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Monoazo reactive dyes: Synthesis and application on cotton, silk and wool fibers

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Abstract

Mono azo reactive dyes are mostly used in textiles industries. The current study was developed to synthesize and apply mono azo reactive dyes. The primary goal of this research article is to highlight synthesized dyes with outstanding fixing properties for the dyeing and printing sectors to invent in future. Diazotized o-anisidine was coupled with several 4-amino-4’-hydroxy benzilidene acetophenone cyanurated coupling component including H-acid, Gamma acid, J-acid, N-methyl J-acid, N-phenyl J-acid, K- acid and peri acid, to create a variety of monoazo reactive dyes. IR and elemental analyses were used to describe them. Moreover, the dyeing capabilities of each of these dyes on silk, wool, and cotton have been evaluated. The wet fastness properties also evaluated. Synthesized mono azo reactive dyes have excellent fixation values as well as fastness properties.

Keywords: synthesis, monoazo reactive dyes, application, cotton, silk, wool, fixation, fastness.

Corantes reativos monoazo: Síntese e aplicação em fibras de algodão, seda e lã

Resumo

Os corantes reativos monoazo são usados principalmente nas indústrias têxteis. O presente estudo foi desenvolvido para sintetizar e aplicar corantes reativos mono azo. O objetivo principal deste artigo de pesquisa é destacar corantes sintetizados com excelentes propriedades de fixação para os setores de tingimento e estamparia investirem ainda mais. A o-anisidina diazotizada foi acoplada a vários componentes de acoplamento cianuratados de 4-amino-4'-hidroxi benzlideno acetofenona, incluindo ácido H, ácido gama, ácido J, ácido N-metil J, ácido N-fenil J, ácido K e peri ácido, para criar uma variedade de corantes reativos monoazo. Análises elementares de IR e nitrogênio foram usadas para descrevê-los. Além disso, as capacidades de tingimento de cada um desses corantes em seda, lã e algodão foram avaliadas. As propriedades de resistência à umidade também foram avaliadas. Os corantes reativos monoazo sintetizados têm excelentes valores de fixação, bem como propriedades de solidez.

Palavras-chave: síntese, corantes monoazoreativos, aplicação, algodão, seda, lã, fixação, solidez.

1. Introduction

The most prevalent type of dye for cellulosic fibres is reactive dye. Bifunctional reactive dyes are often utilized because they are simple to use. Reactive dyes have a fairly straightforward structural makeup (Patel; Patel, 2010). Many unique structures have been found that are beneficial in commercial applications to wool, silk, and cotton as well as their mixes with other fibres, and the structural creation of new reactive dyes has been a topic of research (Manoj et al., 2022). Due to their formation of chemical bonds with the textile fibre, reactive dyes have high wet-fastness.

Reactive dyes are easy to wash out of the non-fixed areas, which are a prerequisite for dyeing and have an efficient use. They should be highly reactive, generate strong yields, and have created high levels of fixing, particularly in dyeing (Wei et al., 2019; Patel; Tandel, 2022). When o-anisidine was diazotized and coupled with different 4-(4'-methoxyphenyl)-6-phenylpyrimidin-2-ylamino cyanurated coupling components, the resulting monoazo reactive dyes were produced.

On silk, wool, and cotton fibres, these dyes produced a violet to yellow colour and demonstrated fair to good light fastness as well as good to exceptional fastness to washing and rubbing. These have been worn out and fixed colours are arranged extremely well. The triazine group in colour molecules makes the tiredness better (Patel et al., 2019). Several chromophores were utilised together with five monochloro-*s*-triazinyl reactive dyes and five m-carboxypyridium-*s*-triazinyl reactive dyes.

This study's major goal was a kinetic analysis of dyes, which revealed that the groups were in the following order: $-OCH_3$ > $-CH_2NSO_2CH_3$ > -N-methylphenyl > -NHCN > -OH. It has been shown that the rate of hydrolysis constant decreases with increasing electron donating value of the substituted on meta-position to the triazine ring (Hung; Wu, 2021).

2. Materials and Methods

All the mentioned chemical products came from commercial sources. Each and every other chemical employed in the synthesis was of a chemical grade. All application work of reactive dyes was done in DyStar Ankleshwar QC laboratory, Gujarat. The Spectrophotometer Data Colour 400 TM was used to measure colour. Maximum absorption (max) was measured using a UV Spectrophotometer SS 5100A Premier Colour scan.

2.1 Synthesis of coupling component

For two hours, 0.01 M L^{-1} solution of cyanuric chloride was stimulated in acetone at temperatures below 50 ºC. The pH of the cyanuric chloride solution was kept at 7 by adding sodium carbonate 20% (*w/v*) before adding 8-amino-1-naphthol-3,6-disulfonic acid (H-acid). For two hours, the mass reaction temperature is kept below 50 ºC. In an obvious solution, cyanurated H-acid is created. A well-stirred combination of cyanurated H-acid and cooled solution was heated to 45 ºC for second condensation. The reaction mass was agitated for three hours at 45 ºC as 4-amino-4-hydroxybenzilidene acetophenone was gradually added to the mixture. The pH of the reaction was kept neutral throughout this time using sodium carbonate solution. To perform a coupling reaction, this reaction mass is used.

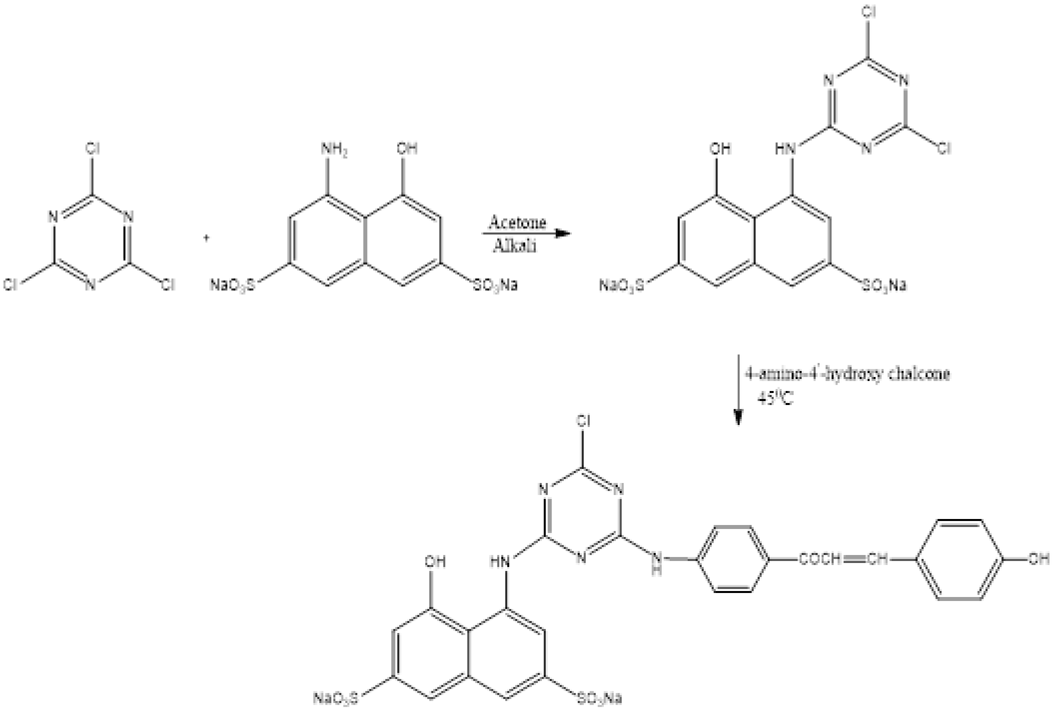

Figure 1. Cyanurated coupling component. Source: Authors, 2023.

2.2 Diazotization of o-anisidine

o-anisidine, 1.23 g (0.01 mol L^{-1}) was dissolved in 120 mL of water. Hydrochloric acid (1.09 g) was added dropwise to this vigorously stirred mixture. A clear solution was attained by progressively raising the mixture's temperature to 70 °C. The solution was chilled to 0 to 5°C in an ice bath. Five minutes of stirring were spent prior to adding a $NaNO_2$ solution (1.38 g in 8 ml of water that had been previously cooled to 0°C). A positive nitrous acid test on starch iodide paper was obtained after continuous stirring for an hour at the same temperature. After removing any excess nitrous acid by simply using the appropriate amount of a sulphamic acid solution. The next coupling step employed the diazo solution.

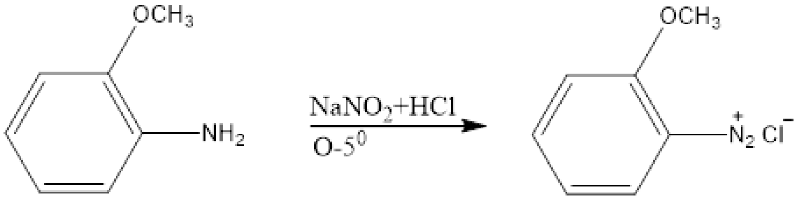

Figure 2. Diazotization of o-anisidine. Source: Authors, 2023.

2.3 Coupling Reaction

When the condensation product reached a temperature of 0 to 5 ºC, a freshly produced diazonium salt of o-anisidine was gently added. By adding sodium carbonate 10% (*w/v*) and keeping the mixture well-stirred for an hour at a temperature of 0 to 5 ºC, the pH of the mixture was kept at 7.5. Following the successful completion of the reaction, the synthesised dye was precipitated using potassium acetate 5% (*w/v*), the filtered product was then washed with ethanol, and dye Z1 (Figure 3) was then dried in an oven at 40 ºC.

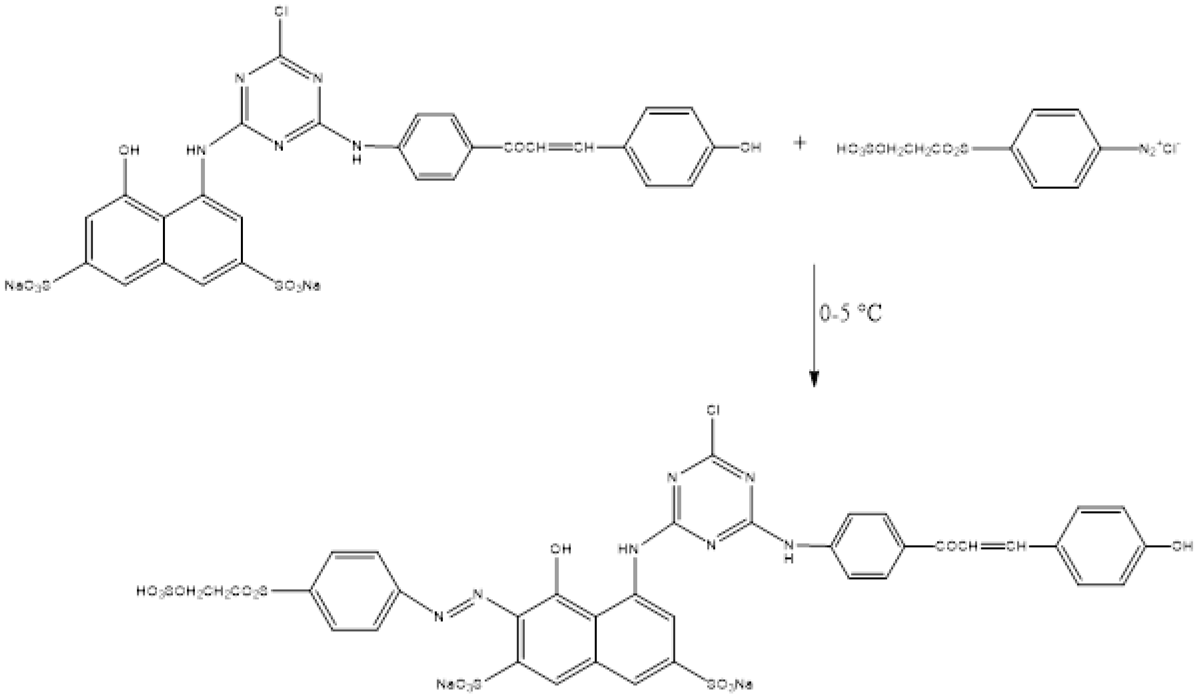

Figure 3. Reactive dyes Z1. Source: Authors, 2023.

Seven reactive dyes was synthesized with follow above reaction only change coupling component such as Gamma acid, J-acid, N methyl J-acid, N-phenyl J-acid, K- acid and peri acid. The structures of synthesized dyes are below…

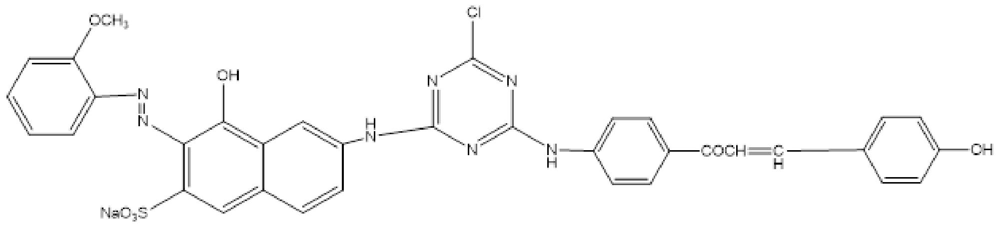

Figure 4. Reactive dyes Z2. Source: Authors, 2023.

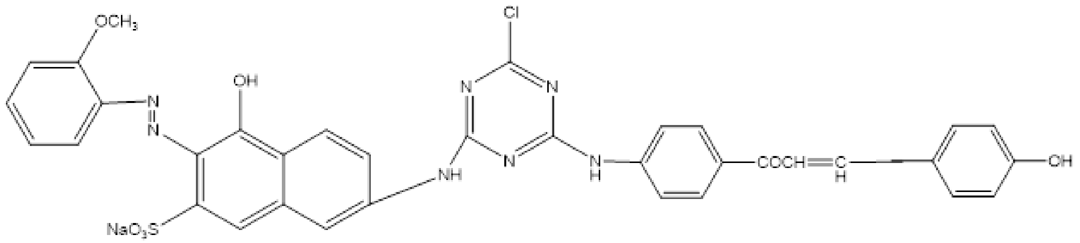

Figure 5. Reactive dyes Z3. Source: Authors, 2023.

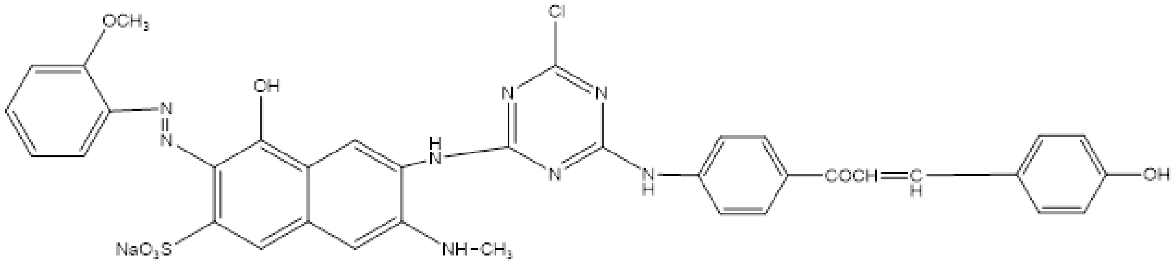

Figure 6. Reactive dyes Z4. Source: Authors, 2023.

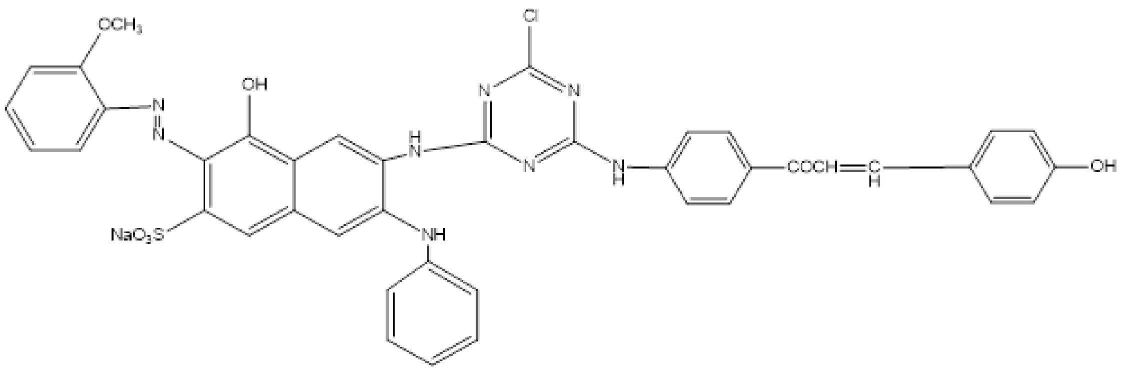

Figure 7. Reactive dyes Z5. Source: Authors, 2023.

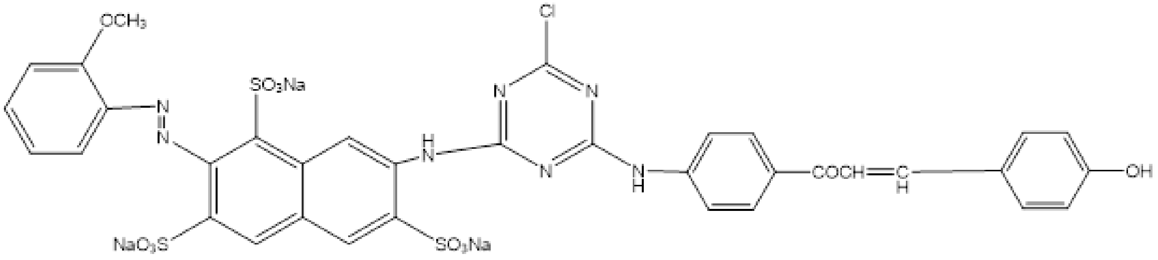

Figure 8. Reactive dyes Z6. Source: Authors, 2023.

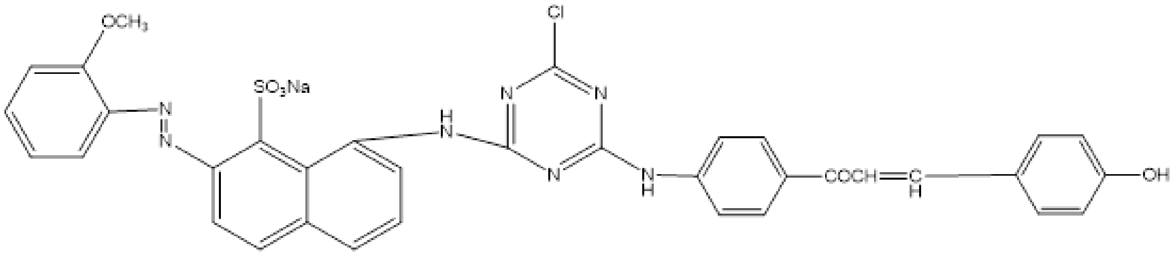

Figure 9. Reactive dyes Z7. Source: Authors, 2023.

2.4 Application test

All synthesized dyes were applied on silk, wool and cotton fabric with exhaust method, fastness properties of dyes were also evaluated. Equations 1 and 2 were used for Exhaustion and Fixation percentages.

$$\% \text{ Exhaustion } E = (Ao - At)/Ao \times 100\% \quad (1)$$

$$\% \text{ Fixation } F = (Ao - At - As)/Ao \times 100\% \quad (2)$$

Ao is the absorbance of initial dye bath, at is residue dye bath after dyeing and as is the absorbance of the soaping liquor.

3. Results and Discussion

3.1 Characterization

The visible absorption spectra, some standard IR spectra, and PMR spectra have all been used to characterise the synthesised dyes. All synthetic dyes have had their visual absorption spectra measured in water between the wavelengths of 550 and 383 nm. Each dye's colour is caused by the presence of substituent and electron oscillation. –N = N– stretching vibration of the azo group was at 1462 cm^{-1}, S = O stretching vibration of the -SO_3Na group was at 1180 and 1090 cm^{-1}, and C - Cl stretching vibration of the chloro group was at 716 cm^{-1}, according to the IR spectra of dye. The physical properties of reactive dyes describe in (Table 1).

Table 1. Characterization of reactive dyes.

Dye No	**Molecular Formula**	**Mol. Wt. (g/M)**	**Yield %**	**% of nitrogen**		**R_f value**
				found	**required**	
Z1	$C_{35}H_{24}ClN_7Na_2O_{10}S_2$	848.17	87	11.45	11.56	0.31
Z2	$C_{35}H_{25}ClN_7NaO_7S$	746.11	84	13.01	13.14	0.43
Z3	$C_{35}H_{25}ClN_7NaO_7S$	746.11	87	13.09	13.14	0.42
Z4	$C_{36}H_{28}ClN_8NaO_7S$	775.17	84	14.32	14.46	0.36
Z5	$C_{41}H_{30}ClN_8NaO_7S$	837.24	87	13.24	13.38	0.41
Z6	$C_{35}H_{23}ClN_7Na_3O_{12}S_3$	934.21	85	10.42	10.50	0.32
Z7	$C_{35}H_{25}ClN_7NaO_6S$	730.13	75	13.31	13.43	0.37

Source: Authors, 2023.

3.2 Application

The degree of dye transfer from the dye bath to the fibre is referred to as exhaustion, and it is often stated as a percentage of the dye that was first added to the dye bath. High levels of weariness and focus are needed for environmental and economic reasons. Fixation of dye refers to how much dye has been incorporated into the fibre of textile products.

Triazine has been utilized to interact with cellulose fibres as a reactive component (Saeed; Shabi, 2018). The structure of dyes containing polar groups, which create physical and chemical interactions with fibres, is in agreement with good exhaustion and fixation values of dyes. The fixation value of synthesized dyes Z1-Z7 were 65-94% and Exhaustion values of dyes were 65 to 92% which shows in (Figure 10 and 11). All dyes have good fixation on silk, wool and cotton fabric.

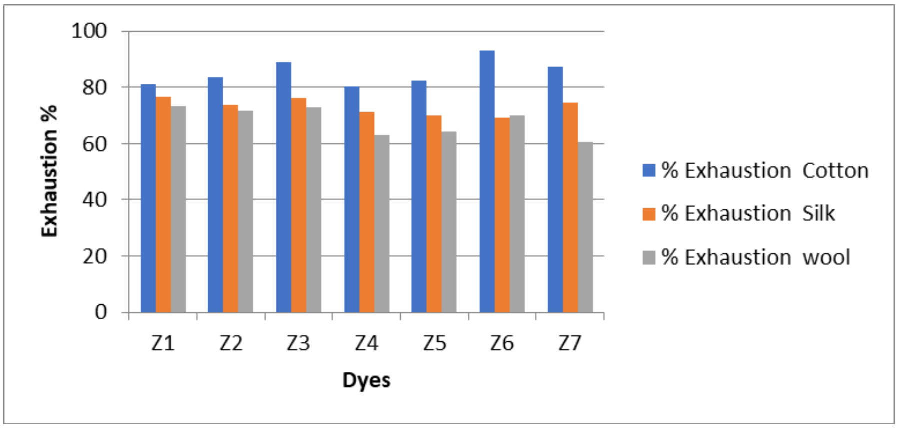

Figure 10. Exhaustion % of dyes. Source: Authors, 2023.

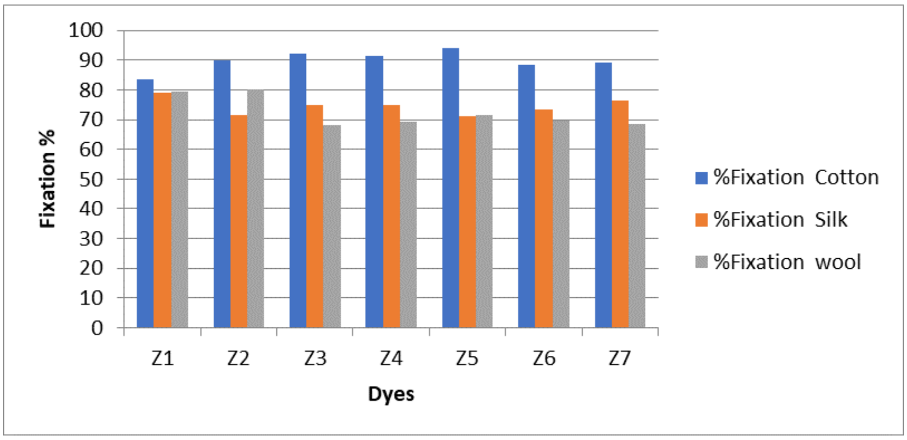

Figure 11. Fixation % of dyes. Source: Authors, 2023.

3.3 Fastness properties

The ability of coloured fibres to resist fading when washed with soap and other cleaning agents is known as wash fastness. The test measures how the fabric's colour changes as well as how the colour of the next cloth is stained. The colours' wash fastness ranged from 3 to 5. The degree to which a dye resists fading as a result of exposure to light is known as light fastness.

The resistance of various colours to light fading varies to varying degrees. All dyes have strong light fastness in the 3-4 range. Colour Fastness to rubbing is a primary test that is always necessary for any coloured cloth, whether printed or dyed. The wash fastness was evaluated using a 5 g L^{-1} standard soap solution at 40 °C for 30 min in accordance with GB/T 3921-2008. Light fastness qualities were examined using a Q-SUN Xe-1-Bxenon light fastness equipment in accordance with BS 1006 1990 B02. Colour shifts all coloured and dyed samples were examined. Visually, Machine Paramount Colour Machin is used. The rubbing fatness of synthesised dyes was evaluated.

Atlas Crock Metre the purpose of rubbing fastness was to assess the amount of colour transfer from the surface of a coloured fabric to a designated test cloth for rubbing. The rubbing fastness of all colours was 3-5.The fastness properties of dyes shows in (Table 2).The azo dyes containing H-acid have high chromophore stability because the chromophoric group executes to the azo-hydrozone tautomerism, which allowed responsible for photo-effect stability. Because of the tight link between dye molecules and fibre, the stability of reactive dye increased when exposed to light.

The transfer of energy from departed dye molecules to fibre also boosted the stability of reactive dye. Because vinyl sulphone is acid stable and CT (Choloro triazine) is alkali stable, it has strong wet fastness properties.The solubility of synthesized dyes was good gives high fastness properties of dyes.Whashing fastness was depends on fixation of reactive dyes sythesized dyes have good fixation value, so problem of waste water is minimum (Karacakaya et al., 2009; Habibah et al., 2017; Patel et al., 2021; Patel et al., 2023; Patel et al., 2023).

Table 2. Fastness properties.

Dye	**Light Fastness**			**Wash Fastness**			**Rubbing Fastness**					
							Wet			**Dry**		
	C	**W**	**S**	**C**	**W**	**S**	**C**	**W**	**S**	**C**	**W**	**S**
Z1	4	3	5	4	4	4	4	3	4	5	3	4
Z2	4	4	4	5	3	4	4	3	5	5	4	4
Z3	3	3	4	4	4	4	3	4	5	5	3	4
Z4	4	3	3	4	4	4	4	3	4	4	3	4
Z5	3	4	4	4	3	4	3	3	4	4	4	4
Z6	4	3	4	4	3	4	3	4	4	4	3	4
Z7	3	4	3	4	4	4	4	4	3	4	4	4

Note: C = Cotton. W = Wool. S = Silk. Light fastness: 1 - Poor; 2 - Alight; 3 - Morderate; 4 - Fair; 5 - Good; 6 - Very Good; 7 - Excellent and 8 - Maximum. Wash and Rubbing fastness: 1 - Poor; 2 - Fair; 3 - Good; 4 - Very Good and 5 - Excellent. Source: Authors, 2023.

4. Conclusions

Diazotized o-anisidine was coupled with several 4-amino-4’-hydroxy benzilidene acetophenone cyanurated coupling component including H-acid, Gamma acid, J-acid, N-methyl J-acid, N-phenyl J-acid, K- acid and peri acid, to create a variety of monoazo reactive dyes. These dyes produced a violet to yellow hue on silk, wool, and cotton fibres. All of these dyes dyed with moderate to good light fastness, good to exceptional wash fastness, and rubbing fastness on varied fabrics. The triazine group of the dye molecule increases its exhaustion, fixing, and fastness characteristics. Thus, these dyes' depletion and fixing are quite good in order.

5. Acknowledgments

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6. Authors’ Contributions

Manoj J. Patel: project structuring, writing, corrections and submission. *Ramnik C. Tandel*: corrections. *Srujal A. Sonera*: writing, and *Sagar K. Bairwa*: writing and corrections.

7. Conflicts of Interest

No conflicts of interest.

8. Ethics Approval

Not applicable.

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