# EFFECT OF FIBER TYPE, YARN PROPERTIES AND FABRIC STRUCTURE ON COLOUR MEASUREMENTS

BY
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## تأثير نوع الشعيرات و خواص الخيوط و التركيب النسجى على متغيرات قياس اللون

ملخص البحث:

أستخدمت ثلاثة أنواع من الأقطان المصرية لإنتاج عدد كبير من الخيوط بنمر مختلفة و أس برم مختلف. و قد أستخدمت خيوط مسرحة و ممشطة وكذلك خيوط منزولة بطريقة الطرف المفتوح لإنتاج 22 عينة من الأقمشة ذات التركيب النسجى مبرد أو سادة. و تم صباغة هذه الأقمشة تحت ظروف واحدة بصبغة سيبا – أزرق 3GE . و قد تم تحليل تأثير كل متغيرات الشعيرات و الخيوط و نوع التركيب النسجى على متغيرات قياس اللون وهى الزهاء– النقاء – درجة البياض – و عمق اللون. و قد وجد أن نوع القطن و طريقة الغزل ومتغيرات الخيط من حيث النمرة و أس البرم و كذلك التركيب النسجى للقماش يؤثر تأثيرا معنويا على متغيرات قياس اللون.

## *Abstract:*

Three types of cotton fibers were used in producing a wide range of yarns. Count, twist factor, spinning parameters was varied at different levels. Twenty two plain and twill fabrics were produced from these yarns. All fabrics were dyed under the same conditions with Ciba reactive dye Blue-3G.E. The effect of fiber, yarn and fabric variables on colour measurements was investigated. Hue, Chroma, Lightness, Colour Strength and colour depth was measured. It was found that cotton type, spinning process, count, twist multiplier and fabric structure affect significantly colour measurements.

## *Introduction:*

Cotton fibers are subjected to severe conditions during growing, variation in temperature humidity and soil type affect fiber properties. Harvesting and ginning accompanied always with mechanical stresses on fibers. At spinning mill, no way, to avoid different compound stresses on fibers. Preparation for weaving and weaving itself apply abnormal additional stresses on fibers. Dyeing process, apply special chemical stresses due to chemical additives, temperature, constitute of dye stuff. The previous history of yarns differs due to the machine aggregate used in spinning and weaving. Dyeing fabrics at definite colour shades under such conditions becomes really difficult. Any serious deviation in colour shade depredate the value of the fabric and lead to big losses . The effect of these variables on color measurements is of great importance to obtain continuously uniform color shade.

The colour is defined by three numbers X, Y, Z which are known as tristimulus values. These values do not correlate well to colour order systems / 1 /. These quantities can, however, be converted into the new ones called psychometric terms, which give visually approximately uniform spacing, and are suitable for both quantitative and qualitative description of colour. A family of such transformed systems are called the " LAB " scales. The best known example being the Hunter "L,A,B" , the Adam's -Nickerson " ANLAB" and the most recently " CIE L*,A*,B* " systems. In all LAB systems " L " means the lightness ranging from 0 - 100 ( 0 for the black and 100 for the white), " a " the red - green axis (+ for red and - for green ), and " b " the yellow - blue axis ( + for yellow and - for blue). Based on guiding principle of equal visual perception of small color differences, the Munsell system / 2 / is both a collection of samples painted to represent equal intervals of visual perception of color difference between adjacent samples, and a system for describing all possible colors in terms of its three coordinates , Munsell Hue, Munshel Value "Lightness" and Munsell Chroma. These coordinates corresponds to three variables commonly used to describe color.

$\Delta L^* = L^*_{sample} - L^*_{substrate}$ = Psychmetriccolour difference in Lightness

$\Delta C^* = C^*_{sample} - C^*_{substrate}$ = Psychmetriccolour difference in Chroma

$\Delta H^* = (E^2 - L^2 - C^2)^{1/2}$ = Psychmetriccolour difference in Hue

$\Delta E^* = (\Delta L^2 + \Delta C^2 + \Delta H^2)^{1/2}$ = PsychmetricTotal colour difference

| | | | |
|---|---|---|---|
| + Δ L* | = Lighter | - Δ L* | = Darker |
| + Δ C* | = Brighter | -Δ C* | = Duller |

colour direction clockwise is - Δ H, and anti clockwise is + Δ H

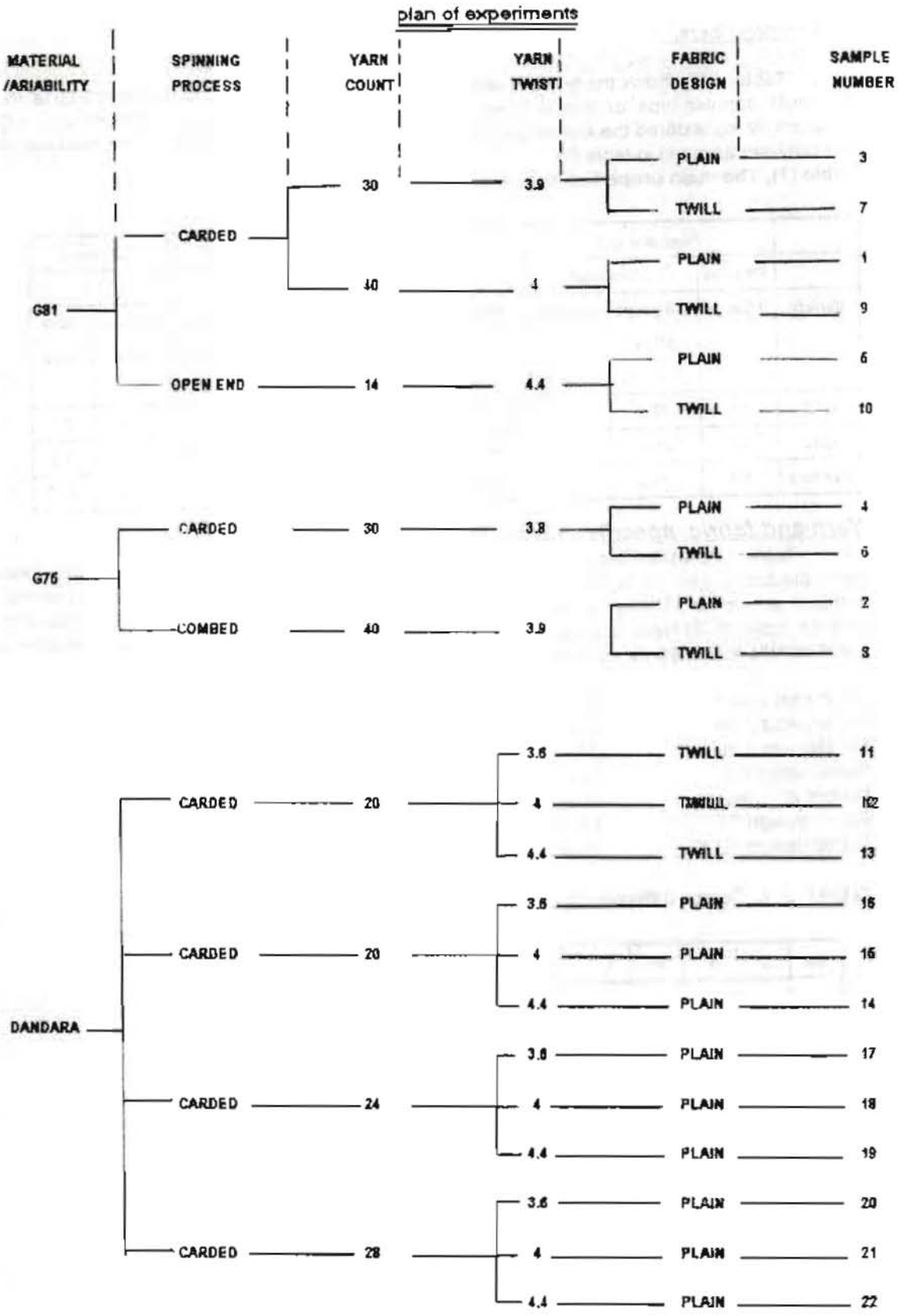
One of the pioneer works of this field is the national project " The behavior of Egyptian cotton" /3/, worked out by the National Research Institute and Alexandria University, where they have investigated the spin ability of Egyptian cotton fibers, moreover the behavior of cotton fibers due to mercerizing. Few of effort have been inserted to investigate the dye ability of the Egyptian fibers. Another work " Improvement of dye absorption "/ 4 / carried out by Mansoura University and National Research Institute. The work investigated the effect of storage time and the effect of the pH factor on the k/s. The dyeing procedure for different fabrics by different dye stuff is optimized.

## ***Experimental part:***

## ***Experimental plan for fabric production:***

The experimental plan have considered:

1- Row material " Giza 81 , Giza 75 and dandara"
2- Different yarn production systems " Ring Spinning and Open End Spinning"
3- Different spinning preperation " Carding and combing preperation"
4- Different yarn counts " Ne. 14 - 40" and twist factor " 3.6 - 4.4 "
5- Different fabric design " twill and plain weave"


plan of experiments
MATERIAL /ARIABILITY
SPINNING PROCESS
YARN COUNT
YARN TWIST
FABRIC DESIGN
SAMPLE NUMBER
G81
CARDED
30
3.9
PLAIN
3
TWILL
7
40
4
PLAIN
1
TWILL
9
OPEN END
14
4.4
PLAIN
6
TWILL
10
G75
CARDED
30
3.8
PLAIN
4
TWILL
5
COMBED
40
3.9
PLAIN
2
TWILL
8
DANDARA
CARDED
20
3.6
TWILL
11
4
TWILL
12
4.4
TWILL
13
CARDED
20
3.6
PLAIN
15
4
PLAIN
16
4.4
PLAIN
14
CARDED
24
3.6
PLAIN
17
4
PLAIN
18
4.4
PLAIN
19
CARDED
28
3.6
PLAIN
20
4
PLAIN
21
4.4
PLAIN
22

*Row cotton fibers:*

Table ( 1 ) shows the types of cotton used " Giza 81, Giza 75 and Dandara ". Giza 75 is the most popular type of cotton used in Egypt ( about 50% of all cotton production) . / 5 /, Dandara is considered the low ranked Egyptian cotton quality. While Giza 81 lies between this two qualities as given in table (1).

**Table (1), The main properties the used fibers.**

| | Fiber strength | | | Fiber length | | | Fiber & Maturity | | | Colour | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pressley | Stelometer | | Fibrograph | | | F / M - T | | | HVI | |
| Variety | 0 Gauge | 1/8 gauge g/Tex. | Elongation | 2.5%SL | 50% SL | Uniformity ratio | Mic. reading | Millitex | Maturity | Reflectance Rd% | Yellowness |
| G75 | 11 | 29.3 | 6.4 | 31.5 | 16.4 | 52.2 | 4.2 | 158 | 90 | 75 | 9.3 |
| G81 | 9.7 | 26.6 | 6 | 29.9 | 14.4 | 49.3 | 3.9 | 148 | 95 | 71 | 8.9 |
| Dandara | 9.4 | 25.8 | 6.2 | 29.2 | 13.7 | 46 | 3.5 | 143 | 78 | 63.6 | 12.2 |

## *Yarn and fabric specifications:*

*Table ( 2 )* shows the main parameters of yarn and fabric produced. 22 different fabrics were produced from different yarns, varying in count, twist multiplier and preparation method , combed or carded. The fabric design was twill and plain weave. The fabrics were produced on Investa loom at El-Nasr company for weaving and dyeing. The details of fabric production is listed as follow: The yarns produced were used as weft .

| | |
|---|---|
| *Warp yarn count* | *20/1* |
| *No. of picks / cm* | *20x2 - 16x2* |
| *No. threads / cm* | *20 - 27* |
| *Fabric width cm* | *128* |
| *Weight of 1 meter* | *ranging between 200 -240 g.* |
| *Fabric design " 1 "* | *Plain weave 2/2* |
| *Fabric design " 2 "* | *Twill 1 / 3* |

**Table ( 2 ), Colour difference between dyed different fabrics**

| No. | L* | a* | b* | L* | C* | H* | K/S | ST% | ΔL | ΔC | ΔH | ΔE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 69.1 | -30.6 | -17.9 | 69.1 | 30.7 | 211.3 | 4.06 | 78 | 1.97 | -3.2 | -0.96 | 3.9 |
| 2 | 69 | -27.2 | -18.2 | 69 | 32.7 | 214 | 4.0 | 77 | 2.1 | -1.8 | -0.12 | 3.5 |
| 3 | 70.4 | -25.1 | -17 | 70.4 | 32.7 | 212.8 | 4.08 | 80 | 3.21 | -1.6 | -0.12 | 3.4 |
| 4 | 69.2 | -26.7 | -18.3 | 69.2 | 32.1 | 212.8 | 4.43 | 87 | 2.07 | 2.3 | -0.16 | 2.75 |
| 5 | 69.2 | -26.3 | -17.4 | 69.2 | 33.4 | 213.3 | 3.36 | 65.6 | 2 | -2.2 | -0.19 | 3.47 |

**Table (2), continued**

| No. | L* | a* | b* | L* | C* | H* | K/S | ST% | ΔL | ΔC | ΔH | ΔE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 70 | -26.7 | -18 | 70 | 33.2 | 214 | 4.1 | 88 | 2.68 | -2.1 | -0.8 | 3.5 |
| 7 | 69.4 | -27.1 | -18.4 | 69.4 | 31.5 | 211.2 | 4.15 | 81.5 | 2.29 | -2.4 | -1.0 | 3.49 |
| 8 | 70.2 | -26.2 | -17.7 | 70.2 | 33.3 | 217.7 | 4.09 | 80.3 | 3.1 | -.06 | -2.4 | 3.93 |
| 9 | 70.7 | -28 | -19.2 | 70.7 | 32.4 | 212.6 | 4.93 | 97 | 3.55 | -1.5 | -0.26 | 3.87 |
| 10 | 70 | -25.8 | -17.4 | 70 | 31.3 | 211.8 | 3.96 | 78 | 2.87 | -2.6 | -0.7 | 3.93 |
| 11 | 67.1 | -25.6 | -16.8 | 67.1 | 35.4 | 215 | 5.42 | 106.5 | -0.06 | 1.49 | 1.1 | 1.88 |
| 12 | 68.9 | -27.7 | -11.5 | 68.9 | 34.9 | 215 | 4.78 | 93.5 | 1.34 | 0.97 | 1.2 | 2 |
| 13 | 67.1 | -27.1 | -11.1 | 67.1 | 35.3 | 215 | 5.34 | 105 | -.03 | 1.3 | 1.1 | 1.7 |
| 14 | 66.2 | -26.4 | -15.6 | 66.2 | 35.5 | 215.3 | 5.76 | 113 | -0.9 | 1.3 | 1.5 | 2.2 |
| 15 | 67 | -27.3 | -11.7 | 67 | 32.5 | 214.3 | 4.9 | 98 | 1.8 | -0.6 | 0.01 | 0 |
| 16 | 69 | -26.9 | -13.8 | 69 | 33 | 213.3 | 5.1 | 101 | 1.38 | -1.9 | -0.12 | 1.4 |
| 17 | 64.6 | -26.7 | -14.6 | 64.6 | 34.7 | 215.1 | 6.38 | 125 | -2.4 | 0.6 | 0.7 | 2.4 |
| 18 | 67.2 | -27.5 | -12.1 | 67.2 | 33.9 | 212.5 | 5.2 | 100 | 0 | 0 | 0 | 0 |
| 19 | 65.8 | -27.1 | -13 | 65.8 | 35.8 | 213.7 | 5.83 | 110 | -1.3 | 1.2 | 1.2 | 2.6 |
| 20 | 64.8 | -25.6 | -11.8 | 64.8 | 34.7 | 211.2 | 6.16 | 121 | -2.39 | 1.0 | -0.3 | 2.5 |
| 21 | 67.9 | -26.4 | -10.1 | 67.9 | 33.8 | 213.5 | 4.7 | 90 | 0.78 | -0.6 | -0.8 | 0.7 |
| 22 | 67.9 | -27.1 | -11.2 | 67.9 | 31.9 | 211.2 | 4.6 | 75 | 0.77 | -1.7 | -0.5 | 2.4 |

- The maximum wave length is 680
- Sample No. 18 is taken as the reference sample.

## *Fabric bleaching :*

The boiling process was provided contiguously on the factory production plant to assure the same conditions for all types of fabrics. Caustic soda concentration is 48 g/l at 100 °C .

The bleaching process is also provided continuously at concentration of 12 g/l and 50% hydrogen peroxide.

***Fabric dyeing:***

*Type of dye* — *Reactive dye, Blue 3G.E. " Phythanol cyanine "*

*Name of firm* — *Ciba-Geigy*

*Liqueur Ratio " LR"* *1 : 20 , 1g fabric : 20 cm3 solution*
*Dyeing, Washing and Soaping according to firm recommendation.*

## Colour Measurements:

The colour measurements was provided on LABSCAN colour system, in El-Nasr company for weaving and dyeing. This instrument determine the value of reflectance curve in the range of 400 - 700 nm. Colour build up is obtained from the reflectance curve at the maximum spectrum absorption λmax. Using Kubelka-Munk equation, the value K/S can obtained.

$$k/s = \frac{(1-R\%)^2}{2R\%} - \frac{(1-R\%)^2}{2R\%}$$

dyed sample substrate

## Methods of evaluation of results:

### Experimental plan for Dandara plain weave 2/2:

To predict the effect of yarn count and twist multiplier on colour measurements, the classical method of plan of experiments was used, the number of factors are two, yarn count and twist multiplier, the level of factors was three, the level of count is Ne. 20, 24, 28 and the level of twist multiplier was 3.6,4.0 and 4.4, thus the design is $3^2$ .

### Contour lines and response surface:

The data was fed to a computer program to calculate the coefficients of the following equation:

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{i=k} \sum_{j=1}^{j=k} b_{ij} x_i x_j$$

Accordingly the equation have the form of:

$$Y = \text{const} + b_1 x_1 + b_2 x_2 + b_{11} x_1^2 + b_{22} x_2^2 + b_{12} x_1 x_2$$

Where $x_1$ denote the yarn count,
$x_2$ denote the twist multiplier
The contour lines and the three dimensional response surface was drawn, to get a clear idea about the behavior of the yield, which in our case represented by the colour measuring elements, as hue, chroma k/s,....etc. The normal statistical methods as F-ratio and analysis of variance, is used to eliminate the insignificant coefficients.

## Results and discussions:

Table ( 2 ) shows the results obtained for colour measurements. The effect of cotton fiber type will be discussed at first, then the effect of spinning system followed by the effect of fabric design . The k/s and the total colour difference will be used as the criteria for colour quality. Only for dandara group of experiments the elements of colour measurements such as the hue, chroma, lightness and colour strength will be considered.

***Effect of cotton fiber type on colour :***

The yarn count for G81 and G75 is Ne. 30, but for Dandara is 28. the first factor is almost the same, also the fabric weaving parameters was kept constant, so that the difference would be attributed to the cotton type. The dandara fabric shows the highest values of k/s followed by G75 and G81, sample 3,4 and 21 respectively. This means that ability of dye absorption for dandara is quite higher than the other types. Consequently the total colour difference $\Delta E$ is the smallest for dandara, i.e. the deviation in colour parameters is small for dandara. The other two fibers show approximately the same deviation. The whiteness before and after bleaching for G81 is measured as ( 37.3 before, and 55.7 after ), and for G75 ( 39.3, 55.8 ) and for dandara is given as (34.7, 54.5). The differences in whiteness for the three types of fibers after bleaching are very small and refer to less than 1% , This means that the differences in colour quality is due to fiber properties. Another factor may play a roll, is the linear density, dandara fibers is more finer compared to G81 and G75, as given in Table (1).

***The effect of spinning process:***

From G75, samples No.4 (plain fabric) and 6 (twill fabric) produced from carded yarns of English count Ne. 30. Samples No. 2 (plain fabric) and 8 (twill fabric) produced from combed yarns of English count 40. The combed cotton fibers show generally small increase in k/s values, compared to carded yarns, this could be explained that the combing process eliminates a considerable amount of short fibers, thus the uniformity of fiber length distribution becomes better, this beside the elimination of dead fibers, GNPs and trashes. The values of k/s for plain weave are relatively better than those of twill weave, this could be attributed the fact, that the plain weave construction 2/2 is more regular in threads distribution in the filling direction than for twill weave. The total colour difference is approximately the same for all fabrics, since they are produced from the same fabrics. This indicate that there is no risk to dye fabrics from the same fibers, and different in spinning process.

***The effect of spinning process on k/s and $\Delta E$ ( O.E & R'S. ):***

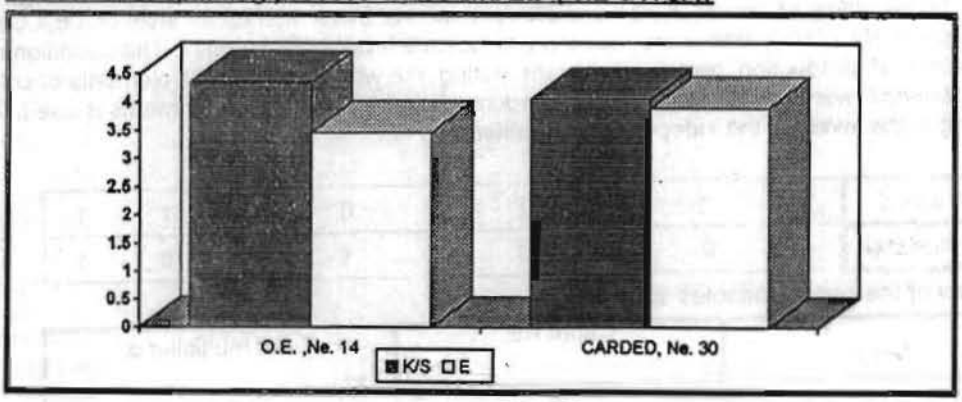



Fig . (2)

Fig. ( 2 ), shows the effect of spinning process on colour measuring, The O.E. shows higher values for k/s, and again about the same for $\Delta E$ . It is well known that the open end yarns have higher volume than ring spinning yarns / 8 /, this may be the cause for better k/s values. It must be noted here that the yarns are of different counts.

***The effect of yarn count:***

Fig.( 3 ) shows the effect of yarn count on colour measurements. For plain weave woven from carded cotton yarns of counts Ne. 40 and Ne. 30 from G81 fibers.

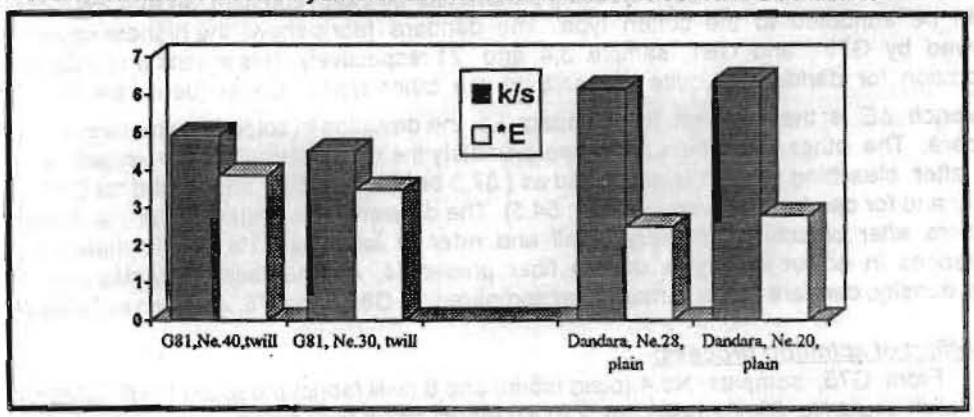



*Fig. ( 3 ), the effect of yarn count on k/s and ΔE*

For dandara cotton, plain weaves which are woven from carded yarns of Ne.20 and 28. Generally the fabrics produced from coarser counts have better values of k/s. The is due to the penetration of dye into coarser yarns is easier than finer counts. the total difference is accordingly have lower values for coarser counts. Here also one can see the differences between the G81 and dandara fibers, where the dandara have higher k/s values and lower total colour difference ΔE .

## *Effect of yarn count and twist multiplier on the elements of colour changing:*

Three yarns of counts 20, 24 and 28 were spun at three twist factor level of 3.6,4.0 and 4.4 respectively. The yarns were used in producing 9 fabrics plain weave. The condition and parameters of production remains constant during the whole process. All elements of colour measurements were considered. The procedure of classical plan of experiments is used. The following is the levels of the independent variables.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Yarn count | -1 | -1 | -1 | 0 | 0 | 0 | 1 | 1 | 1 |
| Twist multiplier | -1 | 0 | 1 | -1 | 0 | 1 | -1 | 0 | 1 |

The level of the coded variables are given as :

| Code | Count Ne. | Twist multiplier α |
|---|---|---|
| -1 | 20 | 3.6 |
| 0 | 24 | 4.0 |
| 1 | 28 | 4.4 |

The multiple regression coefficients were calculated according to Eqs. [ 1 ] and [ 2 ] stated in method of evaluations. The response surface and contour lines were plotted using a computer program /6/.

***Interaction of yarn count and twist factor on k/s:***

Fig. ( 4 ), show the contour lines and response surface of k/s as a function of yarn count and twist factor. It can be observed that the k/s increases as count is coarser, i.e. better dye absorption. While it is clear also that using smaller twist factor improves the k/s, this is true because the yarn structure becomes more bulky.

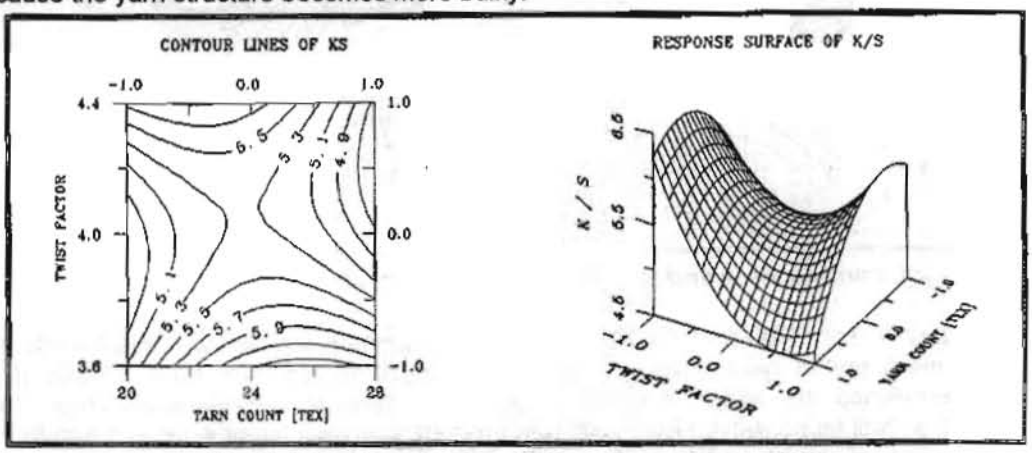



*Fig.( 4 ),Contour lines and response surface of K/S*

***Interaction of yarn count and twist factor on colour strength ST:***

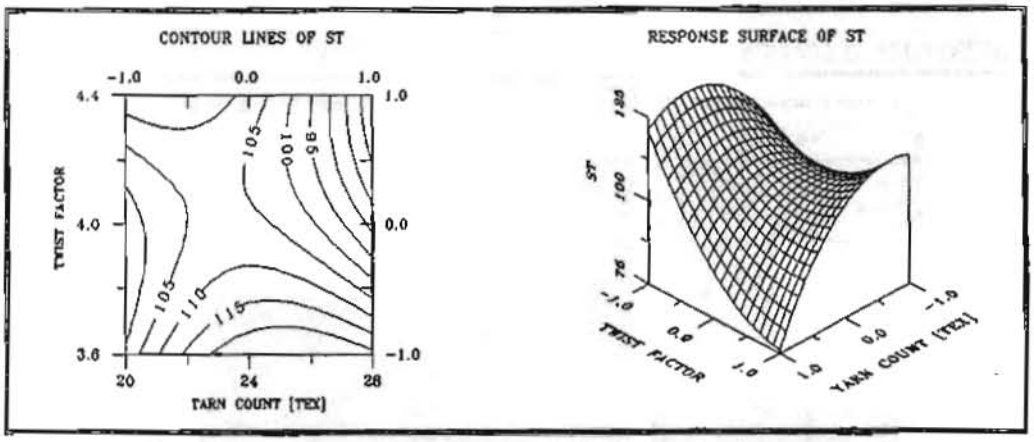



*Fig.(5), contour lines and response surface of colour strength*

The colour strength is a relative measure to a sample taken as a reference. In our case the sample No. 18 is taken as 100 %. The relative deviation ST % is another form of k/s. It is seen clearly the similarity of both figures. Here is also clear the negative effect on yarn count and twist factor, i.e. as the count becomes finer (+1), which is Ne. 28, the ST values becomes smaller. Also, the same for the twist factor, the colour strength becomes higher as the twist level is lower. This fact may help the weavers and the spinners to chose the proper twist factor, not only for the mechanical properties of fabrics, but also for the colour measurements.

***The differences in lightness:***

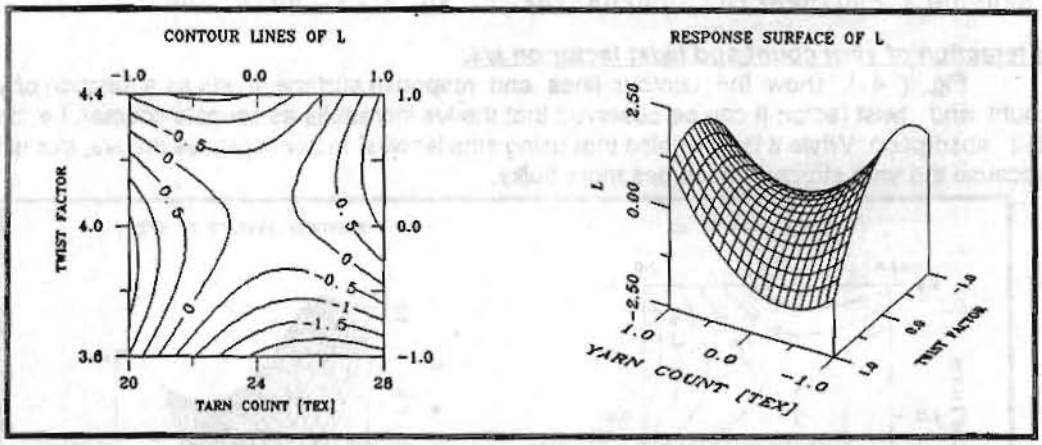



***Fig.(6), contour lines and response surface for colour lightness differences ΔL***

The contour lines of the light difference is a typical mini-max. shape, i.e. where the difference reaches maximum at twist factor, the difference becomes minimum from the side of yarn count. Sometimes this shape is called " saddle " shape /7/. The reference sample No. 18, represent a twill fabric, woven from yarn count Ne. 24, and twist factor 4, i.e. lies exactly in the middle values of count and twist factor. The negative values indicate darker colour and vice versa. the lower the twist level is, the darker the colour of the fabric. From the other side, the coarser the count is, the darker the fabric colour. It is clear that both yarn count and twist factor affect the shade of the colour. Special care have to be taken when dyeing different fabrics, even when they have the same structure, but different yarn count and/or different twist factor.

***The difference in chroma ΔC:***

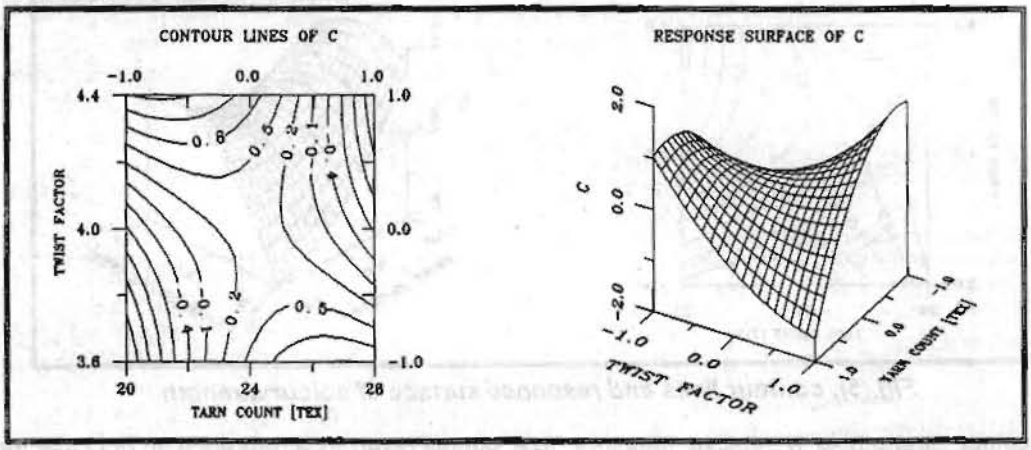



***Fig.(7), contour lines and response surface of differences in chroma ΔC***

The ΔC indicates the colour purity. In the colour circle, when the colour is at the out side, this means less interfered with other colours and more pure. In our case both yarn count and twist factor act negatively on ΔC, i.e. as the yarn becomes coarser with lower twist, the colour of the fabric becomes more pure, this is logic, since the coarser count with lower twist absorbs more colour and the colour concentration becomes higher.

***The colour difference in hue ΔH:***

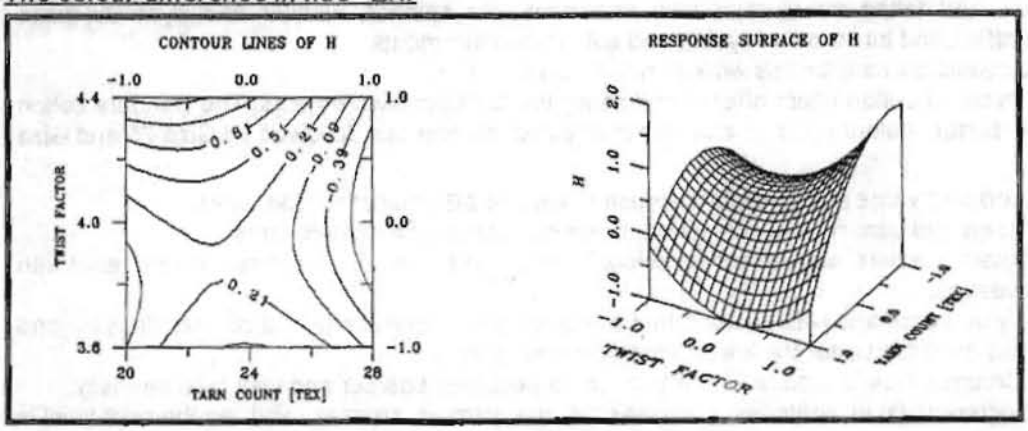



***Fig.(9), contour lines and response surface of hue ΔH***

The difference in hue, in our case means the deviation from standard sample, and hence the original dye is a turkiuase in colour, so the positive values indicates that the colour becomes more blue, and the negatives values, means that the colour tends to be green in colour. Accordingly, as the yarn count is coarse, the fabric tends to be green, and as the yarn is fine, the fabric tends to be blue. The twist factor have no great effect on hue, but the general trend as the twist factor is high, the fabric tends to be green. This phenomenon is very important not only for dyers but also for the weavers and spinners. Logically, yarn mixing is a pronounced cause of colour shading, and leads to real troubles.

***The total colour difference ΔE:***

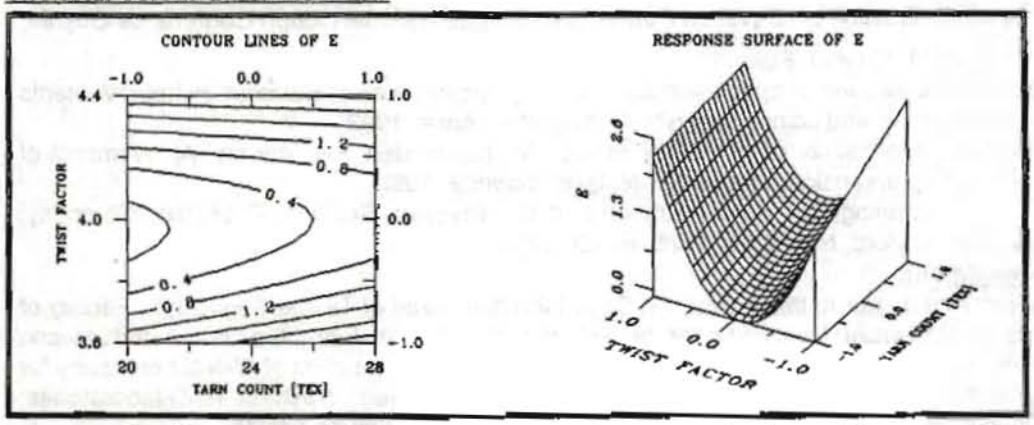



***Fig. (9), contour lines an response surface of total colour difference ΔE***

The total colour difference is mainly affected by the twist factor. The yarn count is of secondary effect. As twist increase, the total colour difference increase, this is true hence the yarn becomes more compact. Also as the yarn count becomes fine, the total colour difference becomes higher. A true minimum is at twist factor 4.

***Conclusions:***

The above results and discussions, spotlights the need of identifying the dye ability and colour measurement for the Egyptian cotton. The relationship between row material, yarn properties and fabric structure is very important for spinner, weaver and dyer. All these process affect and interact the dyeing and colour measurements.

Particular conclusions from this work may be drawn:

- The type of cotton fibers affect significantly the colour measurements. The Dandara cotton have better colour build up and less total colour differences, followed by Giza 75 and Giza 81.
- The combed yarns shows slight increase in k/s and $\Delta E$ against carded yarns.
- The open end yarn have relatively better k/s compared with carded yarns.
- The plain weaves shows better colour build up and total colour difference compared with twill weaves.
- The yarn count and twist factor affect colour build up significantly, the coarser the yarn and the less twist the better the k/s and the colour strength.
- The Chroma, Hue, increase as the yarn count becomes coarser and less twist intensity
- The differences in lightness increases as the yarn is coarser, and as the twist level is higher.
- The twist factor affect significantly the total colour difference, where the yarn count have no pronounced effect on colour measurements.

***References:***

1- Derbyshire, A.N. and Marshall V., Value analysis of dyes- A new method based on colour measurements, J. Soc. Dyers and Colourists, 96, 166,(1966)

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***Acknowledgment:***

The author would like to thank Prof. Dr. Sayed Ibrahim, head of Textile Eng. Dept., Faculty of Engineering, Mansoura University for his valuable discussions during the course of this work. Also deep thanks due to Dr. Abdel Azim Mohammed former president of El-Nasr company for weaving and dyeing, Dr. Shawky El-Bedewy, Chemist Ahmed Nashaat, R&D laboratories, Eng. Felfela head of weaving sector, Eng. Ahmed Abou Asy, spinning sector .