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Characterization and comparison of salt-free reactive dyed cationized cotton hosiery fabrics with that of conventional dyed cotton fabrics

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ABSTRACT

One of the major problems in reactive dyeing of cotton goods is the usage of salt during the dyeing process. The treatment of coloured salt laden effluent is one of the scorching issues in the textile processing house as it significantly increases the cost of the dyed goods. The coloured salt laden effluent generated after dyeing is to be treated by an effluent treatment process before being discharged. Removal of salt from effluent significantly increases the cost of dyed goods. Cationization of cotton is an effective way to eliminate usage of salt in reactive dyeing process. The aim of this study is to carry out industrial scale cationization of cotton hosiery fabrics by exhaust method followed by salt-free reactive dyeing with ultra-deep jet Black dye of shade 9.95%. Fabric without cationization treatment was dyed by conventional dyeing route which involves usage of salt for the same shade percentage. The colour strength of cationized dyed fabric was found to be almost equal to the conventionally dyed fabrics. The total dye fixation (%) of cationized cotton dyed fabric was 58.2%, whereas for conventional dyed cotton fabric it was 51.7%. The effluent parameters of the both routes were compared and it was found that for salt-free reactive dyeing process, the total dissolved solid (TDS) value was four times lower than the conventional dyeing process. Based on the results obtained, the usage of salt can be eliminated for cationized cotton fabric during reactive dyeing process.

1. Introduction

Colouration of textile is one of the important steps in textile processing sequence. Different types of dyes are used for colouration depending upon the type of fabrics (John, 1995). Cotton fabrics are mostly dyed with reactive dyes. Reactive dyeing of cotton involves two stages, exhaustion and fixation (Joseph, 2000). At the exhaustion stage of dyeing, salt is added depending upon the shade percentage to overcome the negative surface charge potential of the wet cotton fibre (Chequer et al., 2013; Correia et al., 1994). After dyeing, the salt laden effluent is subjected to the effluent treatment process before discharge or for reuse (Kumar and Joseph, 2006; Nelliyat, 2007).

The effluent coming out of the industries is subjected to zero liquid discharge treatment system (ZLDTS). The implementation of this system ensures that the water is again reused for dyeing after separation of salt (Vishnu et al., 2008). The separation of salt from the effluent significantly increases the dyeing cost by 10%, since this process (ZLDTS) increase the operation and maintenance costs include chemicals cost, power, steam, manpower, membrane replacement and sludge management cost (Vishnu and Joseph, 2008). Moreover the efficiency of the salt removal system decreases as time progress due to scaling of membrane and machinery (Khatri et al., 2015). Hence the industries are reluctant to embrace this approach (Manjunath and Tayal, 2013). It can be inferred from the information presented above that the reduction or elimination of salt during reactive dyeing process will be very useful for knit processors (Nelliyat, 2007; Yoganandan, 2015). The efforts in this direction can be summarized under three categories namely modification of dyeing machinery, reactive dyes and cotton substrate. The dyeing machines are modified to operate at low material to liquor ratio, so that quantum of salt usage could be reduced. The introduction of ultra-low liquor ratio dyeing machines which operate at 1:4 materials to liquor ratio, padder with low through volume capacity and E-Control dyeing machines considerably reduce the amount of salt consumed in the reactive dyeing process (Khatri et al., 2015). Modified dyes such as Cibacron LS range of dyes, Novacron LS dyes, Teegafix HE dyes and

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List of abbreviations and symbols

CDF	Conventional dyed fabric
CHPTAC	3-Chloro-2-hydroxypropyl trimethylammonium chloride
COD	Chemical oxygen demand
L*, a* & b*	Colour coordinates values
ΔE	Colour difference
K/S	Colour strength
MCT-VS	Combination of monochlorotriazine and vinyl sulphone based reactive dye
CIE	International commission on illumination
ISO	International organization for standardization
L*	Lightness or darkness value
NTU	Neflon turbidity unit
Pt/Co	Platinum-Cobalt scale
a*	Redder or greener tone of the dyed fabric
RCS	Relative colour strength
RO	Reverse osmosis
RUI	Relative unlevelness index
SFD	Salt-free dyeing
SFDF	Salt-free dyed fabric
T	Total dye fixation
TDS	Total dissolved solids
TSS	Total suspended solids
b*	Yellower or bluer tone of the dyed fabric
ZLDTS	Zero liquid discharge treatment system

environmentally friendly dyes such as Procion XL+ and Ramazol's EF range of dyes require low quantity of salt (Ahmed, 1995; Taylor, 2000). In case of all these modified reactive dyes achievement of desired hue and fastness is an impediment to its implementation in industries (Khatri et al., 2015; Singha et al., 2013). Modification of cotton substrate by cationization process is an effective method for achieving good dyeability and reduces salt usage at the source. This is achieved by treating cotton with cationic agents such as monomers like 2,3-epoxypropyl-trimethylammonium chloride (Glytac A), 3-chloro-2-hydroxypropyl trimethyl ammonium chloride, 1-chloro-2-hydroxy-3-trimethylammonium chloride, N, N, N-trimethyl glycine (betaine), 2-choloro-2-dimethylaminoethyl hydrochloride, ethylene diamine tetra acetic acid (EDTA), dimethyl ethanolamine (Aktek and Millat, 2017), cationic polymers such as polyepichlorohydrin resin, poly (4-vinyl pyridine) quaternary ammonium compound, 2-methacryloyloxy ethyl trimethylammonium chloride, poly (vinylamine chloride), tertiary amine cationic polyacrylamide, polyamino carboxylic acid (Lichtfouse et al., 2015), biopolymers such as chitosan and its derivatives, cationic starch and its derivatives, chicken feather and keratin (Arivithamani et al., 2014; Varadarajan and Venkatachalam, 2015) and commercial cationic agents such as EcoFAST™ CR 2000 (3-chloro-2-hydroxypropyl trimethylammonium chloride), cibafix WFF (polyamino chlorohydrin quaternary ammonium compound), solfix E (Arivithamani and Dev, 2016; Choudhury, 2014; Lewis and Mcllroy, 1997).

Among these cationic agents 3-chloro-2-hydroxypropyl trimethylammonium chloride (CHPTAC) has shown potential for scale up and the major limitation is that it has to be applied to cotton fabric by cold-pad-batch process which is difficult to implement in industry as most of the industries follow exhaust process (Fang et al., 2015; Tarbuk et al., 2014; Wang et al., 2009). In this paper dyeing was carried out for producing ultra-deep jet black dye of shade 9.95% using combination dyes of Black GDNN−8.2% and Navy Blue−1.75% by exhaust method. The ultra-deep jet black dye recipe was chosen for this study because black is one of the most commonly used dye for garments and other textile products (Fu et al., 2013). Comparison was made between conventional and cationized fabric dyeing in terms of colour strength, tonal variations, fastness properties, dye penetrability and process cycle. In addition to that effluents generated by both the routes were characterized. The main contribution of this work is unique of its kind as mostly cationization of cotton is carried out by cold pad-batch method which industry will not embrace as it is an additional investment. The paper reports the recipe and procedure for carrying out cationization of cotton hosiery fabrics using existing machinery in the industry. The recipe and procedure reported in the paper will be useful for all the textile dyers around the globe and can be followed using the existing machinery.

2. Materials and methods

2.1. Materials

The materials used in this study are given in Table 1.

2.2. Methods

2.2.1. Preparatory and cationization process

The process sequence for the conventional and salt-free dyeing (SFD) route is given as a flowchart in Fig. 1. As a first step, the fabric was prepared for dyeing by carrying out scouring and bleaching process in a single step by exhaustion technique using a soft flow dyeing machine of DMS-Dilnmenler-Dye Jumbo HT fabric dyeing machine supplied by Turkey with materials to liquor ratio of 1:6 at temperature of 95 °C for 40 min. The detailed explanation of the

Table 1
List of materials and chemicals used in this study.

Materials and chemicals	Specification and quantity	Source
Fabric: Grey cotton tubular knitted fabric	Knit structure: Single jersey Cover factor: 180 g/m^2 Quantity: 25 kg/trial	White house processing unit, Andhra Pradesh
Cationic agent: 3-Chloro-2-hydroxypropyl trimethylammonium chloride	Concentration: 65.4% Quantity: 80 g/L	Dow Chemical Pvt. Ltd., Tiruppur
Reactive dyes: Ultra-deep jet black dye	Black (9.95%) with combination of Black GDNN−8.2% and Navy Blue−1.75%	Colourtex Industries Ltd., Tiruppur
Auxiliary chemicals	Sodium carbonate, Sodium hydroxide, Acetic acid, Soap solution	Local chemical suppliers in Tiruppur