Journal of Sciences and Multidisciplinary Research
Volume 6, No. 2, 2014
ISSN: 2277-0135

EFFECT OF BLEND RATIO ON DYE UPTAKE OF DIFFERENT BLENDS OF FLAX/COTTON WOVEN FABRICS

Sule, A.T.[1], Lawal, A.S.[2] and Giwa, A.[2]
[1]Department of Textile Technology and Fashion, Kano State Polytechnic, Kano-Nigeria
[2]Department of Textile Science and Technology, Ahmadu Bello University, Zaria-Nigeria
E-mail: amirgetso@yahoo.com

Abstract: In the textile industries Wool/Cotton blend is no doubt the oldest fibre combination of all, however, the wool is not readily available and is very expensive. In the long run it is anticipated that Flax/Cotton blend will address the raw material crisis in wool/cotton blend. Since flax and cotton have similar physical and chemical properties, chemical processing and dyeing of the blend may pose less problems. Furthermore cost of production will be reduced. Four different blends of flax/cotton woven fabrics (10/90, 30/70, 50/50 and 70/30) and 100% cotton woven fabric for control and comparison, were desized scoured, bleached and mercerized using normal methods for pretreatment of cotton fibre. The five samples were dyed with Solophenyl Brown direct dye and dye uptake and related dyeing kinetics measurements were done based on visible light colourimetry using a UV- Visible spectrophotometer. The highest percentage dye exhaustion was recorded by Sample D (50/50 F/C) at 80°C. Also the flax/cotton blends exhibit maximum diffusion coefficient at a lower temperature (80°C) than that of the control (90°C). Generally, the diffusion coefficient was found to increase with increasing flax content in the blend while the reverse is the case with activation energy.

Keywords: Fibre Blending, Diffusion Coefficient, Arrhenius Equation, Activation Energy

INTRODUCTION

Fibre blending is commonly defined as the process of forming fibre mixture by combining different fibre components, either of the same or different types, to produce a homogenous fibre assembly [6]. Blending different types of fibres is a widely practiced means of enhancing the performance and the aesthetic qualities of a fabric. When successfully done, a blend consists of different compatible components of known properties combined in such a way that their characteristics emerge as a new and reproducible product.

In most of our textile industries mixing of different cotton fibres is carried out where different proportions of cottons of known physical properties are combined to produce cotton of average physical properties for economy and smooth running of the processing machineries. The oldest mixture of all is wool and cotton, which is used to make fabrics known as unions. For this reason dyeing of mixtures of these two fibres is referred to as union dyeing [11]. Where ideal properties cannot be obtained from cotton mixing, a blend of polyester/cotton is often used to produce fabrics with acceptable characteristics to the end user [1].

In the same light, fabrics are produced from flax/cotton blend and have been found to possess superior properties compared to those produced from 100% cotton [6]. These properties include improved fluid absorption, antistatic, hygienic and UV-protective properties which give them a wider range of applications such as health clothes (handkerchiefs, towels, tablecloths, bed sheets, collars, garments, etc), upholstery and industrial (e.g. with computers and electronic equipment) [4].

Blend ratio affects the dye uptake of blends to a large extent depending on the nature of the fibres in the blend and the type of dyes used. Stapleton and Waters [10] investigated the dyeing behaviour of the Procinyl (ICI) range of reactive disperse dyes on wool–polyester blends. Two of the dyes were found to dye both components of such blends to approximately the same depth while the remaining three dyes in the range strongly favoured the wool component. The dyeability of blended polypropylene / polyester fibres evaluated on the basis of colour strength (K/S) was also reported [2]. The K/S values were found to be dependent on the composition of the blended fibres. The results show that even the affinity of the disperse dyes used on the blended fibres and the amounts of exhausted dye in the blend PP/PES depend on the composition of these fibres. Many works on cross-dyeing of protein and cellulosic fibres [11] indicate that achieving a good level dyeing depends on the composition and nature of the fibres.

MATERIALS AND METHOD

Materials

Four differently blended flax/cotton woven fabrics (10/90, 30/70, 50/50 and 70/30) and 100% cotton were used in this work.

Desizing

The weights of the five different samples (10/90, 30/70, 50/50, 70/30 flax/cotton blended and 100% cotton woven fabrics) were determined. 2% stock solution of the enzyme was prepared and its pH adjusted to 6.5 with formic acid. The samples after being thoroughly wetted were treated in 1% (owf) solution of the enzyme at room temperature for 25 minutes. This was followed by caustic wash using 2.5% sodium hydroxide (20% owf) at 90°C, then washed with water at 90°C, squeezed and dried in an electric oven. The desized samples were then weighed.

Scouring

2% stock solution of sodium hydroxide and 0.4% wetting agent were prepared, and 20% (owf) of each were measured out separately. The various samples were padded with the solution of the wetting agent for 5 minutes then boiled for 1hour in the sodium hydroxide solution. The samples were rinsed with hot water, padded with 1% acetic acid for 5 minutes, rinsed with tap water and dried at room temperature. The weights of the samples were then determined.

Bleaching

Stock solutions of 35% hydrogen peroxide, 2% sodium hydroxide, 2% sodium silicate and 1% wetting agent were prepared. The bleaching bath was set (owf) as follows:

Hydrogen peroxide	=	5%
Sodium hydroxide	=	1.4%
Sodium silicate	=	3%
Wetting agent	=	1%
Liquor ratio	=	50:1

Samples were treated in the bleaching liquor at the boil for 1hour, rinsed with water and dried. The weights of the samples were finally determined.

Mercerization

20% sodium hydroxide, 1% acetic acid and 5% wetting agent solutions were prepared. The samples were wetted out in 20% (owf) wetting agent for 5 minutes, removed and squeezed, then treated in 30% (owf) sodium hydroxide at room temperature for 1 minute. Samples were removed, squeezed and rinsed in 3% (owf) acetic acid at 40°C for 5 minutes after which they were washed with cold water, dried and weighed.

Determination of Wavelength of Maximum Absorption (Λ_{max}) of the Dye

1% solution of the dye (Solophenyl Brown) was made in 50% Pyridine, diluted with 50ml distilled water and scanned in the visible spectrum with a JENWAY UV – Visible Spectrophotometer.

Determination of the Kinetics of Dyeing

The samples were dyed with Solophenyl Brown (direct) dye using 1% owf at a liquor ratio of 100:1. 1% sodium chloride was used as assistant. Dyeing was carried out at 50°C, 60°C, 70°C, 80°C and 90°C for 2, 5, 10, 15 minutes and 1hour respectively. At the end of the prescribed periods the samples were removed, quickly rinsed in cold water and stripped in 10mls of 50% Pyridine solution at the boil for 20minutes. The extracted solutions were diluted to 50mls and scanned at the wavelength of maximum absorption of the dye.

Using the data graphs of M_t/M_∞ against time was plotted. From the slopes of the graphs the diffusion coefficients and activation energies were computed according to the equations below. M_t is the absorbance at time t.

M_∞ is the absorbance at equilibrium (1hr).

Diffusion Coefficient:

$$(D_T) = \frac{(\text{slope})^2 \pi}{4} \quad (1)$$

From Arrhenius equation,

$$DT = D_0 e^{-E/RT} \quad (2)$$

$$InD_T = InD_O - E/RT \quad (3)$$

A plot of ln D_T against 1/T is linear with a negative slope from which E, the activation energy is calculated.

D_T is the diffusion coefficient at a given temperature while D_o is a constant determined from the intercept of the curve on the ln D_T axis.

R is the gas constant = 8.314 $Jmol^{-1}k^{-1}$

$$E = slope \times R \quad (4)$$

RESULTS AND DISCUSSIONS

The wavelength of maximum absorption of the dye in the visible region was found to be 505nm (Figure 1). The visible region extends from the far violet (400nm) through blue, green, yellow and orange to the far red (700nm). This means that the dye absorbs at blue – green region reflecting its own colour, which is reddish brown. When white light falls on a substance, the wavelength of maximum absorbance is removed by absorption and the remaining wavelengths are reflected to the eye to determine the colour of the substance observed. It was observed that at 70^{o}C Sample D shows highest exhaustion (54.8%) while Sample E has the least (39.8%). Sample D again has the highest exhaustion at 80^{o}C (66.2%) followed by Samples A (61.7%) and E (51.1%). Samples C and B have 49.7% and 43.0% respectively. The control Sample A (100% cotton) shows maximum exhaustion at 90^{o}C in contrast to the blend samples which have exhaustion below 50%.

The data was used to plot rate curves for the samples and diffusion coefficients of the dye in the different samples were computed from their slopes using Fick's second law. The law was used according to approximations made by Vickerstaff where a non steady state condition of an infinite bath was assumed.

The diffusion process is believed to depend on affinity of dyes to fibres, concentration of dyes in bath, temperature and time of dyeing and textile auxiliaries [9]. Other factors may be ionizable groups within the dye and the fibre, size and nature of the dye molecule and the crystallinity or otherwise of the fibre. Generally the diffusion coefficients of all the Samples (A – E) increased with increase in temperature. This is expected since diffusion coefficient is temperature dependent. For the blended samples, however, a fall in the D_T values was observed at 90^{o}C.

This may be due to the dyeing behaviour of the dye at that temperature. Dyes often have an optimum dyeing temperature usually determined by a temperature range test. In this case, the optimum dyeing temperature is that with highest diffusion coefficient for a convenient dyeing time under the given conditions.

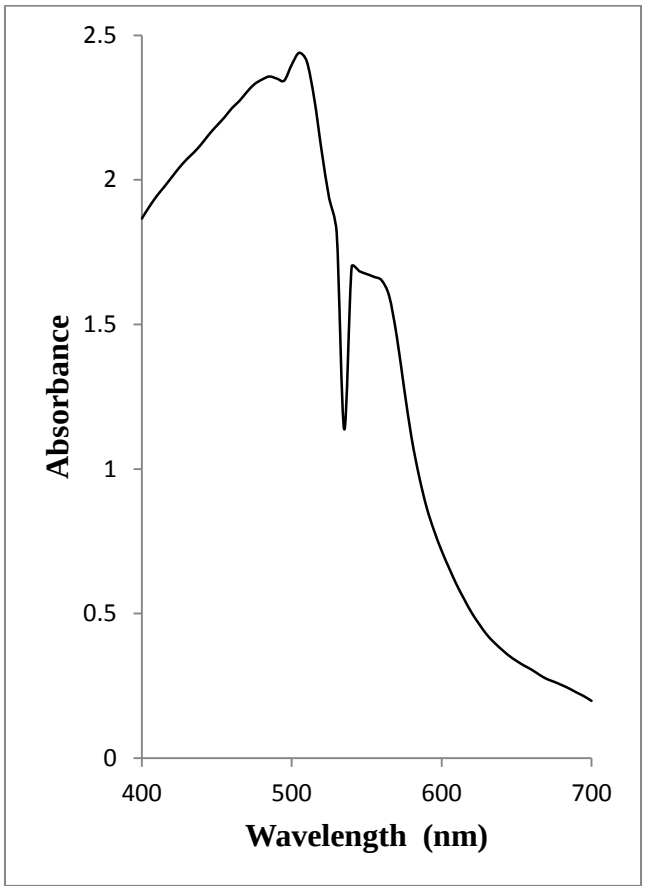

Figure 1: Visible Spectrograph of Solophenyl Brown Direct Dye in Pyridine

Table 1: Summary of Kinetic Data of the Samples

Sample	Max % Exhaustion (M_t/M_∞)	Max. Diff. Coefficient (D) (s^{-1})	Activation Energy ($Jmol^{-1}$)
A	63.8 (90^oC)	$3.465x10^{-4}$ (90^oC)	62903.724
B	49.5 (70^oC)	$1.768x10^{-4}$(80^oC)	43041.578
C	49.7 (80^oC)	$2.012x10^{-4}$(80^oC)	41204.184
D	66.2 (80^oC)	$3.465x10^{-4}$(80^oC)	51754.65
E	51.1 (80^oC)	$1.768x10^{-4}$(80^oC)	36814.392

From the data obtained, Sample D (50/50 blend) exhibit higher values of diffusion coefficient over the temperature range except at 50^oC where Sample E (70/30 blend) has the highest diffusion coefficient.

The activation energy of diffusion is related to the energy necessary to disrupt the intermolecular forces in the internal structure of the fibre/polymer to bring about dye penetration. It gives an assessment of the forces necessary to overcome during dyeing [12]. Table1 shows the effect of blend ratio as investigated in this work with respect to the activation energy. The activation energy of the control sample (Sample A) is the highest (62,903.72 $Jmol^{-1}$). The higher the activation energy, the more rigid the structure making up the fibre and the more the energy required to push the molecules of the dyes into the accessible regions of the fibres. It has been found by Lemin and Vickerstaff [7] that direct correlation exists between the number of cross links within the fibre and activation energy. In other words, an increase in the number of cross-links decreases the dye diffusion. Pretreatments of the fibre, which leads to break up of cross-links, have been found to increase the rate of dyeing and hence reduce the activation energy. According to Sivaraja Iyer [8], the increase in activation energy because of cross-linking is attributable to the reduction in the accessibility and average pore size of the pretreated fibres.

Sample E (70/30 blend) has the least activation energy of diffusion (36,814.39 $Jmol^{-1}$) followed by Sample C (41,204.18 $Jmol^{-1}$) then Sample B (43,041.58 Jmol-1) and Sample D (51,754.65 $Jmol^{-1}$). Except for the discrepancy from Sample D, the activation energy generally decreases with increased flax content. The discrepancy may be due to experimental errors or effects of residual pretreatment chemicals as mentioned previously. The diffusion of dye molecules into sample D (50/50 blend) could be faster than into Sample E (70/30 blend), but it is easier for the dye to penetrate the fibre micropores of Sample E which contains more flax. Even though flax is a bit more crystalline than cotton, it has higher moisture regain [3]. Consequently flax takes up more dye since it swells more in the dyeing liquor. Furthermore fabrics produced from flax/cotton blend have been found to possess superior properties compared to those produced from 100% cotton which included improved fluid absorption [4]. Again alkali pretreatment of the cellulosic fibres leads to the increase in the amount of amorphous cellulose at the expense of crystalline cellulose [5]. The important modification occurring here is the removal of hydrogen bonding in the network structure.

Considering the results obtained the activation energy of diffusion generally decreased with increase in flax content of the blends. It could be argued from the aforementioned that some form of opening-up in the cellulose structure had taken place because of the cleaning of the natural admixtures (scouring) and swelling (mercerization) on the material. The opening-up is predicated on the increase in the moisture absorption and on the decrease in the activation energy of the blends compared to the control.

SUMMARY AND CONCLUSION

This work has shown that it is possible and economical to dye different blends of flax/cotton. The four different blends of flax/cotton woven fabrics were successfully desized, scoured, bleached and mercerized in the same way as 100% cotton fabric was being pretreated.

Both four blends of flax/cotton fibres show satisfactory dye exhaustion but, the highest percentage dye exhaustion was recorded by Sample D at 80°C. The flax/cotton blends exhibit maximum diffusion coefficient at a lower temperature (80°C) than that of the control (90°C). Incidentally Sample D (50/50) has the highest diffusion coefficient of all the samples.

All the blend Samples (B – E) recorded lower activation energies compared to the control Sample (A) with satisfactory exhaustion at optimum dyeing temperature. This means that it is more economical to dye flax/cotton blends since less energy is required to push the dye molecules in to their structure.

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Reference to this paper should be made as follows: Sule, A.T. *et al.* (2014), Effect of Blend Ratio on Dye Uptake of Different Blends of Flax/Cotton Woven Fabrics. *J. of Sciences and Multidisciplinary Research,* Vol. 6, No. 2, Pp. 9 – 16.