# Experiment 2: The Effects of Dyeing Conditions, Dyebath Auxiliaries, Mordants and Fiber Types on the Dyeing and the Color Properties of Fabrics

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## Introduction

This experiment aims to study the effect of dyebath conditions, auxiliaries, mordants, and fiber types, on the shade and depth of color for selected dyed fabrics by the use of spectrophotometer. A direct dye of varying concentrations was applied on several nylon, cotton and acrylic swatches so as to study the effects of dye on the selected fabrics: cotton fabrics, acrylic fabrics, nylon fabric and polyester-cotton (50:50) blend fabric. The dye was used in varying concentrations so as to determine the optimal point when its application brings out the desired effects on the fabric without any wastage or uneven pattern arising from its (dye) excessive use.

Heat and agitation are fundamental components in the dyeing process since the two factors have a direct influence on the rate and patterns of dye uptake and the speed of dye absorption by the fabrics. For instance, the application of heat under different agitation conditions is known to increase the rate dye uptake and absorption in nylon. Similarly, the experiment also studied the effects of leveling agents such as bases and acids in then dyeing process. This follows the principle that ionic attraction encourages opposite charges (the negatively and positively charged particles) between the dye molecule and the charge of the fiber to attract towards each other. To this effect, basic and acid comonomers in acrylic were studied to investigate the whole concept of ionic attraction.

Furthermore, the mordant dyes were studied particularly to determine the effectiveness of dye on colorfastness. The application of disperse dyes was used during the experiment to study the differences in depth of hue shades in two fabrics namely nylon and polyester during the experiment. The union and cross dyeing of polyester and cotton blends were equally studied to establish the effects of dye on the color properties of fabrics.

**Requirements:** The following items were required for the experiment: four samples of cotton fabrics, two different acrylic fabric, three samples of nylon fabric, four samples of wool, two samples of polyester-cotton (50:50) blend fabric, direct dye solution, disperse dye suspension, sodium chloride (NaCl) solution, acid dye solution, basic dye solution, sodium sulfate solution ($Na_2SO_4$), sulfuric acid solution ($H_2SO_4$), acetic acid solution ($CH_3COOH$), Potassium dichromate ($K_2Cr_2O_7$), cupric sulfate ($CuSO_4$), Potassium aluminum sulfate [$KAl(SO_4)_s$].

## Results

Results attained from the above experiment were recorded as shown in the table below:

1. **Dyeing cotton with direct dyes**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E | r | K/S | R |
|---|---|---|---|---|---|---|---|---|---|---|
| Solution 1 | 72.38 | 25.08 | 43.54 | - | - | - | - | .8398 | .0153 | 83.98 |
| Solution 2 | 65.68 | 34.18 | 52.70 | -6.70 | 9.10 | 9.17 | 14.55 | .8353 | .0162 | 83.53 |
| Solution 3 | 62.87 | 38.20 | 69.86 | -9.51 | 13.12 | 26.33 | 30.92 | .8348 | .0163 | 83.48 |
| Solution 4 | 59.61 | 42.45 | 90.74 | -12.76 | 17.37 | 47.20 | 51.89 | .8298 | .0175 | 82.98 |

**2. The effects of Heat and Agitation on Dyeing**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| Room temperature | 69.74 | -14.97 | -20.25 | - | - | - | - |
| Heat Only | 47.76 | -19.34 | -35.27 | -21.98 | -4.37 | -15.02 | 26.98 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Heat + Agitation | 49.16 | -19.20 | -33.20 | -20.58 | -4.23 | -12.95 | 24.68 |

**3. The effects of Leveling Agent and Acid on Dyeing**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| (c) salt + acid | 45.74 | -19.36 | -37.03 | - | - | - | - |
| (a) Salt only | 54.92 | -21.85 | -31.82 | 9.18 | -2.49 | 5.21 | 10.85 |
| (b) Acid only | 44.29 | -19.00 | -38.25 | -1.45 | 0.36 | -1.22 | 1.93 |

**4. Dyeing Acrylic with Acidic and Basic Dyes**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| Acid: Acrylic 16 | 83.46 | -3.95 | 1.78 | - | - | - | - |
| Acid: Acrylic 36 | 34.88 | -18.48 | -31.65 | -48.58 | -14.53 | -33.43 | 60.73 |
| Basic: Acrylic 16 | 49.81 | 41.29 | 85.30 | - | - | - | - |
| Basic: Acrylic 36 | 71.45 | 13.03 | 49.92 | 21.64 | -28.27 | -35.38 | 50.19 |

**5. Mordanting of Acid Dyed Wool**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| No mordant | 31.56 | -23.93 | -34.52 | - | - | - | - |
| $K_2Cr_2O_7$ | 15.49 | -1.52 | 25.59 | -16.07 | 22.41 | 60.11 | 66.13 |
| $CuSO_4$ | 30.26 | -24.75 | -20.36 | -1.30 | -0.82 | 14.16 | 14.24 |
| $KAl(SO_4)_2$ | 36.04 | -23.14 | -29.83 | 4.48 | 0.49 | 4.69 | 6.50 |

**6. Dyeing Nylon and Polyester with Disperse Wool**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| Nylon | 28.12 | 20.83 | -60.26 | - | - | - | - |
| Polyester | 56.07 | 0.93 | -28.98 | 27.95 | -19.90 | 31.28 | 46.43 |

**7. Union and Cross Dyeing**

| | L* | a* | b* | Delta L* | Delta a* | Delta b* | Delta E |
|---|---|---|---|---|---|---|---|
| Union | 48.95 | -3.91 | -31.12 | - | - | - | - |
| Cross | 34.72 | 21.75 | -37.61 | -14.23 | 25.66 | -6.49 | 30.05 |

## Discussion

Concentration of direct dyes has an effect on the cotton fabric more so in the presence of a base and a leveling agent (sodium chloride). Due to the heavy presence of hydrogen bonds in the structures of the cellulose fibers, cotton swells in a basic solution thus forming crystalline regions within the cotton fabric which the long thin and narrow dye molecules easily fit. Similarly, sodium chloride is used as a leveling agent to increase the migration of dye molecules into the fiber. This guarantees the uniform distribution of dye molecules onto the fabric.

An increase in the dye concentration and leveling agent, as evident from the yellowish-orange swatches, has greatly increased the absorption of dye onto the fabric by a percentage margin exceeding 60%. Reading from the experimental values, solution 1 (standard solution) which has the lowest dye concentration has L* value of 72.38 while that of the sample 4 with the highest concentration of dye stands at 59.61. This is an indication that the fabric in the sample 4 is darker than the one placed in a standard sample is lighter. The value of L* therefore diminishes with the increasing dye concentrations.

The value of a* is directly proportional to the dye concentration. The low dye concentrated standard solution 1 has a* value of 25.08 compared to 42.45 in solution 4 with the highest concentration of direct dye. Changes in a* denotes a movement from green towards red by the dye molecules. Similarly, the values of b* and K/S ratio increase with the concentrations of dye proportionally up to an optimal point when further increase in the dye concentration will result into uneven dying and wastefulness.

The movement of dye molecules through a solution is necessary in the dyeing process since it brings the long narrow molecules into contact with the fiber upon which they act. Heating and continuous stirring of the dye solution increases the movement of dye molecules thus increasing the vigor and intensity by which the molecules penetrate the fiber. Heating and agitation stirring generate kinetic energy that precipitates the motion of the dye particles throughout the solution. This explains why the third sample exhibited the greatest absorption of dye with a uniform appearance due to the combined action of heating and agitation compared to first and third samples that were strictly stirred and heated respectively.

In terms of dyeing and fabric properties, first sample appeared to be uniformly dyed but lighter than the heated sample. Similarly, the third sample appeared blotchy and unevenly dyed due to sheer lack of agitation. The overall color difference, $\Delta E$, in the second sample is computed to be 26.98 while the second and third samples stand at -21.98 and -20.58 respectively. The L* and b* values also decreased significantly as shown in the result section.

Acidic dyes are known to contain the negatively charged polar groups as $–SO_3H$ which are greatly attracted to the positively charged polyamide fibers with free amino groups ($-NH_2$) at the polar ends. The inorganic salts such as sodium phosphate and sodium chloride are both used as a leveling agent because their systematic application brings about a uniform dye color by the retarding the rate of dye and instead allow dye molecules to evenly exhaust into the fabric. Comparing the results of the three samples, the first sample (salt only) was the lightest blue with the least L* of 54.92 against 44.29 and 45.74 in second and third samples. Although the second (acid only) and third sample (salt + acid) appeared both darker and bluer than first sample, acid proven to be superior in promoting dye uptake in the nylon fiber. As such, addition of salt to the acid was wasteful since acids can just produce the required results in the absence of leveling agents.

Dyeing of acrylic fibers with acid and basic dyes gives varying results depending on polar charges of the resultant comonomer and acrylonitrile units. Because the opposite charges attract, the basic comonomers tend to be attracted more to an acid dye with an anionic (negatively) charge. On the flip side, acid comonomer is attracted to a basic dye with a cationic (positive) charge. When two samples of acrylic samples (Acrylic 16 and acrylic 36) were both placed into an acid dye solution, acrylic 36 gives a brilliant blue color with the acid dye with a L* value of 83.46 and 1.78 b*reading in the blue direction while acrylic 16 had very little dye uptake. This indicates that acrylic 36 absorbs most acid dye. However, acrylic 16 is instead brilliantly dyed. In a sharp contrast, acrylic 16 is more brilliantly dyed with the basic dye solution due to the presence of an acidic comonomer. The difference between Acrylic 16 and Acrylic 36 in the basic dye was determined to be 50.19.

The mordants are applied to the protein fibers such as wool to improve colorfastness by forming strong, large complexes with the dyes, decreasing solubility and trapping the dye molecules within the fiber, thereby increasing colorfastness. The use of mordants such as potassium dichromate and potassium aluminum sulfate are known to improve electron density and distribution of the dye. The nature of the fabric also has an influence on the property of dyeing.

## Conclusion

Various dyeing conditions, dyebath auxiliaries, mordants, fiber types and color properties of fabric have effects on shade and depth of color for the selected fabric as corroborated by spectrophotometry. The concentration of direct dyes, heating and agitation, presence of leveling agents such sodium phosphate and mordants like potassium dichromate and potassium aluminum sulfate are known to enhance colorfastness, durability, and increased performance of the final dyed product. Other factors that effects dyeing include property and nature of fabrics. The invaluable knowledge accrued from this experiment is very useful in guiding textile and clothing industry on how they can perform effective and quality dyeing without any uneven patterns or excessive use of reagents which would otherwise be avoided.