Perfect Shade Matching in Dyeing by Using Only Colortools (Datacolor spectrometer)

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Abstract
Though Textile Trade has been developed in the world on 114 BC, but after long time, during twenty first century, shade matching according to buyer approval has become a vital task. In dyeing factories it's a difficult task to match completely according to the buyer's given approval. Spectrometer can help a great for matching. Datacolor brand has already become a popular name in this trade. It has two softwares---Colortools and DCIMatch. In Colortools, it shows dl, da*, db* etc. that means amount of depth, amount of reddish/greenish and amount of yellowish/bluish respectively. But it does not explain how exactly shade should be matched to the standard. In DCIMatch, by taking correction recipe, a very correct recipe can be obtained. But it needs development of database for some years and also this DCIMatch is expensive. In Bangladesh around 60% of factories buy only Colortools. Here I have shown some result of my research, using that formula anyone can give a very useful correction recipe from result of Colortools.*

Keywords: *Shade difference in dyeing, Color tools.*

1. Introduction
Color is an indispensable part of life that had been focused in human life from the early age of earth. According to anthropologists, mankind used animal skins, vegetables to fulfill their demands of wearing clothes. Gradually wearing clothes does not meet only their protecting from bad weather, but also a tradition had been grown to show beautifulness on cloth. Color is therefore a great invention to illustrate the beauty on cloth. This practice had been started since 4500 BC. At that early stage, people could dye very limited colors, such as Red, blue etc. At the early stages of Renaissance, color industries had been spread out where different colors had been produced. Still there was some limitation. But now! Million of colors are continuously chosen by buyers which are bloomed in the fabrics. Even now in the market many color albums are sold which have thousands of colors (The Textile Institute Book store).

2. Purpose
The latest tradition has become such that the color which is chosen by buyer is to be matched around or at least 95% by the dye industry. Perfect matching of the color according to the choice of buyer is not an easy task. At before technologist used their eyes and experience to match a color. At that matching, efficiency was not very high.
Recently a color matching instrument named Spectrophotometer has been developed. The machine can identify the changes perfectly between the swatch given by the buyer (which is generally called standard) and the substrate color (which is normally called batch). With the help of this instrument, color matching can be completed with full perfection (Journal of the Society of Dyers and Colourists, Volume 81, Issue 5, pages 201-205, May 1965).
It has two softwares---Colortools and DCIMatch. In Colortools, it shows dl*, da*, db* etc. that means amount of depth, amount of reddish/greenish, amount of yellowish/bluish respectively.

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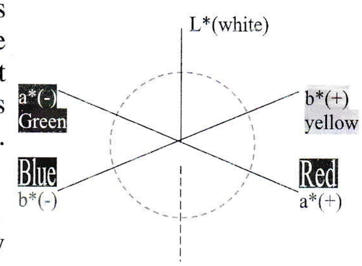
But it does not explain how exactly shade should be matched to the standard. For example dl* 0.50 means 5% excessive red or 5% shortage of green. But what is to be done for correction? Increasing green or decreasing red. Also the question is whether decreasing or increasing 5% in amount? Actually total solution of the problem is different. In DCIMatch, by taking correction recipe, a very correct recipe can be obtained. But it needs development of database for some years and also this DCIMatch is expensive. In Bangladesh around 60% factories buy only Colortools. Here I have shown some result of my research, using that formula anyone can give a very useful correction recipe from result of Colortools (Datacolor Catalogue).

3. Theoretical Discussion

Theoretically from any light color, any dark color can be produced perfectly with mixing primarily three colors. These are red, yellow and blue. Here I have done my experiment based on CIELAB.

In 1976 CIE recommended this system. It is the mostly used system up to today. A rectangular three dimensional color space (l*a*b*) in which all surface colors can be represented. The distance between the points representing the colors of two samples is proportional to the visual color difference between them. The axes are scaled so that a just perceptible color difference is represented by unit distance. L*a*b* values can be interpreted in terms of hue, lightness (value) and depth of color (chroma) (G.J. Chambarline and G.G. Chambarline).



When a standard is scanned and then a dyed substrate is scanned by spectrometer, it shows the difference of colors at the following way-

1st example: dl* da* db*
0.75 1.0 -0.55

2nd example:
dl* da* db*
-1.0 -0.40 1.35

Here it is seen that there can be two values of each term: one is + or empty (no sign), which refers positive; another is -, which refers negative.

Table 1: The meanings of different color values.

	dl*	da*	db*
Positive	lighter	more red/less green	more yellow/les s blue
Negative	darker	Less red/more green	More blue/less yellow

(Margulis, Dan Report-2006) (Hunter, Richard Sewall Report-July 1948).

By analysis of these data, any color can be matched to the standard. Lighter means absence of overall colors while darker means excess of overall colors. Each value in the examples refers the amount of changes in percentage if the value is multiplied by 10. In the 1st example:

0.75(dl*) means 0.75 × 10=7.5% lighter

1.0 (da*) means 1.0 × 10=10% more red/less green

-0.55(db*) means 0.55 × 10=5.5% more blue/less yellow.

In the 2nd example:

-1.0(dl*) means 1.0 × 10=10% darker

-0.40(da*) means 0.40 × 10=4% more green/less red

1.35(db*) means 1.35 × 10=13.5% more yellow/less blue
In primary sense, solution is easy; such as when the dyed swatch (generally called as batch) is redder or less green; for matching with standard, red is to be decreased or green is to be increased. Again, when the batch is more yellow or less blue, yellow is to be decreased or blue is to be increased.

But the question is, for the 1st sample, which one is to be done---red is to be decreased or green is to be increased; again whether yel low is to be increased or blue is to be decreased. In the second sample whether green is to be decreased or red is to be increased; again whether yellow is to be decreased or blue is to be increased.

4. Experimental Description
For solution we may consider depth of color which is shown by dl*. In the 1st example,.75 dl* means 7.5% lighter. When the batch is lighter, it has an easy meaning that there is shortage of color. So, for the 1st example, (as less green) green is to be increased in lieu of decreasing red. Again (as less yellow) yellow is to be increased in lieu of decreasing blue. In the second example, batch is darker. So, green is to be decreased in lieu of increasing red and yellow is to be decreased in lieu of increasing blue.

Here a question can be arisen that primary colors are three--red, yellow and blue; by adding or deleting of those any color can be produced; so, how green can be increased or decreased? Actually green is a combination of yellow and blue. So, if we decrease yellow and blue in same amount, same amount of green will be decreased. For instance-
20% green = 20% yellow + 20% blue

Therefore for decreasing 20% green, we have to decrease 20% yellow and 20% blue.
Now the question is what do we understand by 20% decreasing or 20% increasing? Here we have to gain knowledge on a recipe of color on a substrate (substrate means the textile product that is dyed). Recipe means combination of colors (red, yellow, blue) that create the color on the substrate. For instance, a recipe of a red color is-
Remazol blue RR: .002%
Remazol Yellow RR: .01%
Remazol Red RR: .3%

Remazol is a renowned brand of Swiss dyes. Here 20% decreasing of yellow means:
0.01% - 0.01 × 20% = 0.008% yellow, that will be in the corrected recipe.
Accordingly in the 1st example, (as depth is lighter) we have to increase 10% green and 5.5% yellow. When we increase 10% green and 5.5% yellow, for increasing of color, some depth of color is also increased. Here we have to confirm that as depth is 7.5% lighter, after adding color maximum 7.5% depth should be increased. So, we have to calculate, how much depth can be increased for adding color. We can achieve a maximum of 95% correct result. Let me explain.

Case 1:
Triactive Navy blue SFB: 0.5%
Triactive Yellow S3R: 0.5%
Triactive Red S3B: 0.5%
In this case amount of all colors are same or can be almost same. Here I shall discuss all solution for this kind of recipe from my research jobs in dyeing.

When blue is increased, increasing of depth will be 1.4 times to average depth. For instance, if 10% blue is increased, 10 × 1.4 = 14% depth will be increased. For red, 10% more depth will be increased. For instance, if 10% red is increased, 10% + 10 × 10% = 11% depth will be increased. For yellow, depth change will be 50%; but here change will be opposite. It means, if 10% yellow is increased, 10% + 10 × 50% = 15% depth will be decreased.

So, another interesting factor is: effect of yellow. For Case 1, for adding blue and red, depth of total color will be increased; for adding yellow, total depth is decreased.
Let us analysis an example. We take the recipe of case 1. The batch is dyed. The result is found as the example 1.

For solution, at first we have to match tones of the shade. Any individual color (mainly primary) is termed as tone. Better way is to start from db*. Here db* value is -5.5. It means that shade is bluish. Accordingly blue is to be decreased. As total depth is lighter, we should not decrease blue; again for minimizing blue, if we increase yellow, total depth will be lighter.

Here we have to consider other factors also. Value of da*is 1.0. It means shade is also reddish. Minimizing red, green is to be introduced. Therefore if we add yellow (already blue is there), green tone will be produced that can minimize red.

Here for minimizing 5.5%blue, we have to add same amount of yellow. So, 5.5% green will be introduced that will decrease 5.5% red.

For going in next step, I have to present another factor here. The dyes that are available in market are not monochromatic colors. For instance Triactive Yellow S3R has 70%yellow and 30% red. So we have to increase yellow as 5.5 × 100/70%= 8%. It can fully minimize 5.5% blue.
Here already 8% × 30/100= 2.5% more red has been produced as that Yellow S3R dye has 30% red. For comparing newly created 2.5% red with existing red (10%), we have to consider amount of dyes in main recipe. Here I have taken the case where all amounts are same (Red, yellow and blue). So, total red deviation will be 10 + 2.5=12.5%.

So, for adding 8% yellow, 5.5% blue is minimized. Here also 5.5% green is produced that has minimized 5.5% red. So, remaining red will be = 12.5% – 5.5% = 7%.
For adding 8% yellow, depth change will be = (- 8) × 1.5% = – 12%. 7% red should not be decreased as total depth has already become: 12% + 7.5(existing light amount) % = 19.5% lighter.
So, for minimizing red, more green is to be added. Therefore for minimizing 7% red, 7% green is to be produced. So, 7% yellow and 7% blue is to be added. Again as yellow S3R is not monochromatic dye, we have to add 7% × 100/70 = 10% yellow.

Triactive Navy Blue SFB is also not monochromatic blue. It is 80% bluish and 20% greenish. So, 7% × 100/80 = 9% blue is to be added.

So adding 10% yellow and 9% blue will minimize 7% red of that dyed batch. 10% yellow produces extra 10% × 30/100 = 3% red and 9% blue produces extra 9% × 20/100 = 2% green. 1% red may remain in the solution, but it can be considered as negligible. Therefore all tones are minimized.
Let us analyze the change of depth for adding 10% yellow and 9% blue.
10% yellow adding will create decreasing of depth of = 10% × 1.5 = 15%
9% blue adding will create increasing of depth of=9% × 1.4=12.5%
So, total result is decreasing of 2.5% depth.

Previously it was 19.5% light. So, total depth will be 19.5+2.5=22% light. Though we have controlled tones, now we have to control depth. For this kind of recipe (where all colors are same/almost same), if overall colors are increased, depth change will be 1.7 times increasing. For instance, if 10% overall color is increased, 10% × 1.7=17% depth is increased. So, for controlling depth 22%/1.7=13% overall color is to be added. 13% overall color adding means adding 13% yellow, 13% red, 13% blue together.
Now if we summarize, we get---
Adding yellow: 8 %(for minimizing blue)
Adding yellow: 9 %(for minimizing red)
Adding blue: 9 %(for minimizing red)
Adding yellow 13 %(for increasing overall depth)

Adding blue 13% (for increasing overall depth)
Adding red 13% (for increasing overall depth)
So, in case of dyeing in lab, solution will be-
Adding yellow = 8% + 9% + 13 = 30%
Adding blue = 9% + 13% = 22%
Adding red = 13%

Therefore, in lab, next (corrected) recipe will be:
TriactiveNavy Blue SFB: 0.5%×1.22= 0.61%
Triactive Yellow S3R: 0.5% × 1.30 = 0.65%
Triactive Red S3B: 0.5% × 1.13 = 0.565%

In dyeing floor, addition is to be given after calculating progression of fixation of dyes. If progression is nil, addition can be added as shown above.
Let us practice another example. Say, another batch is dyed according to case 1 recipe and shows a deviation as given in example 2.

For solution, at first we can minimize 13.5%yellow.Therefore 13.5% × 100/80 = 17% blue is to be added. Depth change will be: 17% × 1.4 = 24% increasing.
Here 13.5% more green will be produced, as yellow is mixed with blue. 17% blue adding produces 17% × 20/100 = 3.5% additional green. So, total amount of green needed to be minimized is:
4 %(existing) + 13.5% + 3.5% = 21%. Now for minimizing green, we have to add 21% red. Triactive Red S3B is not monochromatic red. It's 85% is red and rest 15% is blue. So, 21% × 100/85 = 24.5% red is to be added. Depth change will be: 24.5% × 1.1 = 27% increasing. Therefore we have controlled the tones. Now we have to control depth. Total depth increased is: 10 %(existing) + 24% + 27% = 61%. For minimizing depth, 61%/1.7 = 36% overall color is to be decreased. So, summarization is:

Adding blue: 17%(for decreasing yellow)
Adding red: 24.5%(for minimizing green)
Decreasing blue: 36% (for decreasing overall depth) Decreasing red: 36% (for decreasing overall depth)
Decreasing yellow: 36 %(for decreasing overall depth)

So, in case of dyeing in lab, solution will be:
Decreasing blue = 36 – 17 = 19%
Decreasing yellow = 36%
Decreasing red = 36 – 24.5 = 11.5%

The solution can also be done in another way. At first we can decrease yellow for minimizing yellow. Secondly as yellow is decreased, green tone will be decreased as yellow present in green is being decreased. So, some blue is to be decreased and also some red is to be increased. Finally depth is to be calculated.

5. Results of the Experiment

Following three dyes were used for this experiment:

a. Triactive Navy Blue SFB
b. Triactive Red S3B
c. Triactive Yellow S3R

Any recipe having dyes of same tones can be corrected by this calculation. For reference of tones I am giving the pictures of the tones at the last of my discussion. Any navy or bluish color having the same tone is of 80% bluish and 20% greenish. So, correction is to done based on this. Again any red having this kind of tone is of 85to 90% reddish and 15 to 10% bluish. Yellow having the tone is of 70% yellowish and 30% reddish. Calculation to correct the recipe is to be followed by these data.

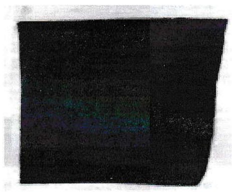
The colors will change the depth in the following way-
For increasing 10%:
For overall colors, depth increasing: 15% to 17%
For blue, depth increases: 13% to 14%
For red, depth increases: 11% to 12%
For yellow, depth decreases: 14% to 15%

The change of depth will be in proportional rate. For changing 5% color, the above change will be half; again for changing 20% color, above change will be double.

Here I have given solution only for those recipes where colors are all same in amount or almost same. If one dye is of high or low amount, this calculation will be not applicable.

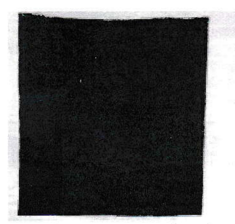
6. Materials and Methods

My results can be applicable for both Datacolor 500 and Datacolor 650. I have done my experiments at Square Knit Fabrics Ltd, Valuka, Mymensingh and at M.L. Yarn Dyeing, Valuka, Mymensingh. I have done all the experiments in D65 light source.



Reference of Red

Reference of Yellow



Reference of Blue

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