TEKSTİL VE MÜHENDİS

(Journal of Textiles and Engineer)

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Effects of Intermingled Yarn Surface Characteristics on Knitted Fabric's Color Parameters

Puntalı İpliklerin Yüzey Özelliklerinin, Bu İpliklerden Örülmüş Kumaşların Renk Parametreleri Üzerindeki Etkisi

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Online Erişime Açıldığı Tarih (Available online):31 Aralık 2018 (31 December 2018)

Bu makaleye atıf yapmak için (To cite this article):

İlkan ÖZKAN, Pınar Duru BAYKAL, Halil ÖZDEMİR (2018): Effects of Intermingled Yarn Surface Characteristics on Knitted Fabric's Color Parameters, Tekstil ve Mühendis, 25: 112, 327-334.

For online version of the article: https://doi.org/10.7216/1300759920182511206

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TMMOB Tekstil Mühendisleri Odası
UCTEA Chamber of Textile Engineers
Tekstil ve Mühendis
Journal of Textiles and Engineer

Yıl (Year) : 2018/4
Cilt (Vol) : 25
Sayı (No) : 112

Araştırma Makalesi / Research Article

EFFECTS OF INTERMINGLED YARN SURFACE CHARACTERISTICS ON KNITTED FABRIC'S COLOR PARAMETERS

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Gönderilme Tarihi / Received: 17.07.2018
Kabul Tarihi / Accepted: 24.11.2018

ABSTRACT: In this research, it is aimed to investigate the effects of intermingled yarns surface structure, caused by difference in number of nips, on the knitted fabrics' color parameters such as lightness (L*), reflectance (R), absorption coefficient / scattering coefficient (K/S) and color difference (ΔE*). For this aim, filament yarns having different number of nips with 283 dtex linear density and 100 filaments were used for producing the single jersey knitted fabrics. Fabrics were dyed and colors parameters of samples were measured. Results were analyzed by using Realcolor 1.3 software package. As a result of study, it was determined that the R and L* values effected by the changing in nips value and fabric's construction.

Keywords: Intermingling, Dyeing, Color Parameters, Color Difference, Knitted Fabric

PUNTALI İPLİKLERİN YÜZEY ÖZELLİKLERİNİN, BU İPLİKLERDEN ÖRÜLMÜŞ KUMAŞLARIN RENK PARAMETRELERİ ÜZERİNDEKİ ETKİSİ

ÖZET: Bu çalışmada puntalanmış ipliklerin punta sayılarındaki değişimin, bu ipliklerden üretilen örme kumaşların açıklık-koyuluk (L*), yansıma (R), Absorpsiyon katsayısı / Saçılma katsayısı (K/S) ve renk farklılığı (ΔE*) değerleri üzerinde etkililerinin araştırılması amaçlanmıştır. Bu amaçla 283 dtex lineer yoğunluğa sahip ve kesitinde 100 filament bulunan, farklı punta sayısına sahip ipliklerden düz örgü kumaşlar üretilmiştir. Üretilen kumaşlar boyanmış ve renk parametreleri ölçülmüştür. Elde edilen sonuçlar Realcolor 1.3 paket programı kullanılarak analiz edilmiştir. Çalışma sonucunda punta sayısı ve kumaş konstrüksiyonundaki değişimin R ve L* değerleri üzerinde etkili olduğu tespit edilmiştir.

Anahtar Kelimeler: Puntalama, Boyama, Renk Parametreleri, Renk Farkı, Örme Kumaş

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DOI: *10.7216/1300759920182511206, www.tekstilvemuhendis.org.tr*

1. INTRODUCTION

The intermingling process is forefront due to economic constraints in textile. It can be easily integrated into existing systems. In addition, it is functional and cost effective than other processes providing cohesion to yarn. Intermingling process changes the arrangement of fibers in filament yarns. As a result, the surface structure and reflection properties of the yarn vary. The air intermingling technique is used to impart filament cohesion in flat and textured multifilament yarns (Figure 1). Friction is one of the most important factors which determine the behavior of fibers in carding, drawing, spinning process and behavior of yarns during fabric formation. But, yarns that consist of many filaments have not friction force because of the parallel arrangement of filaments. The most common method used to impart the necessary cohesion to multifilament yarn is known as intermingling, using an air jet positioned on the path of the yarn. This creates intermittent, knot-like, entangled nodes in the yarn (referred to as 'nips' or 'tacks' in industry – which will be referred to as 'nips' henceforth) that significantly increase the interfilament cohesion [1]. Increasing economic constraints on the textile industry brought forward alternative a less expensive methods to conventional techniques. Intermingling as an alternative to sizing, twisting in texturing, drawing, spinning, and knotting in splicing, and also blending as a new process. Therefore, the intermingling process, provided that the interest problems are overcome, appears to be promising for the future of textile industry [2].

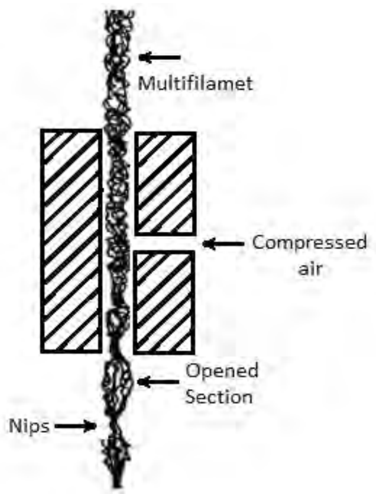

Figure 1. The intermingling process

Textured POY can be produced as intermingled or non-intermingled during the process of texturing. These yarns are mostly preferred for knitted and woven fabrics [1]. There are several studies carried out on intermingling process. Most of them are focused on the effective parameters on the intermingling process and the effects of these parameters on the intermingled yarn. But, in literature, no studies have been found on the dyeing properties of fabrics made from intermingled yarns. On the other hand, there are various studies about the effective factors on the color properties of textile materials. Some of them are summarized below.

The color perception of fabrics is affected by many parameters such as fiber fineness, cross section, yarn type, hairiness, twist level, texturing process, weaving and knitting structure, porosity, roughness, finishing methods etc. When light rays fall on a textile surface, a part of lights absorbed and another part is reflected. The color of the material depends on the ratio of reflected and absorbed rays [3]. A textile product is formed with combination of many fine fibers. The structure of a textile product can be likened to cluster that composed of many glass sticks. This analogy helps to explain the physical behavior of textile material. Part of light falling into the upper surface of each fiber is reflected as a glass stick. Many white fibers are located successive in a textile product so nearly all of light falling into the surface is reflected. Different from glass, the reflection of light occurs in various directions because of the fibers in the textile surface are oriented in various shapes [4].

The concentration of dye on a fabric after a given dyeing time can be determined by measurement of the reflectance spectra of the dyed fabric followed by application of the Kubelka-Munk relationship in which

$$K/S = (1-R)^2 / 2R = A \bullet C \qquad (1)$$

K/S is the scattering coefficient and directly related to dye concentration, whereas R is the reflectance of the fabric at a wavelength of maximum absorption [5]. This equation consists of light absorption coefficient "K" at the wavelength of maximum absorption, light scattering coefficient "S" and reflectance "R" of fabric. K/S value is referred as the color strength of objects. This value is equal multiplication of absorption coefficient (A) with concentration of the absorption (C) of dyestuff [4].

The CIE 1976 L*a*b* color space is the most widely used method for measuring and ordering object color. It is routinely employed throughout the World by those controlling the color of textiles, inks, paints, plastics, paper, printed materials, and other objects. It is sometimes referred to as the CIELAB color space. The 1976 CIELAB system improved on the 1931 system by organizing colors so that numeric differences between colors agreed consistently well with visual perceptions. This improvement facilitated and simplified the communication of color difference information between parties [6]. In the CIE L*a*b* uniform color space are given in Figure 2.

In the CIE L*a*b* uniform color space, the coordinates are:

- L* - the lightness coordinate.
- a* - the red/green coordinate, with +a* indicating red, and -a* indicating green.
- b* - the yellow/blue coordinate, with +b* indicating yellow, and -b* indicating blue [6].

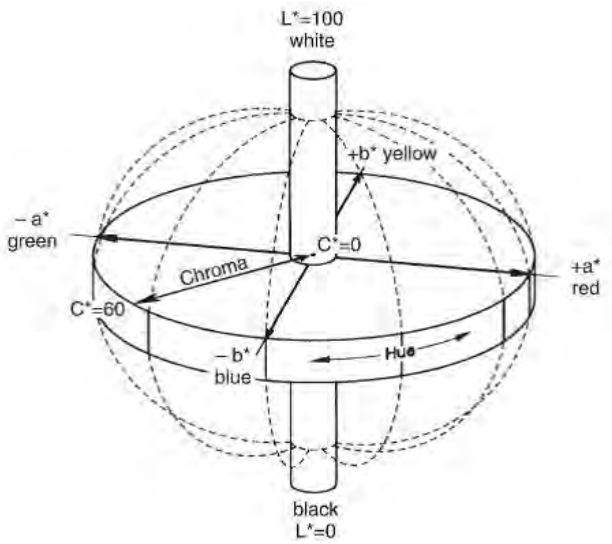

Figure 2. The CIE L*a*b* uniform color space [7]

Fabric permeability is very important in terms of reflection and color. Fabric color depends on the state of light that passes through the pores and reflected background thus the porosity is an effective parameter on fabric color. Porosity depends on structural parameters of fabric. This feature can be eliminated for a very tight (compact) fabric structure. However, porosity has an important effect on spectrophotometric measurement of fabrics that have different structures. In these particular cases, reflectance analysis of the fabric is important for the color analysis. In the case of high amount of space between the fibers, more dimensional change occurs in the yarn structure. This change affects colors of yarn and fabric significantly. Yarn diameter has direct effect on fabric color due to the relation between yarn cross-section and fabric's structural parameters [8]. Covering factor is defined as the degree of covered area by warp/weft yarns. This factor provides evaluation about compactness and permeability of the fabric [9, 10]. Fiber fineness, warp/weft density and woven pattern determine the reflectance properties and appearance of woven fabrics. Interlacing points of yarns and warp/weft density are closely related to fabric covering factor [11]. When the cover factor increases, less light passes through the gaps among the yarns and the fibers of the fabric. Hence, fabrics having high covering factor have high light absorbance and K/S values. Therefore all the light falling on the surface of the fabric is absorbed or reflected, any light that interacts with the surface is not lost [12].

Çay et al. (2007) investigated the effects of warp-weft density variation and fabric porosity of the cotton fabrics on their color in reactive dyeing. Moreover, it was stated that the higher colour yields (K/S) occurred with the higher porosity of the fabrics and this interaction was more significant in dark shades [13]. Gabrijelčič et al. (2004) examined the influence of the yarn count and density on the colour values of a fabric simulation [14]. Kim et al. (2004) investigated the effects of weave types (plain, twill, and satin) and varying levels of yarn twist on fabric luster [15]. Li et al. (2009) studied about the prediction of shade depth of a dyed polyester fabric based on fibre fineness and fabric structure [16]. Shams-Nateri et al. (2006) examined the color behavior and reflectance factors of fibers in their cross-sectional and longitudinal directions. They applied a neural network to relate the color of fibers in the cross-sectional and the longitudinal directions [17]. Akgün et al. (2012b) investigated the relationship between surface roughness, fabric balance and percentage reflectance of various types of fabrics based on polyester yarn [18]. Senthilkumar et al. (2011) examined the effect of humidity, fabric surface geometry and dye type on of cotton fabrics [19]. Becerir et al. (2007) stated that the bulky structure of knitted fabric, yarn type, hairiness and yarn count have a very important role on light reflection. In addition, they identified the knitted fabrics made of ring-spun yarn could be dyed in a darker color and have high color saturation than made of compact yarn [20]. Micheal and Dyab (2001) studied on knitted fabrics having different weave types (interlock, jersey, rib). They have determined the fabrics knitted by Open End (OE) rotor yarns have higher K/S values than fabrics knitted by ring-spun yarns after reactive dyeing owing to more open structure of OE spun yarns [21]. Kretzschmar et al. (2007) studied about color assessment of knitted fabrics that produced by ring-compact and ring spun yarns. Fabrics knitted by ring-compact yarns have higher K/S values than fabrics knitted by ring-spun yarns however this difference is not statistically significant [22]. In another similar study, Özdil et al. (2005) reported that the knitted fabrics produced by ring and compact yarns have not significant difference for L,a,b and K/S values [23]. Çeken and Göktepe (2005) determined that fabrics knitted by compact yarns can be dyed darker color than the fabrics knitted by ring yarns in terms of color difference (ΔE^*) and the K/S values [24]. Özdemir and Oğulata (2011) reported that fabrics knitted by vortex yarns can be dyed darker color than the fabrics knitted by OE yarns because of the spinning system and yarn structure [25]. Jebali et al., investigated the effect of test conditions and structural parameters of knitted fabrics for establishing the relationship among sample characteristics, test conditions and surface roughness parameters. They were obtained multiple regression models for predicting the surface roughness parameters [26].

A number of studies have been conducted to investigate how the surface texture of a fabric affects its instrumental color (color difference and color attributes, such as lightness, croma, and hue). The results showed that surface texture influences the color of the samples instrumentally and visually [27, 28].

There is not a similar study about effects of number of nips on the color properties in the literature. So, in this research, it is aimed to investigate the effects of intermingled yarns surface structure, caused by difference in number of nips, on the knitted fabrics' color parameters. In this respect, it is thought that the study will contribute to the literature.

2. MATERIALS AND METHODS

2.1. Materials

In this study, industrial polyester POY (Partially Oriented Yarn) filaments with 283 dtex linear density and 100 filaments in cross section were used for producing the intermingled yarn. All intermingled POY filaments have round cross-section.

2.2. Methods

Polyester POY filaments were intermingled by Hemaks HMX114 model intermingling machine. "TEMCO Y profile LD 22" air-jet was used in intermingling process. Number of nips of intermingled yarns was tested using Itemat Lab TSI test device. Each bobbin was tested 10 times and the mean values are shown in Table 1.

Table 1. Samples yarns' number of nips

Sample	Number of nips (pcs / m)
POY	5,0
N1	23,4
N2	67,4
N3	72,2
N4	80,5

Intermingled yarns' microscopy images obtained at 30x magnification ratio by SDL International brand trinocular microscope are shown in Figure 3.

Intermingled yarns with five different number of nips were knitted to single jersey fabrics by IPM brand sample type circular knitting machine. All the machine parameters were kept constant. Laboratory type circular knitting machine's specifications are given in Table 2.

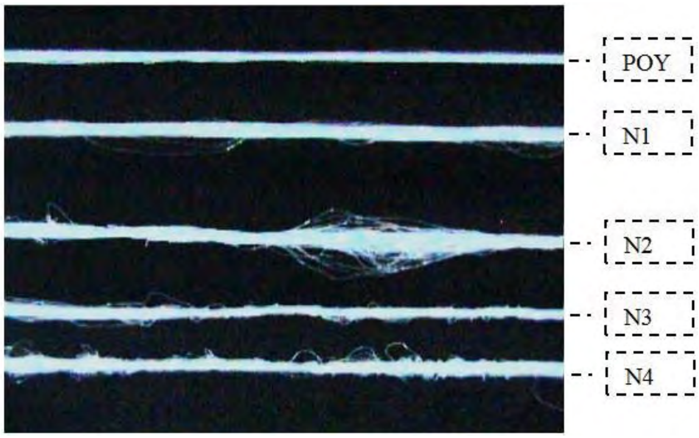

Figure 3 - Intermingled yarns' microscopy images

Table 2. Laboratory type circular knitting machine's specifications

Producer	IPM Trade Co. Ltd.
Knitted Roller	3 ½-inch, single-head
Speed (rpm)	0-400
Machine gauge (number of needles per inch)	18
Weave type	Single Jersey

Undyed knitted fabric samples' images at 30x magnification ratio are shown in Figure 4.

Standard pre-treatment and dyeing of fabrics were processed according to recipes in Table 3.

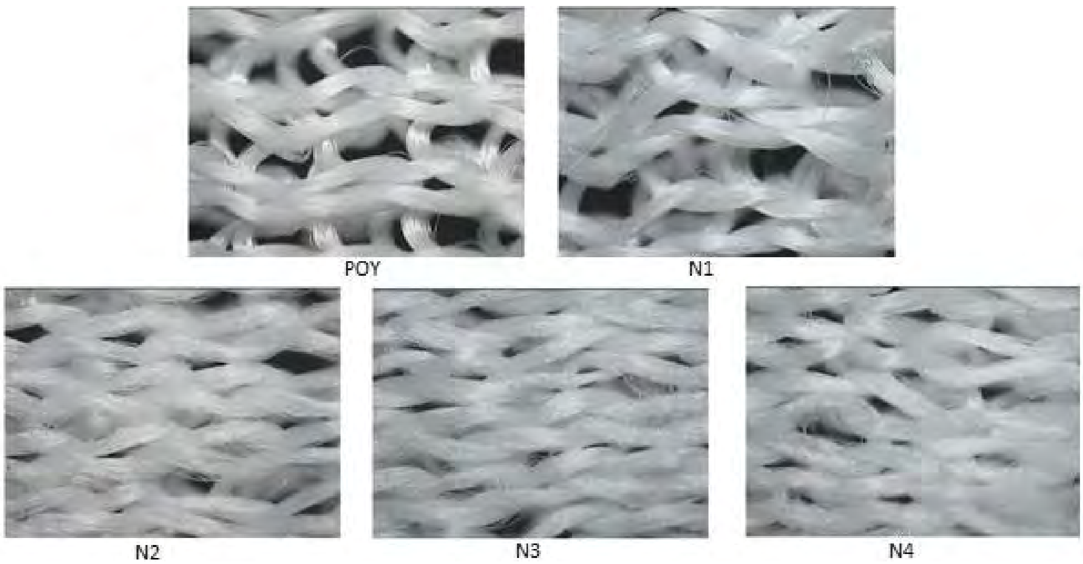

Figure 4. Images of undyed knitted fabrics after pretreatment

Fabric dyeing processes were carried out in 3 % concentrations and 10/1 liquor ratio by Dyetech sample dyeing machine. A dark color dyeing was preferred to minimize the reflection of the dyed fabric [20]. The surface reflection differences due to yarn hairiness and surface irregularity are closely related to the applied dye concentrations. The high dye concentrations applied may have masked the effects of hairiness on reflectance because of the greater light-absorption area. Process graph is shown in Figure 5.

Table 3. Pre-treatment, dyeing and reductive clearing processes of the samples

Process	Recipes
Pre-treatment	– Caustic soda - 2g / l, – Soap - 1g / l, – 80 ^{0}C - 20 min.
Dyeing process *(Liquor ratio: 10/1)* *(Concentrations 3 %)*	– Steapers Royal Blue CE-5R: 3% – Dispersing agent - 1g / l – Acetic acid - 1g / l – Anticreasing agent - 0,5 g/ l
Reductive clearing	– Sodium hydrosulphite - 2g / l – Caustic - 3g / l – Acetic acid - 1g / l

Dyed knitted fabric sample images obtained in magnification ratio of 30x using the digital microscope are shown in Figure 6.

The colour yields of the dyed samples were calculated by the Kubelka-Munk (Equation 1). Colors parameters of dyed fabrics were measured with a Minolta CM-3600d spectral photometer with a 10° normal observer and norm light D65. The measurement positions of the fabric samples were kept as standard in Figure 6 and all samples were measured five times. K/S values and CIELAB coordinates were obtained by using Realcolor 1.3 software package. L* values of the dyed fabrics were calculated over the visible spectrum, while K/S values were calculated at λ_{max} (630 nm). The K/S value is used to measure light absorption, the dyeing properties of the dyes, and the amount of the retained in the fibers after dyeing. These are very closely related to the fabric structure (surface structure, bulkiness, porosity, hairiness and arrangement of fiber). In addition the ΔE^*_{ab} value was taken as a measure of color difference. According to DIN 6174, the ΔE^*_{ab} colour difference is calculated as follows:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2} \qquad (2)$$

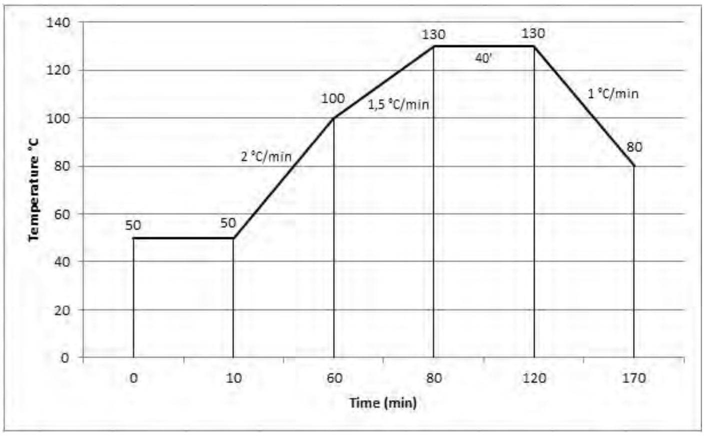

Figure 5. Dyeing process graph

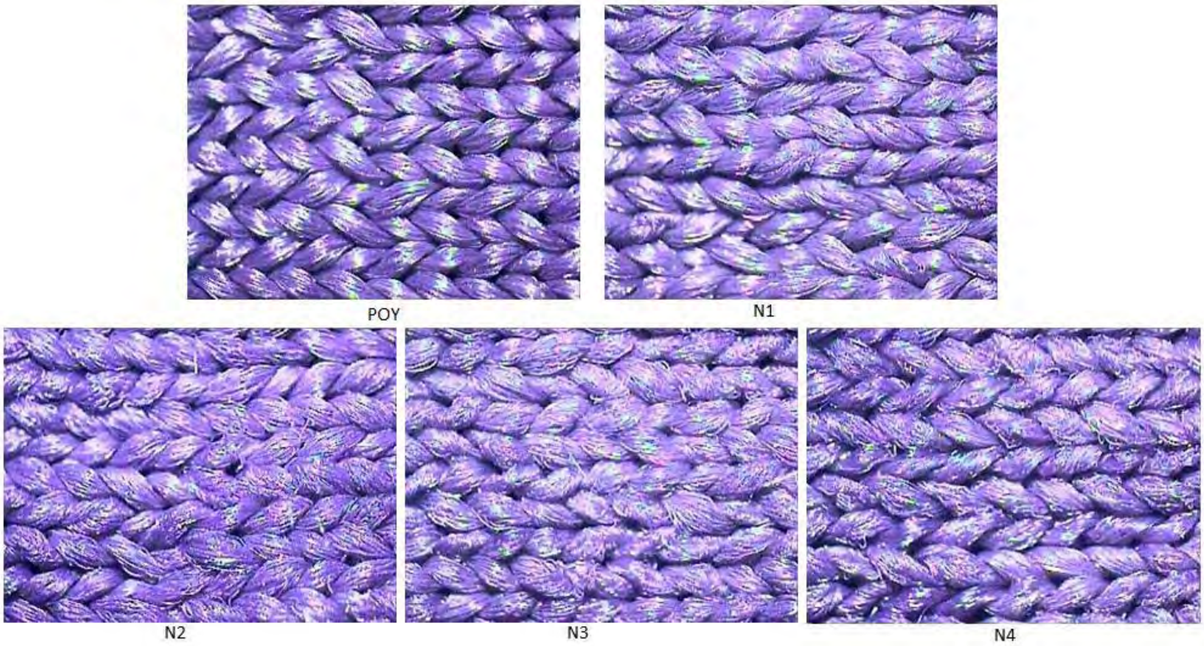

Figure 6. Images of fabrics after dyeing

3. RESULTS AND DISCUSSION

The increased hairiness and deformation of the yarn surface after intermingling can be easily seen from the Figure 3. Deterioration of filaments in yarn structure caused yarn hairiness and bulkiness. This change is seen in the knitted fabric structure as expected. In Figure 4, the increase in hairiness and bulkiness, decrease in porosity can be easily observed.

Relaxation occurs in fabric structure after the knitting and dyeing processes. Loop structure becomes more compact by changing with the effect of relaxation of fabric. Figure 6 shows the change in hairiness and deformation of the dyed fabric according to the sample types.

In the study, color parameters calculated according to CIELAB 1976 L*a*b* color space are given in Table 4.

Table 4. Color measurement results

Samples	L*	a*	b*	C*	h°
POY	15,73	9,40	-21,41	23,38	293,70
N1	16,43	10,53	-23,84	26,07	293,84
N2	16,98	12,18	-27,82	30,37	293,65
N3	16,66	11,94	-27,26	29,76	293,65
N3	16,18	11,76	-27,30	29,72	293,30

Dyed and undyed knitted fabrics' L* values are shown in Figure 7. When the number of nips increases, L* values of undyed fabrics increase regularly (Figure 7a). Undyed fabrics with more nips reflect more light due to their less porosity and more compact structures. The loop structure becomes more compact due to relaxing and shrinking of the fabric after dyeing. Therefore, the porosities of the dyed fabric samples are close to each other. Thus, after dyeing, hairiness becomes much more effective than compactness of fabric. When the number of nips increases, L* values of dyed fabrics increase until the sample which has 72,2 nips (Figure 7b). The surface unevenness, hairiness and deformation of the fabrics increased obviously by effect of dyeing process when the nips value exceeded 67. Therefore, L* values showed a decreasing trend after that point.

Reflectance (R) increases with the increasing in number of nips for undyed fabrics (Figure 8a). Fabric porosity decreases as a result of increasing in fabric cover factor with increasing in the number of nips. Thus, fabric structure becomes more compact. Compactness of all fabrics becomes similar after dyeing process. Therefore, color parameters are affected by only deterioration of filaments and hairiness of fabric instead of porosity. After dyeing, hairiness becomes much more effective on R-value than porosity of fabric. Evenness of fabrics' surface is deteriorated by increasing in the hairiness of dyed fabrics. Thus, R values showed a decreasing trend after N1 (Figure 8b).

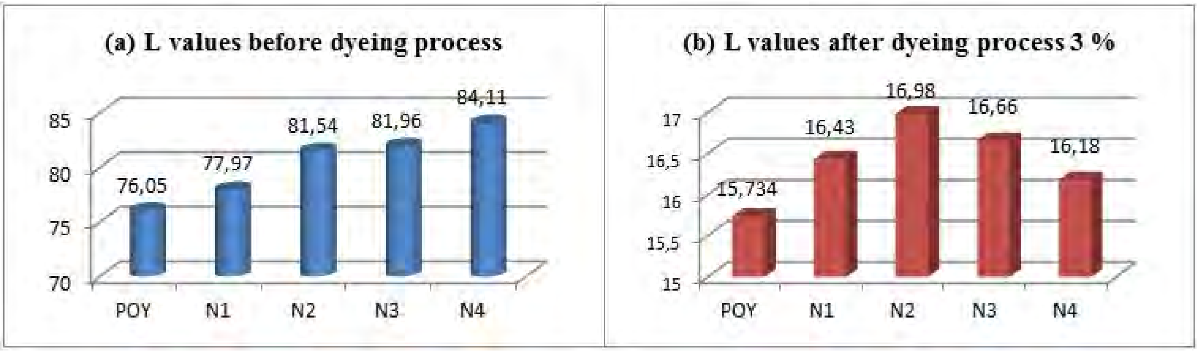

Figure. 7 – L* values before (a) and after (b) dyeing process

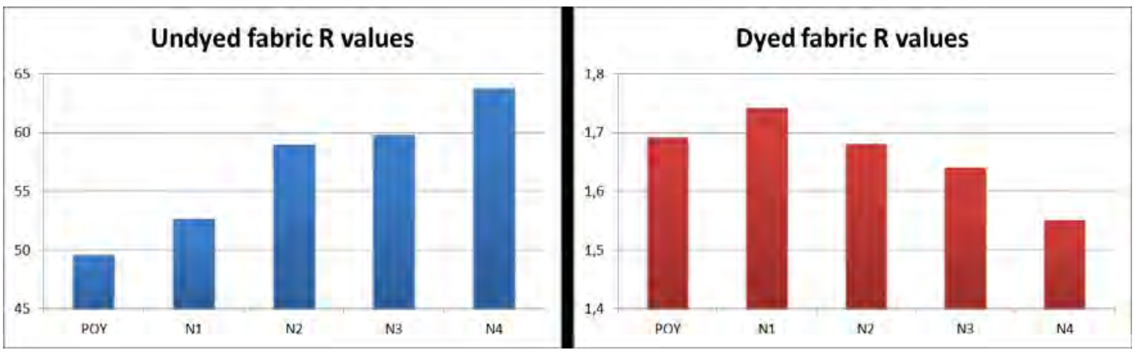

Figure 8. R values before (a) and after (b) dyeing process

Transition of light between yarn and fiber decreases with the covering factor of fabrics increases. Light waves are not only in the fabric surface, but also diffuse into the depth of the fabric. Surface reflection is decreased because of the light waves moving to the inner area of surface. Incoming light from surface is important for the color measurement thus reflectance and lightness values increase in parallel. Interaction between dyeing process and increasing in number of nips caused the deterioration of the fiber placement and increasing in hairiness and cover factor. After the specific nips level, reflection properties of the fabric vary because of the hairiness and surface unevenness of the fabrics. Thus reflectance values decreases depending on surface roughness, growing angle of light reflection and increasing distance of the light waves in fabric structure [3]. The wavelength of maximum absorption (630 nm) is considered for comparison of K/S values (Figure 9).

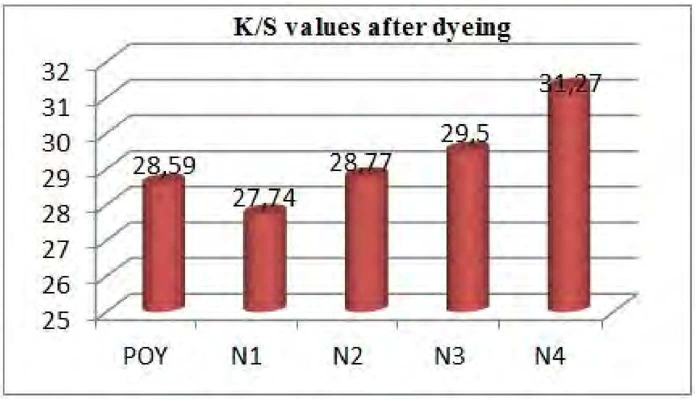

Figure 9. K/S values after dyeing

Surface area of filament widens and spaces among yarns in knitted fabric decrease due to intermingling process (Figure 4) thus optical contact increases. In this case, scattering coefficient (S) of Kubelka-Munk equation decreases herewith K/S increases. Fabric thickness increases by increasing number of nips [29]. Therefore light-path length increases. As a result of increasing in thickness, S and R values decrease. Moreover, increasing in hairiness causes increasing in dyeing absorption thereby K/S values increase. K/S values are calculated according to R values of the fabric samples (Eq. 1). Therefore, there is a mathematical relationship between K/S and R values as seen in Figure 8b and Figure 9.

In consideration the POY yarns, visible color difference was determined among knitted fabrics which produced by POY and other yarns having different number of nips (N1-N4) (ΔE^*_{ab}>1.0-1.2) (Table 5). There is a similar situation occurred among N1 and the other fabrics. However, knitted fabrics produced by yarns having high and closer nips values show low and acceptable color difference values (ΔE^*_{ab}<1.0-1.2).

It can be explained by the similar surface unevenness and hairiness characteristics of fabrics produced with increasing number of nips. Because, when the nips value exceeded 67, the surface unevenness, hairiness and deformation of the fabrics seem to be close to each other according to Figure 6.

According to Table 5, there is an obvious change in color of surface from POY to N2 (67 nips) however N2, N3 and N4 have smaller changes in surface properties and hairiness than POY and N1.

Table 5. Color Difference (CIELAB 1976)

Standard	Samples	Color Difference (ΔE* 1976)
POY	N1	2,78
	N2	7,1
	N3	6,45
	N4	6,36
N1	N2	4,34
	N3	3,70
	N4	3,67
N2	N3	0,69
	N4	1,04
N3	N4	0,51

4. CONCLUSION

Intermingling process deteriorates arrangement of filaments in the yarn and causes changing of the yarn bulkiness. Depending on the level of intermingling, appearance, thickness and porosity (cover factor) features of knitted fabrics change.

As a result of study, it was determined that the increase in nips values decrease the porosity of fabrics and so, cover factor increases. Hairiness, surface unevenness, and bulkiness of the knitted fabrics vary for dyed and undyed fabrics so color parameters should be considered separately. Reflectance and lightness values increase with the increasing in number of nips for undyed fabrics. The loop structure becomes more compact due to relaxing and shrinking of the fabric after dyeing. Therefore, the porosities of the dyed fabric samples are close to each other. Thus, after dyeing, hairiness becomes much more effective than porosity of fabric. For this reason, L* and R values of dyed fabrics decrease for higher than the 67 nips values.

Fabric thickness increases by increasing number of nips. As a result of increasing in thickness, S and R values decrease. Moreover, increasing in hairiness causes increasing in dyeing absorption thereby K/S values increase. Results demonstrated that the fabrics knitted by yarn having high level nips can be dyed using lesser amounts of dyestuffs. This knowledge can be providing a decline in the cost of finishing.

It can be said that the knitted fabrics produced by yarns having closer nips values have acceptable color difference range (such as 67,4 and 72,2). The unacceptable color difference occurs when the difference between the nips values increases.

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