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# Effect of New Functional Dye on Some Comfort Attributes of Suiting Wool Fabrics Using Kawabata Evaluation System

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**Abstract**

Clothing comfort is essential for any wearer. It is desirable for all apparel products. Tactile and thermal factors are related to human comfort. The aim of this study is to study the effect of new dye based on (Pyrido Pyrimidine Heptadinone Derivative) as new colour dye on some comfort attributes of KES mechanical properties and thermal properties of wool fabric as well as tensile, bending and shear properties. It was found that dyeing process affect tensile energy and tensile extensibility significantly in warp direction, shear rigidity and shear hysteresis in warp directions, bending rigidity in weft direction, and bending hysteresis in both directions. A significant difference was found for compressional properties LC, WC, and RC before and after dyeing. A significant increase in SMD geometrical surface roughness was found after dyeing wool fabrics in weft direction. Also a significant decrease in thermal conductivity and q max was found after dyeing. The wool fabric under study was found to be used in men's and women's winter suits with total hand values (THV) 4.96 and 4.28 respectively.

Keywords: Kawabata system, wool, Functional dyeing, Surface roughness, Thermal conductivity, Shear hysteresis, Bending hysteresis, Total hand value

## 1. Introduction

Kawabata evaluation system is used as a guide for dyers and finishers in clothing industry. It gives dyers an indication for the product consistency to insure efficient conversion into fabric and clothes. It is important for product development, quality control system, and product specification in textile industry. The Kawabata Evaluation System (KES) was used to test tensile, bending, and shearing properties of linen fabric treated with different finishing processes [1-4]. The evaluation of Kawabata system is a very important especially for wool and nylon industry. This system helps in the development of new fabrics before production. Also, it helps in discovering the problems during clothing manufacturing to avoid them [5-9].

Mechanical and surface properties of fabrics such as tensile, bending, compression, shearing, surface friction, and other constructional properties such as weight and thickness are challenging to measure subjectively. These all properties are linked to fabric handle. Therefore, it requires the objective measurement technique to enumerate the fabric handle using some other means. Objective evaluation uses several types of equipment to assess the tactile comfort of the textile product instead of irregular human factors. Such kinds of fabric quality are indispensable in the functional and smart textile manufacturing industry, particularly for the quality control and inspection of the textile-based product [10-14].

Wool fabrics were dyed with new coloured material based on pirido-pyrimidine derivatives, the dyed wool

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acquiring high performance and many fictional properties such as antimicrobials UPF property. The new coloured material had the possibility to improve moisture comfort properties of dyed wool fabrics [15, 16].

Wool fabric specimens modified with AgNPs shows good physical properties and enhancement of the dyeing properties of NP-treated wool fabric with AR 18 [17]. The colour strength values of the SiO2 NPs incorporated wool and polyamide 6 fabrics are significantly higher than the untreated fabrics with different dyestuffs [18].

Sarra Said et al studied the effect of ecological washing on some comfort properties of cotton fabric. The tensile strength decreased after washing. Also bending rigidity (B), and bending hysteresis decreased after washing. Coefficient of friction MIU decreased after treatment [19]. Ahmed Ramadan et al stated that the fabric shear properties determine the performance properties and the appearances where it is subjected to a variety of complex deformations during usage as closing. They found highly significant effect of the weave structures and weft density on the measured shear rigidity, shear hysteresis [20].

The purpose of this study is to evaluate the effect of new colour material (Pyrido Pyrimidine) on KES-FB mechanical and thermal properties of wool fabric. The total hand values (THV) of dyed wool fabric will determined. And determine the possibility of using dyed wool fabrics used in men's and women's winter suits.

## 2. Experimental

*2.1. Wool fabric*

Wool fabrics (Australian merino wool of mean fiber diameter 20.8 μm) was kindly supplied from Misr for Spinning and Weaving Co., El-Mehalla El-Kobra, Egypt.

*2.2. Preparation of new coloured material: Pyrido Pyrimidine Heptadinone Derivative (PPH)*

The new coloured material was prepared in two steps, in first step compound 1 was prepared as shown in reference [16], and as follows:

A mixture of compound 7-amino-5-(4-(dimethylamino)phenyl)-1,2,3,4,5,8-hexahydro-2-oxo-(4-oxo-2-thioxothiazolidinyl)-4-thioxopyrido[2,3-d]pyrimidine-6-carbonitrile (0.01 mol), was reacted with 1,6-bis(4-hydroxy-3-methoxyphenyl)hexa-1,5-diene-3,4-dione (0.01mol), in ethanol (30 ml) in the presence of nanochitosan (10 mol%) was refluxed for 3hs with stirring, After completion of the reaction monitored by TLC, t left to cool at room temperature, filtered off , the solvent was removed under vacuum. The solid that formed was recrystallized from acetone, dried under vacuum to afford compound as shown in fig. 1.

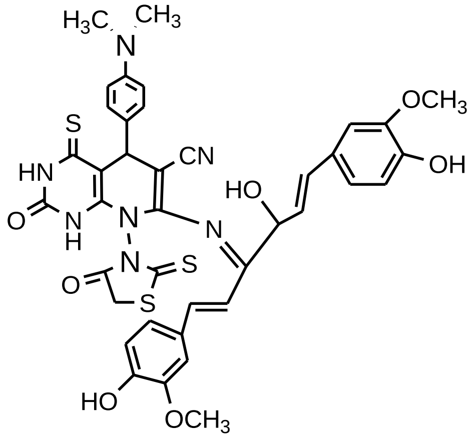



Fig.1: Pyrido Pyrimidine Heptadinone Derivative (PPH)

*2.3. Characterizations and measurements*

*2.3.1. Fourier Transform infrared spectroscopy analysis FTIR*

After incorporating of the samples into a KBr pellet, detection of functional groups located on the surface of the samples were specified. FTIR analyses within the range of 400 to 4000 $cm^{-1-}$were recorded with Fourier Transform Infrared Spectrophotometer (JASCO FT/IR-4700).

3340-3355 $cm^{-1}$ for (3-OH), 3238- 3220 $cm^{-1}$ for (2-NH), 1685-1699 $cm^{-1}$ for ( 2-C=O), 1649 $cm^{-1}$ (CN), 1233-1245 $cm^{-1}$ for ($-CH_3$-N-$CH_3$), 1220-1235 $cm^{-1}$ (2C=S),1140-1159 $cm^{-1}$ ( 2-$OCH_3$),1100-1120 (CH-aromatic ).

*2.4. Dyeing method by IR machine*

The dyeing was carried out in a high pressure and high temperature dyeing Machine. The wool fabrics was immersed in dyeing solution containing the new rhodamine derivative (4%) at pH 4 using acetic acid to adjust it. The dye bath was heated steadily from room temperature until the dyeing temperature was achieved at 90°C, then held at that temperature for 60 min. The dye bath was cooled to 60 °C. After dyeing the dyed samples were rinsed in soft water and washed with 3g/l non-ionic detergent (Triton x-100) at 50°C for 30 minutes. Wool fabric with the following specifications was dyed using new colour material.

*2.5. Scanning electron microscopy (SEM)*

Quanta FEG 250 scanning electron microscopy (SEM) with 30 kV scanning voltages was employed to observe the morphologies of undyed and dyed wool fabrics.

*2.6. KES- FB fabric Measurement*

Tensile, bending, shearing, and surface roughness properties of wool undyed and dyed fabrics have been measured on the KES-FB system. Table 2 shows properties measured by KES system. It consists of four instruments as follows

*2.6.1. KES-FB1 Tensile and shear properties*

In the tensile test, tensile linearity (LT), tensile energy (WT), tensile resilience (RT), and extensibility (EMT) have been measured. Shear properties of fabrics are described by parameters such as the shear rigidity(G), hysteresis of shear force at 0.5° shear angle (HG) and hysteresis of shear force at 5° shear angle (2HG).

*2.6.2. KES-FB2 Bending properties*

The bending rigidity (B) and the hysteresis of bending moment (2HB) are determined by the bending test.

*2.6.3. KES-FB 3 Compressional properties*

Three parameters describe the compressional properties of fabrics. They are the linearity of compression/thickness curve (LC), compressional energy (WC), and compressional resilience (RC).

*2.6.4. KES-FB4 Surface roughness modules*

Surface properties of friction resistance and surface contour (roughness) are determined using the KES-FB4 surface tester.

The surface fabric properties are described by the parameters such as coefficient of friction (MIU), mean deviation of MIU

(MMD), and geometrical roughness (SMD). MIU – coefficient of surface friction (unit less) its values 0 to 1 with higher value corresponding to greater friction or resistance and drag.

MMD– Mean deviation of MIU is unit less.

SMD – Mean deviation of fabric surface profile or geometrical surface roughness geometric roughness is expressed in µm; higher values correspond to geometrically rougher surface.

*2.7. Thermal conductivity (heat flow; W) measurement*

The constant thermal conductivity has been measured at which heat transmitted from a heat plate with a constant temperature (30℃) through a sample to a heat plate with a separate constant temperature (20℃).

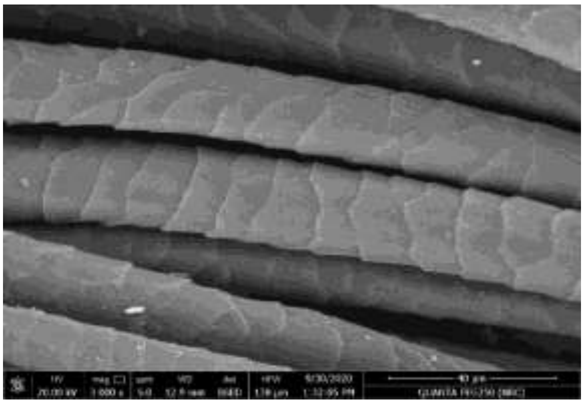
Q Max (peak heat flux)

The feeling of coldness or warmth varies according to the amount of heat transferred from skin to fabric. The Thermo lab device measures this feeling by evaluating q max.

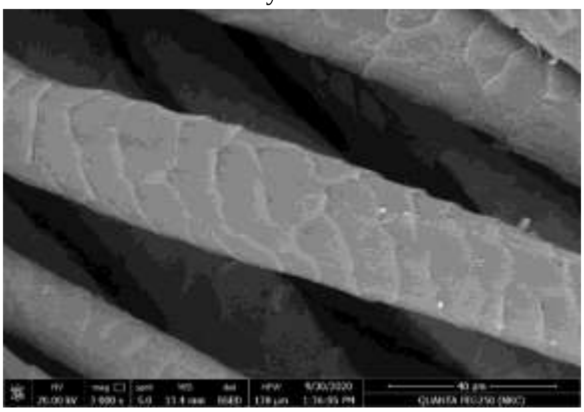
**3. Results and Discussions**

*3.1. Scanning electron microscopy (SEM)*

Figure 2 shows scan electron microscopy of the undyed and dyed wool fabrics with new coloured material Pyrido Pyrimidine. It is obvious that there is a slight change in the shape of the dyed wool scale as a result of the presence of a light layer that covered some of the spaces between the scales. With slight erosion of the scales which affected many mechanical properties



Undyed wool



Dyed wool

Fig. 2: Scan electron microscopy of the undyed and dyed wool fabrics with new coloured material

*3.2. Physical and Functional Characteristics*

Table 1 shows some properties (density, thickness, weight, and moisture regain) of the undyed and dyed wool fabrics with new coloured material Pyrido Pyrimidine. From table 1 it was found that the fabric thickness increased by 28% after dyeing process. This may be due to felting of wool during dyeing procss. Table 2 shows KES praamaters of undyed and dyed wool fabrics with the new colour materials (Pyrido Pyrimidine).

*3.3. Tensile and shear properties KES-FB1*

*3.3.1. Tensile properties*

The following table shows the average results of tensile properties for both undyed and dyed wool fabrics with new coloured material based on Pyrido Pyrimidine.

Applying paired comparison t test, a significant difference between tensile energy was found between the undyed wool and dyed wool fabrics in warp direction (with p value = 0.002). Tensile energy WT increased after dyeing in warp direction which mean higher stretchability. Also a significant difference in tensile extensibility (EMT) in warp direction was found (with p value = 0.0002). Extensibility EMT increased after dyeing in warp direction. No significant difference was found in weft direction for both previous properties. No significant difference between tensile recovery (RT) was found before and after dyeing in both directions. Figure 3 shows the tensile hysteresis curve for both dyed and undyed wool fabrics in warp direction. The red plot for dyed fabric and the green for the undyed one.

Table 1: Specifications of undyed Fabric and dyed fabric

| Property | Undyed wool | Dyed wool |
|---|---|---|
| Fabric density (yarn/cm) | 26*24 | 27*26 |
| Fabric thickness (mm) | 0.96 | 1.234 |
| Fabric weight (gm/cm$^{2)}$) | 244.4 | 261 |
| Moistur regaine % | 9.9 | 10.8 |

Table 2: KES-FB Mechanical and surface parameters of fabric

| Test | Symbol | Description | Unit |
|---|---|---|---|
| Tensile | LT<br>WT<br>RT<br>EM | Linearity of load/extension curve<br>Tensile energy<br>Tensile resilience<br>Extensibility | –<br>(g·cm)/cm 2<br>%<br>% |
| Shearing | G<br>2HG<br>2HG5 | Shear stiffness<br>Hysteresis of shear force at 0.5° shear angle<br>Hysteresis of shear force at 5° shear angle | g/(cm·deg)<br>g/cm<br>g/cm |
| Bending | B<br>2HB | Bending rigidity<br>Hysteresis of bending moment | (g·cm$^2$)/cm<br>(g·cm)/cm |
| Compression | LC<br>WC<br>RC | Linearity of compression/thickness curve<br>Compressional energy<br>Compressional resilience | –<br>(g·cm)/cm 2<br>% |
| Surface characteristics | MIU<br>MMD<br>SMD | Coefficient of friction Mean<br>Deviation of MIU<br>Geometrical roughness | –<br>–<br>μm |
| Thickness | T | Fabric thickness | mm |
| Mass per square centimeter | W | Fabric mass per square meter | mg/cm$^2$ |

Table 3: Tensile properties of dyed and undyed wool fabrics

| Property | Warp dyed | Warp undyed | Weft dyed | Weft undyed |
|---|---|---|---|---|
| LT (-) | 1.176 | 1.245 | 1.165 | 1.219 |
| WT ((g·cm)/ cm$^2$) | 11.975 | 7.569 | 10.834 | 10.459 |
| RT (%) | 70.234 | 77.621 | 70.37 | 74.38 |
| EMT (%) | 4.103 | 2.446 | 3.74 | 3.456 |

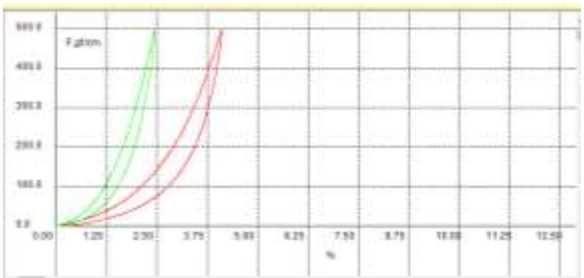


Figure 3 Tensile hysteresis curve for both dyed and undyed wool fabrics in warp direction

From Figure 2 it is obvious that dyed wool fabric acquired more extensibility in warp direction. Figure 4 shows the tensile hysteresis curve for both dyed and undyed wool fabrics in weft direction. The red plot for dyed fabric and the green for the undyed.

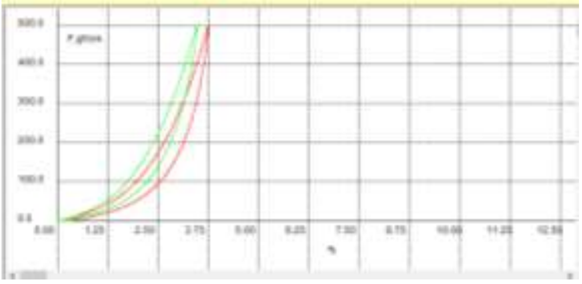


Figure 4: tensile hysteresis curve for both dyed and undyed wool fabrics in weft direction

From Figure 4 it is obvious that dyed wool fabric acquired less extensibility in weft direction than that acquired in warp direction (figure1). This may be due to the interaction of the new dye with the fabric. An ionic bond may form as a result of the presence of different charges between the dye and the fibers.

*3.3.2. Shear properties*

The results of shear properties for both dyed and undyed wool fabrics are given in Table 4.

Table 4: Shear properties of dyed and undyed wool fabrics

| Property | Warp direction Dyed | Warp direction undyed | Weft direction dyed | Weft direction undyed |
|---|---|---|---|---|
| G-MEAN gf/cm*deg | 0.6 | 0.55 | 0.58 | 0.55 |
| 2HG-MEAN gf/cm | 1 | 0.67 | 0.94 | 0.68 |
| 2HG5-MEAN gf/cm | 1.52 | 1.19 | 1.4 | 1.29 |

Applying paired comparison t test, a significant difference between shear rigidity was found between the undyed wool and dyed wool fabrics in warp direction (with p value = 0.003). Shear rigidity increased after dyeing in warp direction which may be attributed to the increase of fabric thickness after dyeing . Also a significant difference in shear hysteresis (2HG) between the undyed wool and dyed wool fabrics in warp direction was found (with p value = 0.00004). A significant difference in shear hysteresis (2HG5) between the undyed wool and dyed wool fabrics in warp direction was found (with p value = 0.00006). There was an increase in shear hysteresis after dyeing which means poor recoverability from initial shear deformation as the shear rigidity increased after dyeing. No significant difference was found between dyed and undyed wool for the previous properties in weft direction.

Figure 5 shows the shear hysteresis of dyed and undyed wool fabrics in warp direction. The red plot for dyed fabric and the green for the undyed one.

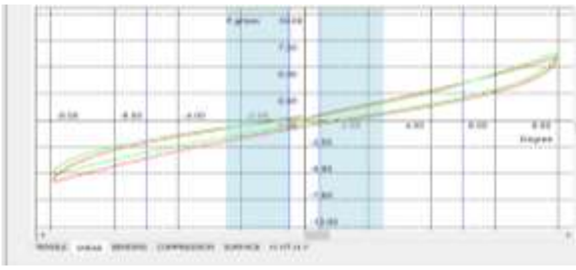


Figure 5: shear hysteresis of dyed and undyed wool fabrics in warp direction

Figure 6 shows the shear hysteresis of dyed and undyed wool fabrics in weft direction. The red plot for dyed fabric and the green for the undyed one.

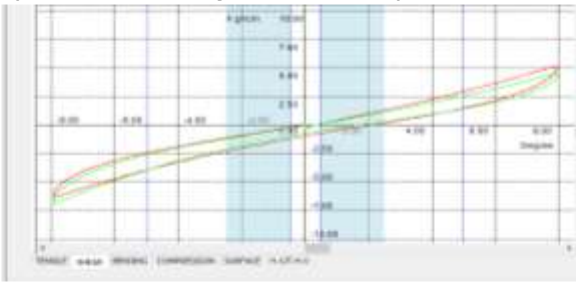


Figure 6: shear hysteresis of dyed and undyed wool fabrics in weft direction

*3.4. Bending properties KES-FB 2*

The values of the average of bending parameters of dyed and undyed fabrics are given in Table 5.

Applying paired comparison t test no significant difference was found between bending rigidity(G) for dyed and undyed wool fabric in warp direction. While a significant difference in bending hysteresis moment (2HB) was found between dyed and undyed wool fabric was found in warp direction (with p value =0.01). A significant difference between bending rigidity for dyed and undyed wool fabric in weft direction was found (with p value=0.03) The increase in bending rigidity may be attributed to the increase of fabric thickness after dyeing. Also a significant difference in bending hysteresis moment(2HB) was found between dyed and undyed wool fabric was found in weft direction (with p value =0.0001).The increase in bending hysteresis moment after dyeing in both directions means lower recoverability from bending after dyeing. As the fabric became stiffer after dyeing the bending hysteresis decreased after dyeing.

Figure 7 shows the bending hysteresis moment of dyed and undyed wool fabrics in warp direction. The red plot for dyed fabric and the green for the undyed one.

Table 5: Shear properties of dyed and undyed wool fabrics

| Property | Warp direction dyed | Warp direction undyed | Weft direction dyed | Weft direction Undyed |
|---|---|---|---|---|
| B-MEAN (gf*cm$^2$/cm) | 0.1677 | 0.1655 | 0.1532 | 0.1446 |
| 2HB ((g.cm)/cm) | 0.06 | 0.05 | 0.06 | 0.04 |

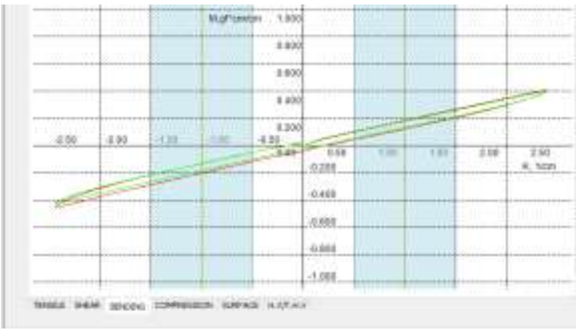


Figure 7: bending hysteresis of dyed and undyed wool fabrics in warp direction

Figure 8 shows the bending hysteresis of dyed and undyed wool fabrics in weft direction. The red plot for dyed fabric and the green for the undyed one.

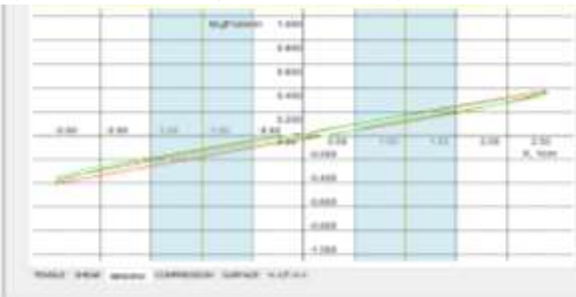


Figure 8: bending hysteresis of dyed and undyed wool fabrics in weft direction

*3.5. Compressional properties KES-FB 3*

The values of compressional parameters for the selected fabrics of both dyed and undyed wool fabrics wth new coloured are shown in Table 6.

Table 6: Compressional properties of dyed and undyed wool fabrics

| Property | Dyed wool | Undyed wool |
|---|---|---|
| LC (–) | 0.356 | 0.38 |
| WC ((g·cm)/cm$^2$ ) | 0.463 | 0.313 |
| RC (%) | 59.84 | 63.9 |

Applying paired comparison t test, a significant difference in compression linearity (LC) was found between the undyed wool and dyed wool fabrics (with p value = 0.05). Also a significant difference in compressional energy (WC) was found (with p value = 0.0002) Compressional energy increased after dyeing which means higher compression susceptibility. A significant difference in compressional resilience (RC) was found (with p value = 0.0009). Compression resilience decreased after dyeing which means lower recoverability from compression. The decrease of RC may be due to the stiffness fabric acquired after dyeing.

Figure 9 shows the compression hysteresis curve for dyed and un dyed wool fabrics. The red plot for dyed fabric and the green for undyed one.

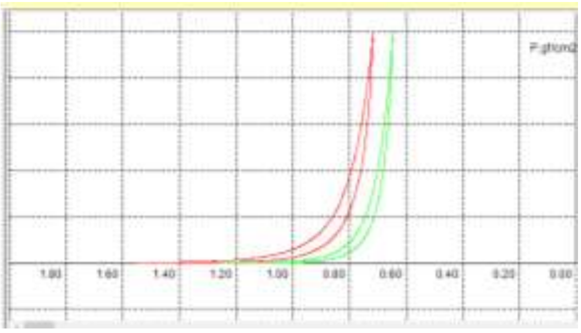


Figure 9: compression hysteresis curve for dyed and un dyed wool fabrics

It is obvious from table 6 and figure 7 that wool fabric acquired more compressibility after dyeing and lost compression resilience after dyeing.

*3.6. Surface roughness modules KES-FB4*

The values of surface roughness parameters for the different fabrics undyed and dyed wool fabrics with new coloured dyestuff are shown in the following tables (7-10).

*3.6.1. Wool (undyed) fabric*

The following tables and charts showed the surface characteristics of undyed wool fabric for both warp and weft directions. Table (7,8) showed the surface characteristics of dyed wool fabric for both warp and warp directions.

Table 7: Surface roughness table – Warp direction

| Reading | MIU | MMD | SMD |
|---|---|---|---|
| | - | - | Mm |
| 1 | 0.149 | 0.0069 | 0.808 |
| 2 | 0.14 | 0.0073 | 0.694 |
| 3 | 0.138 | 0.0064 | 0.706 |
| AVG | 0.142 | 0.0069 | 0.736 |

Table 8: Surface roughness table – Weft direction

| Reading | MIU | MMD | SMD |
|---|---|---|---|
| | - | - | μm |
| 1 | 0.151 | 0.0069 | 0.721 |
| 2 | 0.146 | 0.0115 | 0.701 |
| 3 | 0.151 | 0.0077 | 0.675 |
| AVG | 0.149 | 0.0087 | 0.699 |

*3.6.2. Wool (dyed) fabric*

The tables (9, 10) showed the surface characteristics of dyed wool fabric for both warp and weft directions. Tables 9,10 show the surface roughness results after dying. Applying paired comparison t test, a significant difference in MIU – coefficient of surface friction has a significant decrease after dyeing (with p value = 0.014) in weft direction while a non-significant difference was found between dyed and undyed fabrics in case of warp direction. Applying paired comparison t test, a significant difference in SMD –has a significant increase after dyeing (with p value = 0.04) in weft direction while a non-significant difference was found between dyed and undyed fabrics in case of warp direction. There was an little increase SMD after dyeing in weft direction. This means the fabric surface become rougher after dyeing which may be attributed to the effect of dyeing temperature.

Figure 10 shows Surface roughness property chart in warp direction for both dyed and undyed wool fabric. The red plot for dyed fabric and the green for undyed one. The upper curve is for MIU while the lower curve is for the SMD.

Figure11 shows Surface roughness property chart in weft direction for both dyed and undyed wool fabrics. The red line indicates the colored wool fabric while the green one for the undyed wool fabric. The upper curve is for MIU while the lower curve is for the SMD.

Table 9: Surface roughness table – Warp direction

| Reading | MIU | MMD | SMD |
|---|---|---|---|
| | - | - | μm |
| 1 | 0.155 | 0.01 | 0.814 |
| 2 | 0.139 | 0.0102 | 0.794 |
| 3 | 0.165 | 0.0088 | 0.836 |
| AVG | 0.135 | 0.0097 | 0.815 |

Table 10: Surface roughness table – Weft direction

| Reading | MIU | MMD | SMD |
|---|---|---|---|
| | - | - | μm |
| 1 | 0.139 | 0.0084 | 0.8 |
| 2 | 0.138 | 0.0073 | 0.782 |
| 3 | 0.13 | 0.0082 | 0.731 |
| AVG | 0.136 | 0.0079 | 0.771 |

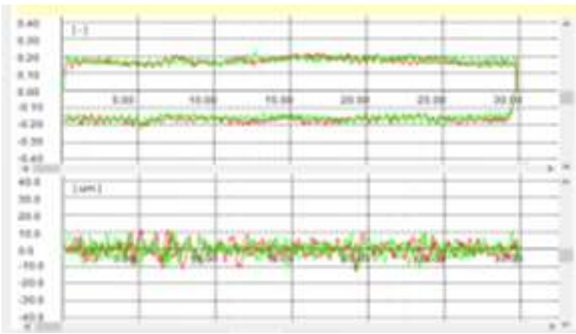


Figure 10: Surface behavior at low deformation MIU and SMD in warp direction

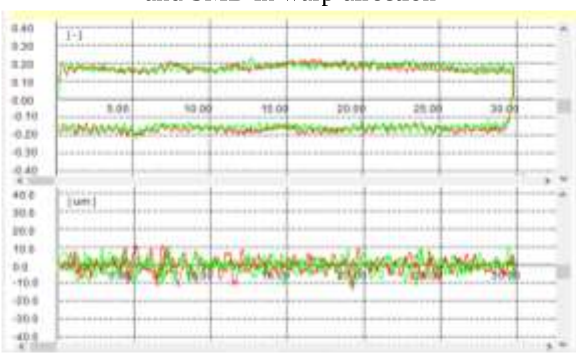


Figure 11: Surface behavior at low deformation MIU and SMD in weft direction

*3.7. Hand values*

The hand values of the primary hands such as koshi (stiffness) and numeri (smoothness), fakurami (fullness and softness), and sofutosa (soft touch) are evaluated by the objective method and then THV (total hand value, quality).Primary hand (HV) values range from 1(weak) to 10 (strong). Total hand values (THV) range from 1(poor) to 5(excellent).

Table 11 shows the results of primary hand values and total hand values of dyed and undyed wool fabrics for both HV KN-101-winterTHV-KN-301-winter (men's suiting) and HV KN-201-winter THV-KN-301-winter (women's suiting) end use.

From Table 11 it was found that the fabric used in the study is most suitable for both men's and a woman's winter suiting. Also it can be noticed that dyeing process increased the total hand value by 10% in case of using wool fabric to make men's winter suits. Also it increased the total hand value by 10% in case of using wool fabric in making women's winter suits.

*3.8. Thermo lab module measurement*

*3.8.1. Thermal conductivity measurement*

Applying paired comparison t test, a significant difference in thermal conductivity was found between the undyed wool and dyed wool fabrics (with p value = 0.000525). The thermal conductivity decreased after dyeing which means heat is harder to transfer through wool fabrics after dying [17].The decrease in thermal conductivity may be attributed to the increase of fabric thickness after dyeing. The decrease in conductivity almost associated with increase in thermal insulation which is desirable in winter suiting.

*3.8.2. Q Max. Table 13 shows the results of Q max.*

Applying paired comparison t test, a significant difference in q max was found between the uncolored wool and colored wool fabrics (with p value = 0.000645) with decrease in q max after dyeing. It was found that the moisture regain of dyed wool fabric was increased about 10%.

**4. Conclusion**

It has been concluded that:

1- Tensile energy WT has significant increase after dyeing in warp direction which mean higher stretchability. Extensibility EMT has significant increase after dyeing in warp direction which means more extensibility in warp direction after dyeing.

Table 11: Primary and total hand values of dyed and undyed wool fabrics

| Sample | Koshi undyed | Koshi dyed | Numeri undyed | Numeri dyed | Fukurami undyed | Fukurami Dyed | Sofutosa undyed | Sofutosa dyed | THV undyed | THV dyed |
|---|---|---|---|---|---|---|---|---|---|---|
| HV KN-101-winter THV-KN-301-winter | 4.92 | 4.44 | 7.37 | 8.39 | 6.25 | 8.02 | | | 4.5 | 4.96 |
| HV KN-201-winter THV-KN-301-winter | 5.89 | 5.64 | 6.23 | 6.88 | 5.16 | 6.21 | 3.65 | 4.12 | 3.88 | 4.28 |

Table 12: Thermal conductivity of dyed and undyed wool fabric

| Dyed (W/cm. °C) | Undyed (W/cm. °C) |
|---|---|
| 1.2100 | 1.2800 |
| 1.2200 | 1.2700 |
| 1.2100 | 1.2600 |
| 1.2133 | 1.2700 |

Table 13: Q- max value for dyed and undyed wool fabric

| Dyed wool (w/cm$^2$) | Undyed wool (w/cm$^2$) |
|---|---|
| 0.0750 | 0.0780 |
| 0.0760 | 0.0770 |
| 0.0740 | 0.0780 |
| 0.0750 | 0.0777 |

2- Dyeing with new coloured material increased significantly for both shear rigidity and shear hysteresis in warp direction which means lower recoverability after shear.
3- Bending rigidity increased significantly in weft direction after dyeing while bending hysteresis increased significantly after dyeing process which means lower recoverability after bending.
4- The geometrical surface roughness SMD of wool fabric has a significant increase after dyeing in weft direction which means rougher surface after dyeing.
5- A significant increase in compressional energy (WC) and significant decrease in compression resilience (RC) was found after dyeing.
6- The thermal conductivity has a significant decrease after dyeing .
7- Although most of KES individual properties gives harder and rougher fabric after dyeing, the total hand value increased by 10% after dyeing for both men's and women's suiting which means better performance in winter suiting.
8- The thermal conductivity decreased after dyeing which is desirable in winter suiting fabric end use to give warmer feeling in winter.
9- It was found that the dyed wool fabric with new coloured material based on based on (Pyrido Pyrimidine Heptadinone Derivative) is suitable for both men's and women's suit. THV total hand value increased after dyeing in both cases. This dye acts as functional dyes.
10- The Kawabata evaluation system serves used as a user-friendly instrument for determining the total hand value of fabric properties. The touch properties of the fabrics can be easily measured. These properties are important for predicting the garment of clothing and identifying the problems that may occur in the textile industry and some of these problems may be solved.

## 5. Declaration of conflicting interests

The authors declared that no conflict of interest with respect to the research, authorship and publication of this article.

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