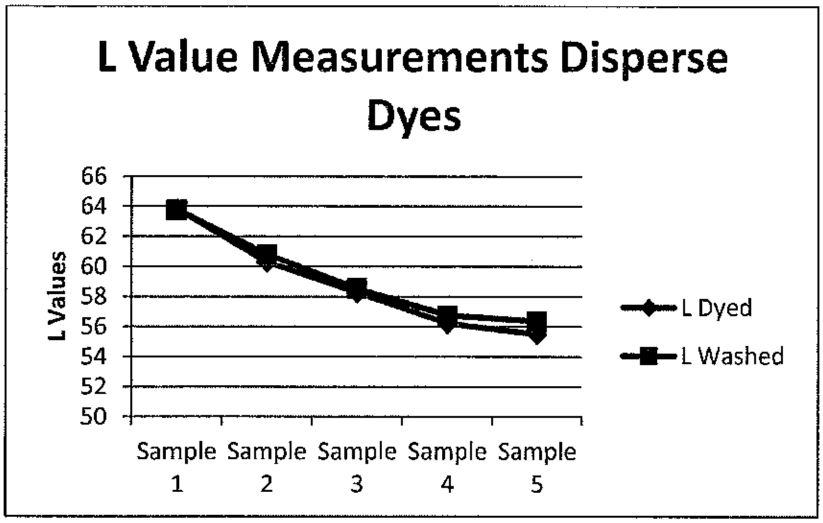


Figure 6 Disperse Dyes "A" Value

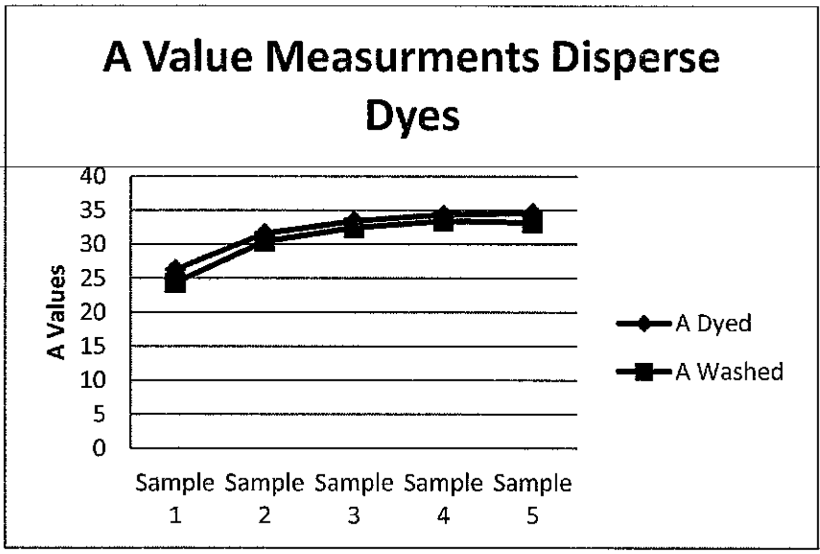


Figure 7 Disperse Dyes "B" Value

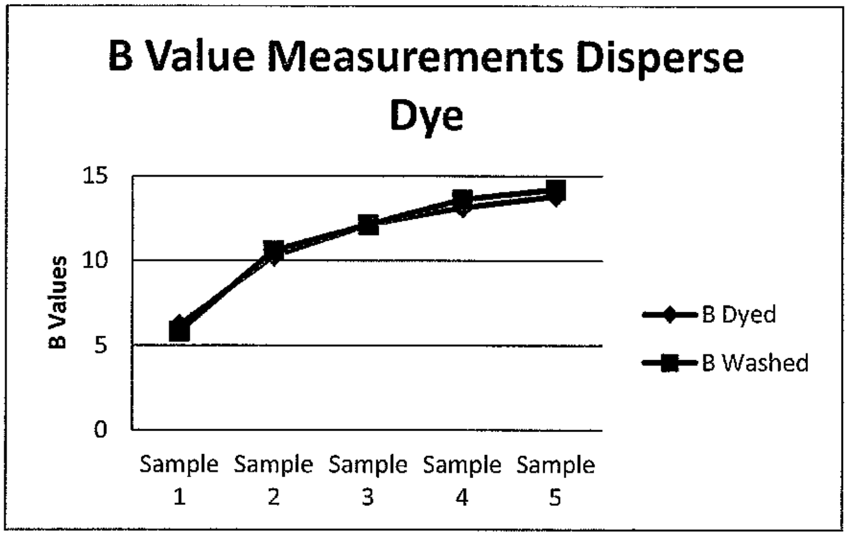


Figure 8 Reactive Dyes "L" Value

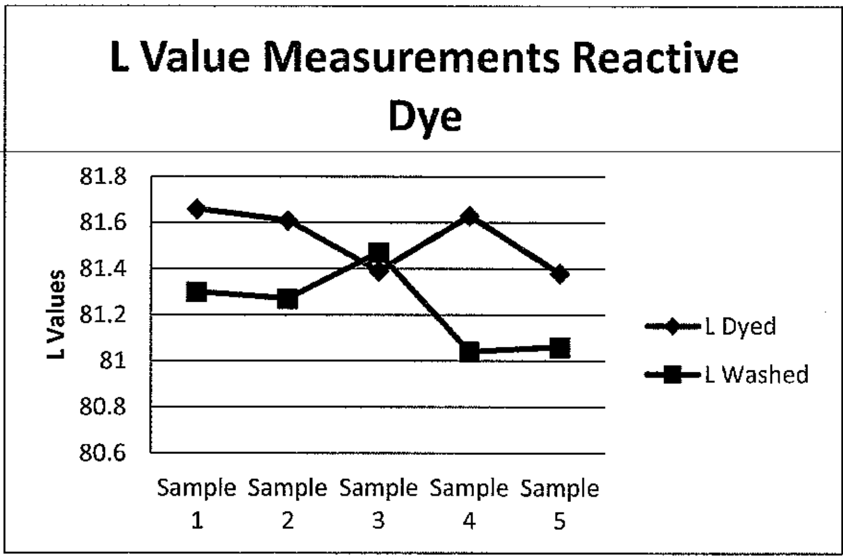


Figure 9 Reactive Dyes "A" Value

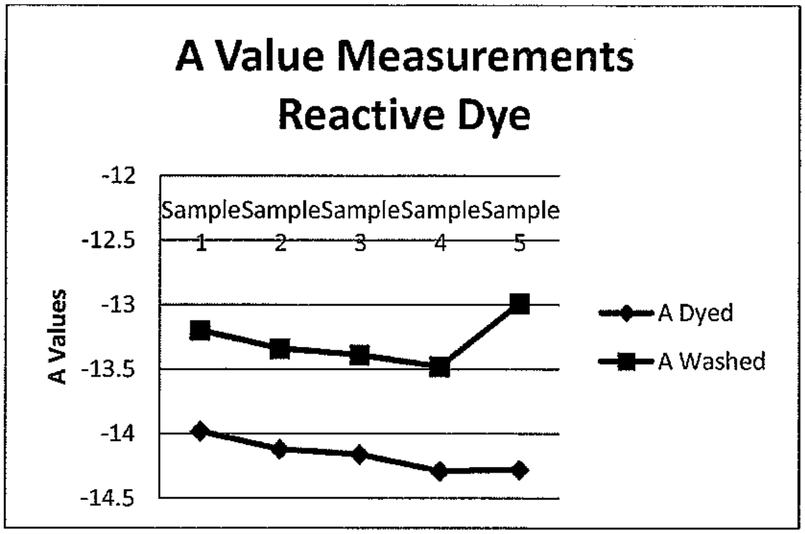


Figure 10 Reactive Dyes "B" Value

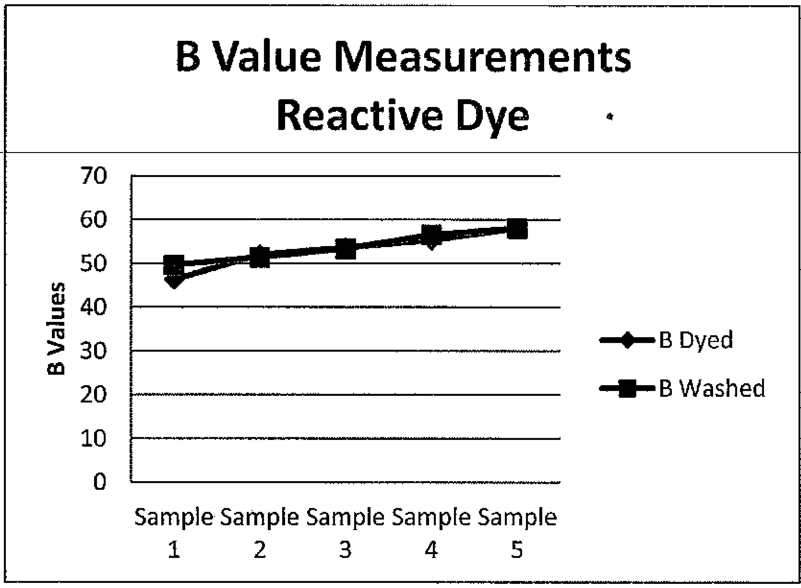


Figure 11 Direct Dyes "L" Value

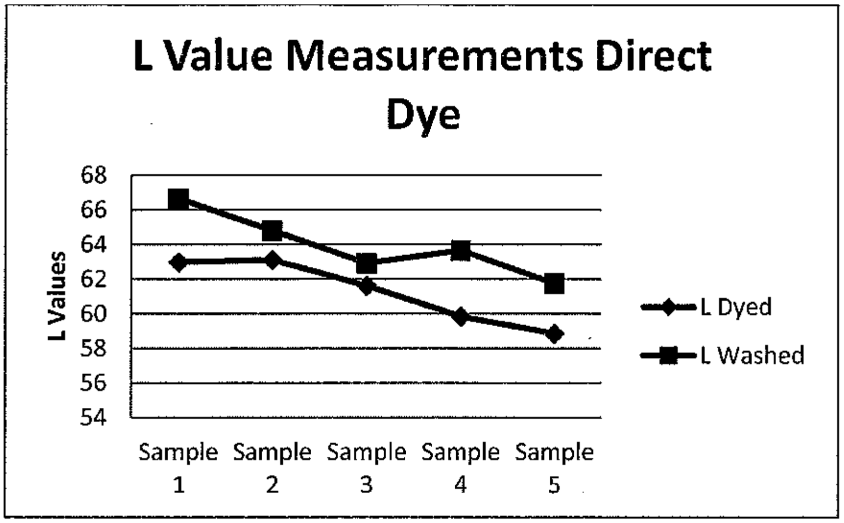


Figure 12 Direct Dyes "A" Value

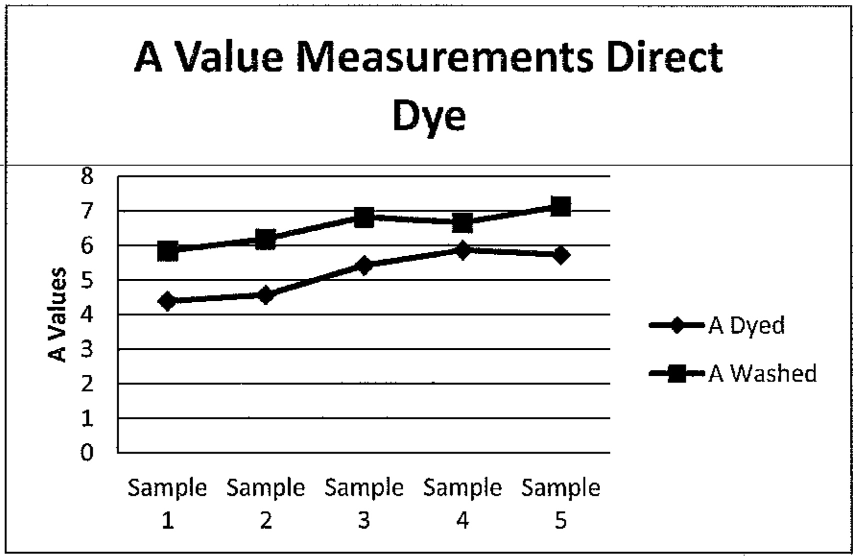
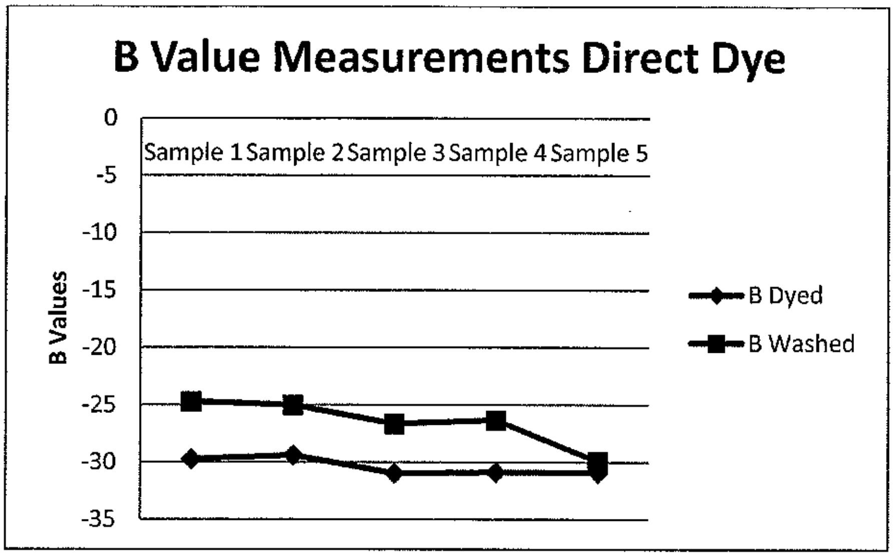


Figure 13 Direct Dyes "B" Value



5 Results and Discussion

5.1 Disperse Dye and Polyester Fabric Results

A pink color of disperse dye was used to dye the polyester fabric. The name of this dye was Prosperse Scarlet D350. When analyzing the tables and figures for disperse dyed fabrics the L, a, b values show the characteristics of a pinkish/red dye. The L value was always positive, the higher the L value means lighter color value. The average dyed L value of the five samples that were taken was 58.82. The average washed fabric L value of the five was 59.24. A possible reason why the L value increased after washing the fabric may be attributed to the removal of auxiliary on the fabric surface that was not attached and thus makes the fabric pinker. The "a" value for the disperse dye samples were also positive because pink is more close to a red color. The average a value between the five samples that were taken was 32.05. Therefore, there was more red in the fabric than green. After washing the fabric, the "a" value for the disperse dye fabric samples slightly dropped to 30.74. This concludes that after washing the fabric, some of the dye was removed because they were unattached particles on the fabric's surface. Finally, the average of the "b" value for all the five fabric samples was 11.12. This shows that there was more yellow than blue in the fabric because pink is a combination of red and yellow as seen in Figure 14. In figures 5 through 7 the L, a, b values are plotted on a graph for both dyed unwashed and washed fabric samples. Each graph shows both the dyed unwashed and washed fabrics that are similar to each other.

Figure 14 Color Eye Spectrophotometric Scan of a Pink Color Dyed Fabric

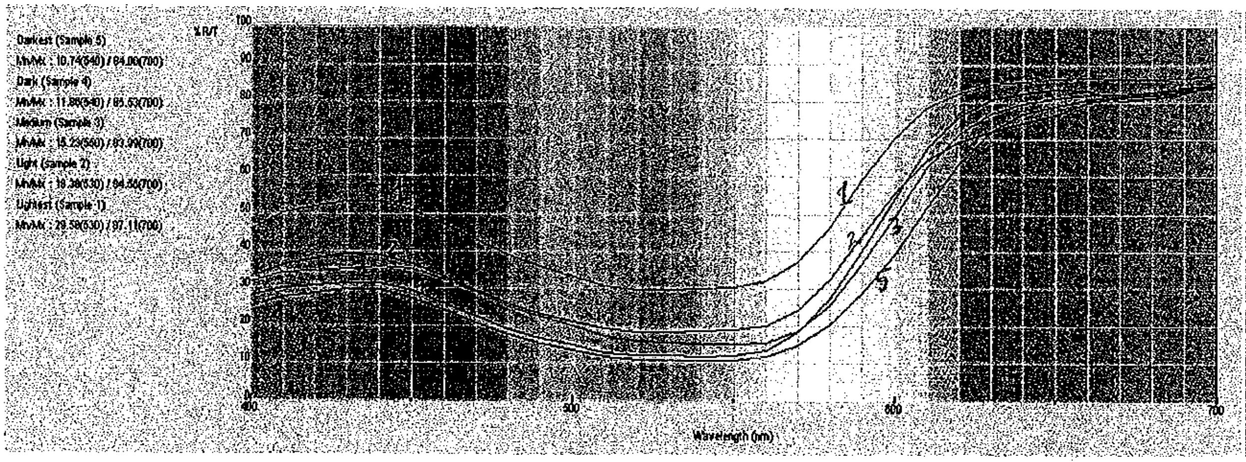


Figure 14

5.2 Reactive Dyeing on Cotton Fabric Results

For the reactive dye, a yellow dye was used on cotton fabric, also known as Pro Sun Yellow 108. When examining the tables and figures for reactive dyed fabrics the L, a, b values show attributes of a yellow dye. The L value was always positive, the higher L value means a lighter color value, and therefore, the dyed fabric samples were a lighter shade of yellow. The average dyed L value of the five samples that were taken was 81.53. The average washed fabric L value of the five samples was 81.23. Analyzing the un-washed and washed fabric sample L values show no significant change because the dye penetrated into the fibers and did not stay on the fabric's surface. The "a" values for reactive dyes were negative, because negative "a" represents green. There was more green values instead of red values in the fabric samples because green is part of yellow color. The average washed fabric "a" value of the five samples was -14.17. The average washed fabric "a" value of the five samples was -13.28. A cause to the "a" value decreasing after washing may be an indication of the dye not attaching to the fabric and therefore, some of the dye was removed from the fabric's surface. Finally, the "B" values in the reactive dye samples were positive because positive "b" corresponds to yellow. There was more yellow values instead of blue, because yellow is the color of dye that was used. The average dyed "b" value of the five samples was 53.08. The average washed fabric "b" value of the five samples was 53.80. When observing the "b" values of the un-washed and washed fabrics there is no significant change because the dye did not stay on the fabric's surface, the dye was penetrated into the fabric's fibers. In figures 8 through 10 the L, a, b values are plotted on a graph for both dyed unwashed and washed fabric samples. Each graph shows both the dyed unwashed and washed fabrics that are similar to each other.

5.3 Direct Dyeing on Cotton Fabric Results

A blue color direct dye was used to dye the cotton fabric. The name of the dye was Pro Royal Blue 4205. When reviewing the tables and figures for direct dyed fabrics, the L, a, b values show traits of blue dye. The L value for direct dye samples were positive, which means there was lighter color values since the L value was high. This shows that the blue fabric is a lighter blue, rather than a darker blue. The "a" values for direct dye samples, both dyed and washed fabrics, show more values of red than green because there red values in blue rather than green, as shown in Figure 14. The average dyed "a" value of the five samples that were taken was 5.19. The average washed fabric "a" value of the five samples that were taken was 6.52. A reason why the The "b" values for the unwashed and washed samples were negative, because negative "b" represents blue, which is the color of dye that was used. The average dyed "b" value of the five samples that were taken was -30.37. The average washed "b" values of the five samples that were taken was -26.54. There was a decrease between the unwashed and washed fabric values because the dye was not attached on the fabric, the dye was lying of the fabric's surface and was released after washing. In figures 11 through 13 the L, a, b values are plotted on a graph for both dyed unwashed and washed fabric samples. Each graph shows both the dyed unwashed and washed fabrics that are similar to each other.

6 Conclusion

After analyzing all of the fabrics with the appropriate dye, there was no significant change between the L, a, b values of the dyed and washed fabric samples. This concludes that the color fastness of the fabric samples were high. Fabrics with high colorfastness do not have problems with the dye shifting hues or fading when exposed to light and other environmental factors and that do not move onto other fabrics or material during storage, processing, use, or care, such as home laundering. However, there was enough change to demonstrate the different color values that was released after washing that correlated with the color of dye that was used, because of the removal of unattached surface chemicals. When fabrics have low colorfastness, the dye doesn't attach to the surface of the fabric and therefore can create problems in production, storage, use, and care.

Disperse and reactive dyed fabric samples did not have a major change between the unwashed and washed fabric samples. The dye was absorbed in the fabric's fibers and did not lay on the fabrics surface. This concludes that disperse and reactive unwashed and washed fabric samples had high colorfastness.

The direct dyed fabric samples did have a slight difference between the unwashed and washed fabric samples. Although the difference was not vast, the samples prove that fabric's can have low colorfastness. The direct dye unwashed and washed fabric samples had a low colorfastness because the dye did not penetrate or bond with the fabric's fibers. Instead, the dye was on the fabric's surface and the dye molecules were unattached from the fabric during washing.

In conclusion, the study proved that disperse and reactive dyed fabrics had high colorfastness and the direct dyed fabrics had a low colorfastness. The CIELAB spectrometer readings were examined to determine if the fabric samples had a high or low colorfastness. Since the disperse and reactive dyed fabrics had a high colorfastness, they would be marketable for textile products. The direct dyed fabric samples did not have a huge significant difference, however, due to low colorfastness; more testing would have to be done in order to make the fabric marketable.

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