

## INVESTIGATION OF INDIGO DYEING USING SODIUM BOROHYDRIDE AS REDUCING AGENT

Banu Yeşim Büyükakinci,<sup>1</sup> Nihal Sokmen<sup>2</sup>

**Abstract:** Indigo, one of the oldest dyes, has a very important role for the textile sector. It is primarily used to dye cotton clothes, and blue jeans and over one billion pairs of jeans around the world are dyed blue with indigo. Although Sodium Hydrosulfite ( $\text{Na}_2\text{S}_2\text{O}_4$ ) is used as a reducing agent in most indigo dyeing processes, it is environmentally unfavorable because of the resultant contaminated toxic wastewater. In addition, the color fastnesses of dyed samples using  $\text{Na}_2\text{S}_2\text{O}_4$  as reducing agent are not good enough.

In the present paper sodium borohydride ( $\text{NaBH}_4$ ) were used as ecologically safe reduction systems for the indigo dyeing of cotton fabric. After dyeing processes, the color yield and fastnesses according to washing and rubbing were measured, and results were compared.

It was found when  $\text{NaBH}_4$  was used as reducing agent instead of  $\text{Na}_2\text{S}_2\text{O}_4$ , the color yield and the fastness properties of the dyed samples improved.

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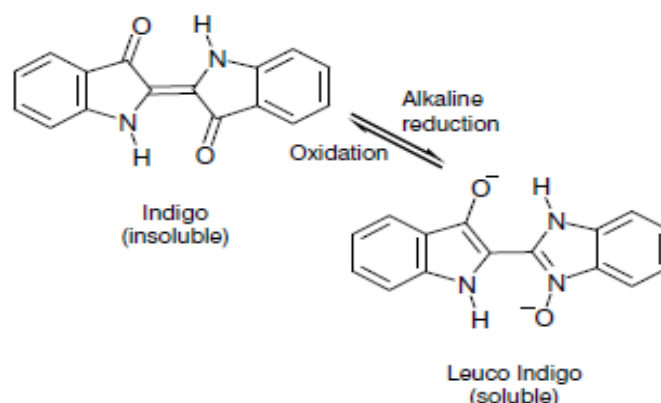
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### Introduction

Indigo, one of the oldest colorants, is widely used for dyeing cotton yarn for blue jeans. Because of the popularity of blue jeans, indigo is still one of the most important of all dyes in present use. The water-insoluble, blue pigment gives a pale yellow, water-soluble leuco form on reduction (Figure 1).

Figure 1: Reversible reduction and oxidation for Indigo



Source: Authors

Although sodium dithionite ( $\text{Na}_2\text{S}_2\text{O}_4$ ) has been used as reducing agent in most indigo dyeing processes because of its low cost, it is considered to be environmentally unfavorable because of the resultant contaminated toxic wastewater (Yao, 2015).

In this work, 100% knitted cotton fabric samples (produced by Kadifetek) were dyed with indigo dye using sodium borohydride as reducing agent instead of sodium dithionite.

Using of the environmentally friendly boron and boron compounds will have very an important roll in the textile industry in the future. Sodium borohydride is a well-known reducing agent and has been extensively employed in chemical synthesis and in some hydrogen generation processes. This compound is non-toxic and has minimal effects on the environment (Dincer 2015, Meksi 2007).

Sodium borohydride is an effective and very selective specialty reducing agent used in organic - biochemical reactions and in the manufacture of pharmaceuticals. It is alternative to  $\text{Na}_2\text{S}_2\text{O}_4$  as reducing agent for indigo dyeing processes with its ecological properties.

<sup>1</sup> Engineering Faculty, Istanbul Aydın University, Istanbul, Turkey, byesimb2@gmail.com

<sup>2</sup> Technology Faculty, Marmara University, Istanbul, Turkey. nsokmen@marmara.edu.tr

Indigo dyes usually have good washing fastness. The light fastness varies from moderate to good in heavy shades. In addition to cotton, other fibres, for example, silk and wool and polyester have also been dyed using different methods in the past. (Baig, 2011; Tichaa, 2013; Meksi,2007-2010)

### Experimental

Materials: In the present study, 100% knitted cotton fabric samples (130g/m<sup>2</sup>) were dyed with Indigo 4B coll liq., supplied by DyStar.

It was found that the color yield and the fastness properties were improved when using NaBH<sub>4</sub> giving fastness properties better than those obtained with Na<sub>2</sub>S<sub>2</sub>O<sub>4</sub> as reducing agent (Merck).

Methods: Dyes were applied at 1% depth of shade (owf), and the liquor/fabric ratio was 20:1.

The dyeings were initiated at 40 °C, then the temperature was raised to 60 °C. After keeping at this temperature for 30 min, the samples were removed from the bath and kept at atmospheric conditions to be oxidised.

The reflectance values of the dyed materials were measured using a SF600 Plus Datacolor spectrophotometer, and the CIELab values were calculated using illuminant D65 / 10° standard observer. K/S, the color strength values of the samples were calculated by using Kubelka Munk equation (Eqn 1) (McDonalds, 1997)

$$K/S = (1-R)^2 / 2R \quad (1)$$

Where K is the absorption coefficient of the substrate, S is the scattering coefficient of the substrate and R is the reflectance of dyed fabric at λ<sub>max</sub>.

The rubbing and wash fastnesses of the dyed cotton fabrics were determined according to ISO105-X12 and ISO105:C06 (A1S ) standards, respectively.

### Results and Discussions

The colorimetric parameters, color strength (K/S) and fastness values are given in Table 1 and Table 2 respectively.

Reducing agent	L*	a*	b*	C*	h°	K/S (max K/S in 600nm)	ΔE
Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub>	30.22	1.04	-32.04	32.06	271.85	19.06	6.508 Darker redder less blue
NaBH <sub>4</sub>	24.43	3.34	-30.15	30.34	276.32	26.97	

Source: Author

The K/S values are 26.97 and 19.06 for the NaBH<sub>4</sub> and Na<sub>2</sub>S<sub>2</sub>O<sub>4</sub> used samples, respectively and the color difference is 6.508. The sample which was dyed by using Na<sub>2</sub>S<sub>2</sub>O<sub>4</sub> as reducing agent is darker redder and less blue than the using NaBH<sub>4</sub>.

Reducing agent	Colour change	Staining*							Rubbing	
		CA	Co	PA	PES	PAN	Wo	Dry	Wet	
Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub>	4-5	4-5	4-5	5	5	4-5	5	4-5	4	
NaBH <sub>4</sub>	5	5	5	5	5	5	5	5	4-5	

Source: Author

As shown in Table 2, it was determined that the results of the samples used NaBH<sub>4</sub> were slightly better, although there was no significant difference in color fastness values of the painted samples using both reducing agents.

### Conclusion

It can be concluded that using NaBH<sub>4</sub> enhances the dye uptake of cotton fabric and dyed samples can be obtained with good color strengths and fastnesses. Using non-harmful chemicals like NaBH<sub>4</sub> in the indigo dyeing processes is very important for the ecosystem. From an environmental point of view, it

is possible to replace the toxic reducing agents (sodium dithionite) by the ecological product as the  $\text{NaBH}_4$  in the reduction process of indigo dye.

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