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DYEING OF NYLON FABRIC USING NANOEMULSION

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ABSTRACT

Oil in water nanoemulsions were used for preparing nanodisperse dyes and applied on nylon fabric at 100°C. Nano emulsion was characterised by nano-particle size analyzer. Dyeing characteristics of fabric dyed with crude disperse dyes using these nanoemulsions and that dyed with commercial form of the same disperse dyes was compared. Dyeing of same colour depth was obtained with equivalent fastness properties thus eliminating the requirement of milling of the crude disperse dye with the dispersing agent resulting in cost, time and energy savings.

KEYWORDS: Disperse Dye, Dyeing, Nanoemulsion, Nylon

Nanotechnology is progressively attracting worldwide attention since it offers huge potential in different areas. Textile industry is also experiencing the benefits of nanotechnology in its diverse field and has practical applications for the in the processing of Textiles as the effects obtained are permanent with less usage of chemical and energy [David et. al., 2002] [Bhattacharyya, 2011]. Nano dyeing is the application of nano size dyes in textile dyeing [Hornyak et. al., 2006] [D. et. al., 2014].

Nylon is semi-crystalline polyamide used as fibre and engineering thermoplastic [RJ, 1988] [I, 1995]. Acid, metal complexes, disperse reactive and disperse dyes are the important classes of dyes used for dyeing of nylon.

Disperse dyes are traditionally non-ionic chemicals with sparing solubility in water and often crystalline with varying particle size. These characteristics are inadequate for dispersing the dyes in water and causes unlevel dyeing. In order to achieve the required particle size and distribution [AN] [Heimanns, 1981] the disperse dye is milled, usually in the presence of a dispersing agent [Derbyshire et. al., 1972]. In conventional dyeing processes, the disperse dyes are applied from fine aqueous dispersion at 130°C on polyester and at 100°C on Nylon fabrics [Choi and Kang, 2006].

In textile processing where the substrate-solution reactions are mainly governed by adsorption phenomenon, the nano emulsion science will possibly open a new way of governing all these reactions. Nanoemulsions are very fine dispersion of oil in water. Droplets of nanoemulsion ranges from 100 to 600 nm in size [El-Aasser et. al., 1988] [Liu et. al., 2006]. Excellent chromatic properties are attributed to the nano scale effects of homogeneous nano colorants [Hu, 2008].

In present work, we prepared oil in water nanoemulsion using high speed homogenizer. Three disperse dyes with different energy levels were prepared and subsequently applied on nylon fabrics. Their fastness properties were studied vis-à-vis the dyeing obtained using the commercial form of the same disperse dyes.

MATERIALS AND METHODS

Materials

Woven Nylon and Paraffin oil (density-0.86 at 25°C, 99%) was procured from a local market in Mumbai, India. Polyoxyethylene (20) sorbitan monooleate (Tween 80, chemically pure grade) as a hydrophilic sufactant was supplied by Mohini Organics Pvt. Ltd., Mumbai, India. Dimethyl formamide (DMF), acetone, acetic acid (AR grade) was obtained from S D Fine-Chem Ltd., Mumbai, India. Saragen 50 as a dispersing agent, saragen KDF as a levelling agent was kindly provided by Sarex Chemical Ltd., Tarapur, India. Non-ionic soap, Auxipon NP was supplied by Auxichem Industries Ltd., Mumbai, India. Three types of crude disperse dyes in the form of wet cake and commercial form of the same was procured from Spectrum Dyestuffs Pvt. Ltd, Surat, India. Dye name, structure, molecular weight, energy level, solid content and λmax of these dyes are listed in Table-I [D. et. al., 2014].

Methods

Solid Content of crude Dye

5 gm of each crude dye was taken in Petri dish and kept in hot air oven (MSI-5, META-LAB SCINTIFIC INDUSTRY, Mumbai, India) at 100°C for 3 hours. Solid content of dyes was then calculated using following formula.

$$\text{Solid Content, } (\%) = \frac{Wi - Wf}{Wi} \times 100 \quad (1)$$

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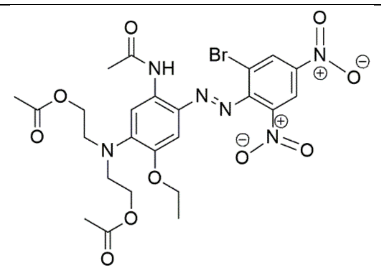
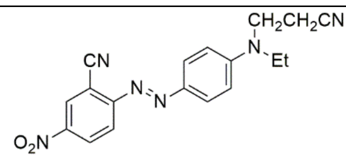
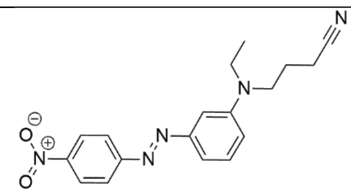
Where, W_i and W_f are the initial and final (after drying) weights of the dyes respectively.

Dye Content in Finished Dye

First each crude disperse dye was dissolved in DMF and a calibration curve was plotted, taking different concentrations and measuring its absorbance at maximum wavelength (λmax) of the respective dye by using UV-Visible spectrophotometer (UV-1800, Shimadzu Corporation, Japan). Commercial dye was dissolved in DMF: water mixture (3:1). The actual amount of dye was found out by noting its absorbance at λmax and tracing it on the previously prepared calibration curve of crude dye.

Table I: Properties of crude disperse dyes

Dye Name	Dye structure	Molecular weight (gm/mole)	Energy level	Solid Content (%)	Maximum Wavelength [λmax](nm)
C.I. Disperse Blue79.2		639.4	High	53.7	587
C.I.Disperse Red 73		348.35	Medium	24.4	528
C.I.Disperse Orange 25		323.35	Low	36.6	481

Preparation of Nanoemulsion

Oil in water nanoemulsion was prepared by using high speed homogenizer of IKA T25 digital ULTRA TURRAX, IKA® India Pvt. Ltd., Karnataka, India. 5 part of Tween 80 was dissolved in 80 part of distilled water into which 15parts paraffin oil was added. This mixture was subjected to homogenization at 12000 rpm for 20 minutes in the homogenizer.

Preparation of Nanodisperse Dye Solution

Required quantity of dried crude dyes were taken for 3% shade according to the solid content of the dyes obtained and were dissolved in 10 ml DMF. This solution was then added drop wise to 90ml nanoemulsion and homogenized at 12000 rpm for 15 minutes.

Measurement of particle size of nanoemulsion and nanodisperse dye

The average particle size of the nano disperse dye solution was measured using nano particle size analyzer (SALD-7500nano, Shimadzu Corporation, Japan).

Preparation of 1% stock solution for commercial dye

1gm of commercial disperse dye was weighed and taken in a volumetric flask. It was pasted first with cold water and diluted to 100ml using hot distilled water.

Dyeing of nylon fabric

The Nylon fabric was scoured using 2 grams per litre Auxipon NP at boil for 30 minutes, washed with cold water and air dried. The fabric was cut into same sample size and weight which was then dyed with MLR 1:30 at 100°C for 60 minutes in Flexi dyeing machine (Rossari Biotech, Mumbai, India). For dyeing with commercial dyes, the dye bath contained required volume of the dye solution from stock solution along with 0.5 gram per litre each of levelling agent and dispersing agent. The pH of the bath was adjusted to 4-5 using acetic acid. Similarly the dyeings with nano disperse dyes was carried out using nano emulsions but without adding any of the above auxiliaries. The percent shade taken for all the cases was maintained at 3% shade. The amount of dye taken was based on the actual amount of dye present in the commercial dye and that in the wet cake. This was done in order to have the same amount of dye in the dyeing bath.

The dyed samples were then subjected for reduction clearing treatment using 2 gram per litre each of caustic soda, sodium hydrosulphite and Auxipon NP at 70°C for 20 minutes. All fabric samples were thoroughly washed with cold water and then air dried.

Evaluation of Colour strength

Spectra Flash® (SF 300, Computer Colour Matching system of Data Colour International, U.S.A) was used to measure the colour strength of the dyed samples in terms of Kubelka Munk function. This was expressed as K⁄S values at maximum wavelength [Ingamells, 1993].

Rubbing Fastness

For evaluating rubbing fatness of dyed samples, crock meter was used as per AATCC 116-1995 standard test method.

Wash Fastness

Washing fastness was evaluated by ISO 3 method using Launder-O-meter for 20 minutes at 60°C with 2 gram per litre non-ionic soap (Auxipon NP) and soda ash at a liquor ratio of 50:1, as per standard method [ISO105-CO6, 2006].

Sublimation Fastness

Fastness to sublimation was determined by AATCC 133-2009 method.

Light Fastness

Light Fastness was determined by ISO 105-B02 test method.

RESULTS AND DISCUSSION

Particle size analysis of nanoemulsion and nanodisperse Dye Solutions

Fig. 1 shows the average droplet size of nanoemulsion and nanodisperes dyes in the range of 20-30 nm.

Active dye content in commercial Dye

Commercial dye contains dispersing agent along with crude dye whose values range from 50 to 90%. Hence it is essential to find out the actual amount of dye present in it. The values for the dyes taken for our study are given in Table-II.

Table II: Active dye content in commercial disperse dye

Disperse dye	C.I. Disperse Blue 79.2	C.I. Disperse Red 73	C.I. Disperse Orange 25
Active dye content (%)	25.84	10.07	15.17

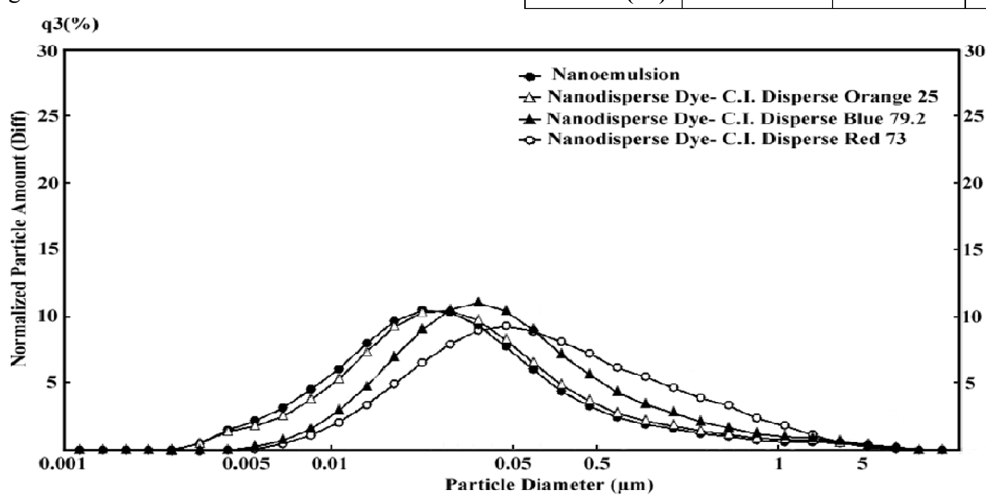


Figure 1: Particle size distribution of Nanoemulsion and Nanodisperes dyes

Colour evaluation of dyed samples

Fig. 2 and Table-III shows the K/S values of the nano disperse dyed samples and that of commercial dyed samples. The values were comparable for all the three dyes taken for the study. This was because of nanoemulsions which assist in penetration of dye molecules in to the compact structure of nylon to a greater extent due to the nano metric size (20-30 nm) of the oil phase containing the dye molecules as against the commercial dyes whose size is always in micrometer range [D. et. al., 2014]. Fig. 3 depicts the actual dyed samples showing the same apparent colour strength.

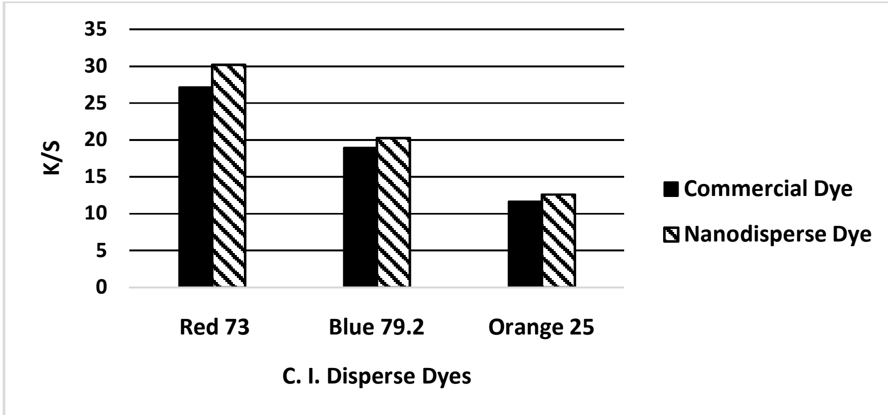


Figure 2: Colour values of nano disperse and commercial dyed samples

Evaluation of Fastness properties

The result of the washing, rubbing, sublimation and light fastness of the dyed samples are summarized in Table-III. It was observed that the fastness properties of all the three nanodisperse dyed samples were at par or better as compared to the commercial disperse dyed samples. The penetration of the disperse dye was to the core of the nylon fibre due to the nano size of the emulsion resulting in excellent fastness properties.

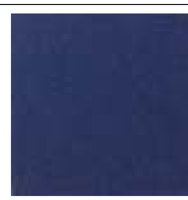
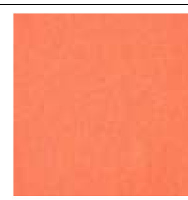
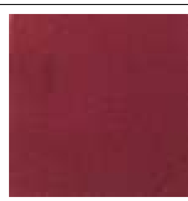
Samples dyeing with	Dye (Shade: 3%)		
	C.I. Disperse Red 73	C.I. Disperse Blue 79.2	C.I. Disperse Orange 25
Commercial dye			
Nanoemulsion dye			

Figure 3: Nano disperse and commercial dyed samples

Table III: Fastness properties of nanodisperse and commercial dyed samples

Samples		K/S Values	Washing	Rubbing		Sublimation at 210^0C	Light
				dry	wet		
C.I. Disperse Red 73	Commercial Dye	27.14	4	4-5	4	4	8
	Nanodisperse Dye	30.18	4-5	4-5	4	3	8
C.I. Disperse Blue 79.2	Commercial Dye	18.97	4-5	5	3-4	4	8
	Nanodisperse Dye	20.23	5	5	3-4	3-4	8
C.I. Disperse Orange 25	Commercial Dye	11.64	4-5	4-5	3-4	3-4	8
	Nanodisperse Dye	12.59	4-5	4-5	3-4	3	8

CONCLUSION

Nano emulsion assisted disperse dyeing of nylon fabric studied in this work, shows comparable colour strength to commercial dyeing samples. Nanoemulsion provide very fine dispersion by reducing dye particles size which also act as transporting medium for the dye in to the fiber core without any addition of auxiliary. This result in considerable saving in the cost of dyeing, dye manufacturing and reducing load on effluent compared to conventional method. The fastness rating of all dyeings with nanoeumlsion were equivalent. The lengthy process of milling the disperse dye using dispersing agent can also be omitted if we use this nano disperse dyes. Thus nanodisperse dyes provides an alternative for dyeing Nylon with disperse dyes saving considerable amount of energy, time and money utilized in manufacturing as well as dyeing using finished commercial disperse dyes.

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