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Application of Low Temperature Microwave Assisted System for Color Removal of Cotton Fabric Dyed with Reactive Black Cotton Fabric

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Abstract

In the textile industries, dyes are used to color the cotton fabric in order to enhance the beauty and to fulfill the basic need of mankind. In the present research work microwave absorber was used in a microwave system for stripping of reactive dyed cotton fabric at low temperature for the development of a cost-effective method. Ice was used during the procedure in order to maintain the low temperature of the reductive solution of NaOH and $Na_2S_2O_4$. The experiment was performed with different concentrations of reductive solution (10 g/L, 15 g/L, and 20 g/L) and different material-to-liquid ratios (1:40, 1:60, and 1:80) for different time intervals (20, 40, 60, 80, and 100 seconds). The maximum stripping percentage calculated was 31.85% for 20 g/L in 1:40 for 100 seconds. The efficiency of stripping parameters like color strength and color coordinates was analyzed by some spectroscopic techniques like spectra flash spectrophotometer. The quality assurance properties of stripped cotton fabric were evaluated by tear and tensile strength, redye ability, and absorbency of cotton fabric. The obtained results were statistically analyzed by mean and standard deviation.

Introduction

Colour is one of the natural aspects that make life in universe so fascinating and attractive. Colourants are used in many industries, including clothes, paints, plastics, photographs, prints, and ceramics (Popli and Patel, 2015). Dyes and pigments are the two categories of colorants (Gürses *et al.*, 2016). A dye is essentially a coloured material that binds to the substrate on which it is applied. Dye is applied in an aqueous solution, which necessitates the addition of a mordant to improve the dye's fastness to the textile fiber (Fariha *et al.*, 2025). A dye is a coloured chemical that is coloured due to the presence of a chromophore as well as its fixed property to acidic and basic groups such as SOH, OH, NR, NH_2, and so on (Simmons, 2021). Textile dyes are of two types: natural and synthetic (dos Santos *et al.*, 2004).

In most cases, adsorption and diffusion are involved in the colouring process (Lim *et al.*, 2010). Printing is similar to partial dying with different colors on cloth to create an appealing pattern (Shang, 2013). In 1876 Otto Witt, a German scientist proposed that the colour of a dye is due to the presence of certain groups with multiple bonds known as chromophores (Mani and Bharagava, 2018). Nitro groups ($-NO_2$), nitroso groups (-NO), carbonyl groups (-CO-), ethylenic bonds (-C=C), acetylenic bonds, and other chromophores are examples. The hue of a dye intensifies as the number of chromophores rises (Papadakis, 2021). Acid dyes are anionic, water-soluble dyes and are used to colour nylon, silk, wool, and modified acrylic fibres (Chakraborty, 2010). Basic dyes are cationic, water-soluble colours are typically applied to acrylic fibres but can also be used to colour paper, wool, and silk (Berradi *et al.*, 2019). In general, they can be described as chromophores that have these pendant groups (Kariyajjanavar *et al.*, 2010).

Textile dyeing frequently employs reactive dyes. Reactive dyes can successfully colour the following fibres: Silk and acetate fibres, as well as cotton, rayon, flax, and other cellulosic fibres, can also be used to make paper (Adeel *et al.*, 2017). Stripping is a common technique used to fix poor dyeing, faulty or uneven dye, and color patches from the fabric surface (Uchimaru *et al.*, 2013). The proportion of reaction dyes removed from cotton fabric is improved by increasing chemical concentration and temperature, although processing losses to the fabric, such as reductions in strength, weight, and tearing resistance rating, occur (Uddin and Islam, 2015). Reductive stripping has a specific mechanism depending on the type of dyes, fibres and reducing agents (Määttänen *et al*., 2019). The stripping assistant increases the reducing agent's ability to remove dyes (Chung *et al*., 2004). Microwaves are electromagnetic waves that have wavelengths between 1 mm and 1 m and frequency between 300 MHz and 300 GHz, durations between 1 nanosecond and 3 picoseconds and photon energies between 1.2 106 eV and 1.2 103 eV. Electromagnetic (EM) waves that are impinging on materials will interact with them through reflection, absorption, and transmission. In comparison to traditional stripping processes, microwave-assisted stripping provides several advantages (Robinson *et al.*, 2008). Microwaves affect the atomic structure of materials as well as any conduction electrons and magnetic dipoles that may exist (Xia *et al*., 2013). Since microwaves are known for their quick and efficient results. Microwave usage was found to reduce the amount of time needed for chemical and water pretreatment (Pang *et al.*, 2021).To improve the efficiency of microwave-assisted stripping, microwave observers are designed to meet the requirements of strong absorption, a broad frequency band, lightweight and a thin thickness (Uddin *et al.*, 2015). Microwave absorbers considerably reduce the electromagnetic wave elasticity throughout a wide absorption bandwidth (Ibrahim *et al.*, 2020). In addition to enhancing the colour fastness capabilities of cotton fabrics, microwave treatment also improved the dyeing behavior of cotton fabric's (Ulloa *et al*., 2019).

METHODOLOGY

Material to liquor ratio

The ratio of fabric mass (mostly in gram) to color resolution volume (mostly in ml) is known as Material to liquor ratio and is very important for dyeing of fabric. Material to liquor ratio was kept 1:30 throughout the dyeing process. 25ml of dye solution is required for dyeing of 1 gram fabric.

Salt Requirement

Sodium sulfate (Na_2SO_4) was used as a salt during dyeing of fabric with reactive dyes. It increases the accessibility of cellulose sites to the dye by decreasing the solubility of reactive dyes in water. The amount of salt required can be calculated by following formula:

$$\text{Salt} = \frac{\text{Req.wt of salt for specific shade} \times \text{wt of material} \times \text{M:L ratio}}{1000}$$

Alkali or Base requirement:

Sodium carbonate (Na_2CO_3) is used as an alkali during dyeing process, as it changes the pH of reactive dye and cellulose fiber, making a permanent connection that binds dye to fiber. Following formula is used to calculate the alkali requirement:

$$\text{Alkali} = \frac{\text{Req.wt of alkali for all shade} \times \text{wt of material} \times \text{M:L ratio}}{1000}$$

Dye Necessity

For 1gram, 2gram and 4gram fabric dyeing, amount of dye requirement can be calculated by following formula:

$$\text{ml} = \frac{\text{gram of fabric} \times \text{\% shade}}{\text{stock solution}}$$

1ml = 0.01g

1ml dye was dissolved in 100ml of water, in order to formulate 1% of standard (stock) solution.

Dyeing

For dyeing process exhaust method was used in the dyeing machine. Sample was dyed with 2% shade of reactive black dye. Fabric dyeing with reactive dyes involves following mechanism:

1. First of all, after exhaustion the dye was absorbed in dyeing bath where electrolyte is present.
2. In the next step alkali helps in fixing the dye into the fabric and then unfixed dye is removed by several washes.

Dyeing of fabric with synthetic dyes

The dyeing of cotton fiber having definite superiority with reactive dyes was approved by using optimized conditions (Shu *et al*., 2018). Colorimetric data such as shade strength in the terms of color coordinates and K/S value was obtained by using spectra flash spectrophotometer (Ogulata and Balci, 2007).

Colour strength and colour stripping percentage measurements

The following equation was used to calculate the K/S values. Each sample's measurements were taken from four different locations to ensure consistency. In order to obtain the average value, measurements were taken twice from each region (Eren *et al.*, 2016).

$$\text{Striping Percentage} = \frac{\frac{K}{S}\text{ value before stripping} - \frac{K}{S}\text{ value after stripping}}{\frac{K}{S}\text{ value before stripping}} \times 10$$

Chemical Stripping

Numerous operating factors, including as the type of reducing agent and oxidising agent, their concentration, temperature, and stripping duration, were optimized in order to study their distinct effects on the process of stripping.

Chemicals for stripping

The following chemicals were used in the stripping process:

1. Reactive black Dyed fabric
2. Sodium Hydroxide (NaOH)
3. Sodium dithionate ($Na_2S_2O_4$)
4. Distilled water

Optimization of stripping process

Microwave assisted stripping treatment was used during chemical stripping process. The whiteness index of fiber, stripping efficiency values in terms of K/S value was obtained from Spectra Flash spectrophotometer and then evaluation was done with conventional techniques (Chatha *et al*., 2014).

Experiments for Reductive stripping

To execute reductive stripping, a solution of sodium dithionite and sodium hydroxide was applied to the textile fabrics. This mixture was used to remove impurities and unwanted colours from the cloth while also reducing the likelihood of harming it (Alam *et al*., 2023).

Preparation of 10g/L reductive solution

After each microwave heating cycle, the temperature of the reductive solution was kept constant at 5°C. In order to prevent a rise in solution temperature above that of room temperature, or 27 °C, the heating cycle was limited to a maximum of 10 seconds. The experiment was run at a low temperature the entire time to investigate how microwave radiation and low temperatures impact fabric stripping. Five different time intervals of

20s, 40s, 60s, 80s and 100s were used to heat the flask in the microwave while stirring continuously.

Experiment (A_6-A_{10})

The reductive solution was submerged in an ice bath to cool it to 5°C in order to investigate how temperature and microwave radiation affected the fabric's ability to be stripped. The flask was heated in the microwave with constant stirring five times at intervals of 20 seconds, 40 seconds, 60 seconds, 80 seconds and 100 seconds.

Experiment (A_{11}-A_{15})

The reductive solution was cooled to a temperature of 5 °C by being placed in an ice bath, where it remained for the duration of the experiment. The sample was added to the cooled reductive solution, and the flask was heated in a microwave for five different times 20, 40, 60, 80 and 100 seconds while being constantly swirled. The fabric was tenderly cleaned in both hot and cold water after the treatment, and then air dried.

Experiment B (B_1-B_5)

15 g/L solution preparation

Experiment B also employed three different materials-to-alcohol ratios. The fabric samples were exposed to the reductive solution in the microwave at various intervals. In the first experiment, 1g of reactive black-dyed cloth was treated in a flask with 40 mL of reductive solution at a material-to-liquor ratio of 1:40. In order to prevent a rise in solution temperature above 27 °C, the heating cycle was kept to a maximum of 10 seconds. The flask was heated in the microwave at five intervals of 20s, 40s, 60s, 80s and 100s while being stirred continuously.

Experiment B (B_6-B_{10})

To test the effects of temperature and microwave radiation on the stripping of the fabric, the reductive solution was cooled to 5°C by submerging it in an ice bath. At this temperature, the experiment was carried out. Continually stirring, the flask was heated in the microwave at intervals of 20 seconds, 40 seconds, 60 seconds, 80 seconds, and 100 seconds. The fabric was then meticulously cleaned with both hot and cold water and allowed to air dry.

Experiment B_{11}-B_{15}

The material-to-liquor ratio for the 15 g/L final test was 1:80. In this process, 80 mL of the reductive solution was used to treat 1g of reactive black-colored cotton material. After cooling the reductive solution, the sample was added. The flask was then cooked in a microwave for five different amounts of time: 20, 40, 60, 80 and 100 seconds with continuous stirring. The fabric was then washed and air-dried.

Experiment C (C_1-C_5)

20 g/L solution preparation

In the first experiment, 1g of reactive black-dyed fabric was subjected to a 40 mL reductive solution treatment in a flask at a material-to-liquor ratio of 1:40. The heating cycle was capped at 10 seconds to keep the solution temperature from exceeding 27 °C (room temperature). Five intervals of 20, 40, 60, 80 and 100 seconds each were used to cook the flask in the microwave.

Experiment (C_6-C_{10})

In the next experiment, a flask was used to expose 1g of reactively black-dyed cotton cloth to 60 mL of reductive solution at a ratio of 1:60. The reductive solution was chilled to 5°C in an ice bath in order to study the effects of temperature and microwave radiation on the stripping of the fabric. During the experiment, this temperature was employed. The flask was cooked in the microwave with constant swirling at intervals of 20 seconds, 40 seconds, 60 seconds, 80 seconds, and 100 seconds.

Experiment (C_{11}-C_{15})

By submerging the reductive solution in an ice bath, a temperature of 5 °C was achieved that remained constant throughout the experiment. The sample was added after the reductive solution had cooled. The flask was then heated in the microwave for five successive intervals of 20 seconds, 40 seconds, 60 seconds, 80 seconds, and 100 seconds while being constantly swirled.

Experiment D

Another series of experiments were created to examine the impact of cold therapy. In these tests, fabric was cold-pretreated (under the same circumstances as for sample 35). Then, this fabric was put through four different experimental setups.

Experiment $D_{1\text{-}2}$: Effect of conditions of sample 35 on cold pretreated sample

The unprocessed fabric was initially cold stripped using a 20 g/l reductive solution in a 1: 40 fabric-to-liquid ratio for 100 seconds in microwave. This cold pretreated fabric was then heated without any cold treatment in microwave using the same conditions as for the cold treated fabric i.e, 20 g/l solution of 1:40 ratio until the fabric was stripped to raw white one. Another cold pretreated fabric was stripped conventionally in same 20 g/l reductive solution of 1:40 M: L ratio until the fabric was completely stripped.

Experiment $D_{3\text{-}4}$: Effect of optimized conditions on cold pretreated sample

During the optimized microwave stripping the cold pretreated fabric was heated directly in microwave using a solution of 25 g/l of NaOH + 75 g/l of $Na_2S_2O_4$ in 1:40 fabric-to-liquid ratio. The D_4 experiment was performed on cold pretreated fabric under optimized conventional method. The solution of 20 g/l NaOH + 30 g/l of $Na_2S_2O_4$ in 1:30 M:L was used. The duration for complete stripping was observed carefully.

Experiment E

Firstly the reactive black dyed fabric was pretreated with 40ml of 20 g/L reductive solution for 100 seconds (with intervals in order to maintain temperature). This microwave assisted cold pretreated sample was then treated with 30ml of $Na_2S_2O_4$ (75g/L) NaOH (25 g/L) solution for 120 seconds in microwave oven (heated directly). Maximum stripping happens by this way.

Experiment F: (F_1-F_{12}) Effect of different concentrations of reductive solution (75%, 50%, 25%) on cold pretreated samples

The unprocessed fabric was initially cold stripped using a 20 g/l reductive solution in a 1: 40 fabric-to-liquid ratio for 100 seconds in microwave. This cold pretreated fabric was then heated without any cold treatment in microwave using the same conditions as for the cold treated fabric i.e, 20 g/l solution of 1:40 ratio until the fabric was stripped to raw white one. Another cold pretreated fabric was stripped conventionally in same 20 g/l reductive solution of 1:40 M: L ratio until the fabric was completely stripped.

Experiment G: Conventional reductive stripping

Firstly the sample was pretreated with 40ml of 20 g/L reductive solution in microwave for 100s (with certain time intervals for maintaining temperature). The solution used for conventional reduction contains NaOH (20g) and sodium dithionate (30g). The pretreated sample was then immersed into 30ml of this solution in a beaker. The sample was then heated for 100 seconds on a hot plate. Then the samples were dried at room temperature and labeled properly.

Stripping percentage

The results of the experiments were calculated in terms of k/s value. K/s values of both stripped and dyed fabrics were obtained by Spectra flash spectrophotometer. Stripping efficiency was then calculated by following formula:

$$\text{Striping Percentage} = \frac{\frac{K}{S}\text{ value before stripping} - \frac{K}{S}\text{ value after stripping}}{\frac{K}{S}\text{ value before stripping}} \times 100$$

Redyeing

Before redyeing, the exhaust method was employed (Wang *et al*., 2018). 0.6 grammes of Na_2SO_4 and yellow reactive dye were used to make a 1% dye solution for this purpose. 1.5 grammes of Na_2CO_3, 1 gramme of fabric, and 30 ml of dye solution. The dyeing machine maintained a steady temperature of 65°C within the dyeing cell for over an hour.

Quality Assurance Test

The strength of the fabric under tension, the whiteness index, the capacity to redye it, the weight loss of the fabric, and the absorbency was all is used to evaluate the quality of stripped cloth (Shamey, 2009).

Neutralization of treated fabric

The neutralization and soaping of the treated fabric was carried out after application of various oxidative and reductive stripping methods (Rashid *et al*., 2020).

Statistical analysis

The data was statistically analyzed by mean standard deviation to observe the variations among different treatments (Pirsaheb *et al*., 2018).

RESULTS AND DISCUSSION

Calorimetric analysis of dyed fabric

Table 1: Calorimetric values of reactive black dyed cotton fabric

Dye	K/S	L*	a*	b*	c*	H
Reactive black dye	7.6898	32.24	-0.58	-3.66	3.70	261

Effect of Microwave-assisted cold stripping using 10 g/L of reductive solution

In spite of the fact that many reducing, stripping, and chemical combinations are used, sodium hydroxide and sodium dithionate were used in this investigation as reducing agents when microwaved (Chung *et al.,* 2004). The experiment lasted up to 100 seconds, during which time the K/S value was assessed using a Spectra-Flash spectrophotometer (SF-600).

Table 2: Stripping of Black dye using 10g/L reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
A_1	20				6.899	10.28
A_2	40				6.718	12.63
A_3	60	10	10	7.6898	6.9958	9.02

A_4	80				6.7233	12.56
A_5	100				7.1616	6.86

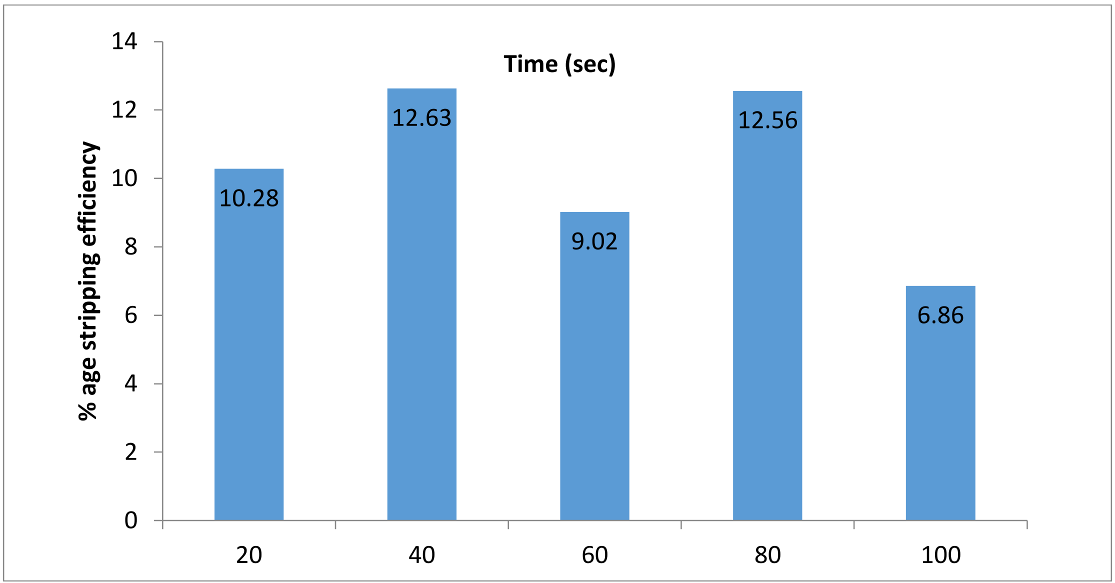

Figure 2: % stripping efficiency values using 10 g/L of reductive solution with 1:40 M : L

Inference

It is noted that at 40 second the stripping percentage is 12.63 which is highest among these samples. There is lack of trendy behavior because of migration (uneven dyed fabric). There is no observable effect of time on the stripping efficiency of samples.

Table 3: Stripping of Black dye using 10g/L reductive solution with 1:60 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
A_6	20	10	10	7.6898	7.4612	2.97
A_7	40				6.824	11.25
A_8	60				6.0771	20.97
A_9	80				6.6981	12.89
A_{10}	100				6.7948	11.638

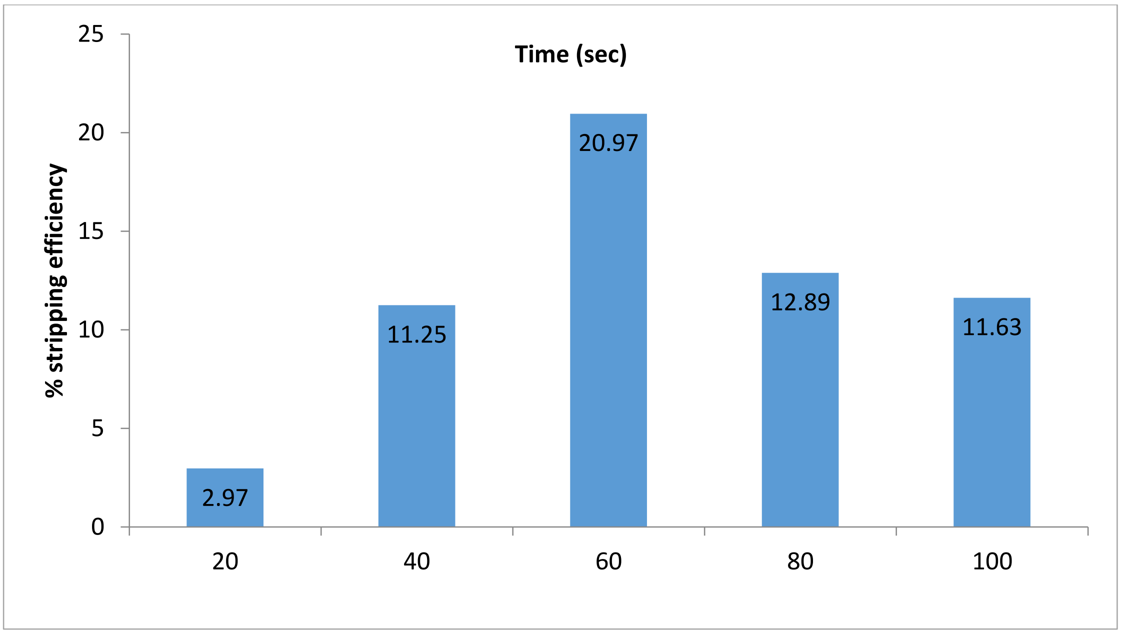

Figure 3: % Stripping of black dyed fabric using 10 g/L reductive soln. with 1:60 M: L

Inference

Alkali hydrolysis is not as efficient at stripping as the alkali reductive technique. Additionally, sodium dithionite disperses azole groups (Krigstin and Sain, 2006). Following studies' K/S values and stripping efficiency values showed that there was hardly any stripping. Rarely did samples have negative stripping percentages. A logical explanation for this peculiar behaviour is the movement of loose colour over fabric.

Table 4: Stripping of Black dye using 10g/L reductive solution with 1:80 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
A_{11}	20	10	10	7.6898	6.9091	10.15
A_{12}	40				6.4421	16.22
A_{13}	60				6.6767	13.17
A_{14}	80				6.7342	12.42
A_{15}	100				6.2554	18.65

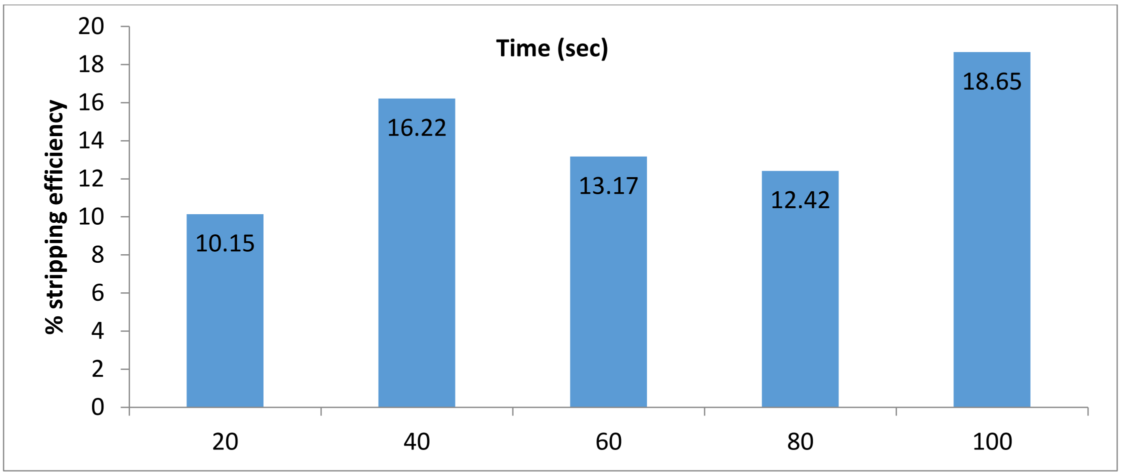

Figure 4: % stripping efficiency of black dyed fabric using 10 g/L reductive soln. with 1:80 M: L

Inference

Additionally, the dye's light and dazzling effect has an impact on the K/S measurements of the Spectra Flash Spectrophotometer. Bright and light colours look dull in a spectrophotometer. The percentage of stripping during this cold stripping process shows no discernable trend.

Table 5: Stripping of Black dye using 15g/L reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
B_1	20	15	15	7.6898	6.7143	12.68
B_2	40				6.8026	11.53
B_3	60				6..8453	10.98
B_4	80				6.8943	10.34
B_5	100				7.4713	2.84

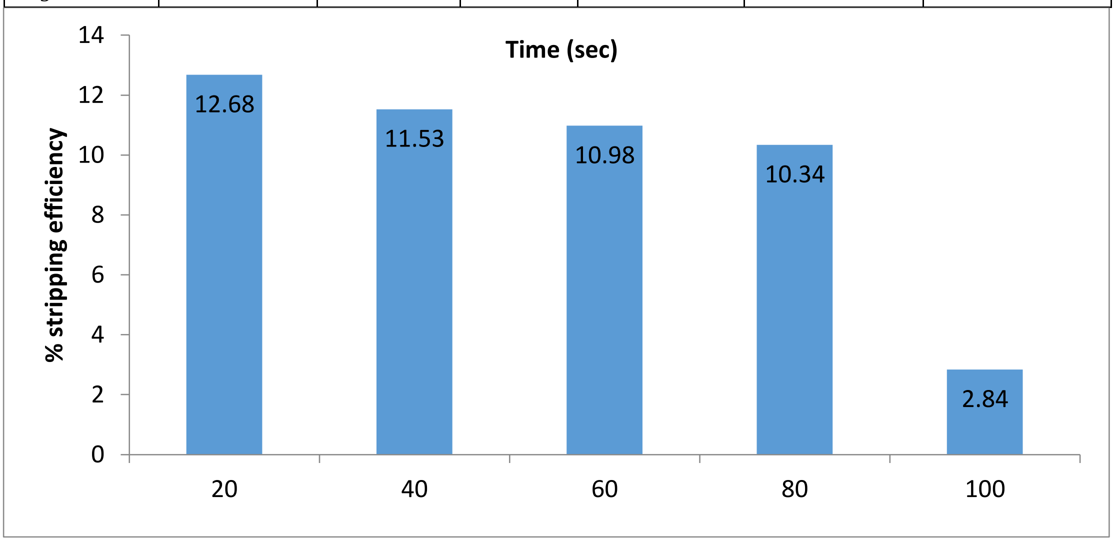

Figure 5: % Stripping of black dyed fabric using 15 g/L reductive soln. with 1:40 M: L

Inference

It is noted that at 20 second the stripping percentage is 12.68 which is highest among these samples. There is lack of trendy behavior because of migration (uneven dyed fabric). There is no observable effect of time on the stripping efficiency of samples. Using the K/S value acquired from the Spectra Flash Spectrophotometer, the effect of cold treatment on fiber was evaluated. Following studies' K/S values showed that there was hardly any stripping.

Table 6: Stripping of reactive Black dye using 15g/L reductive solution with 1:60 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
B_6	20	15	15	7.6898	6.7250	12.54
B_7	40				7.5311	2.96
B_8	60				6.7522	12.19
B_9	80				7.2595	5.59
B_{10}	100				6.4000	16.77

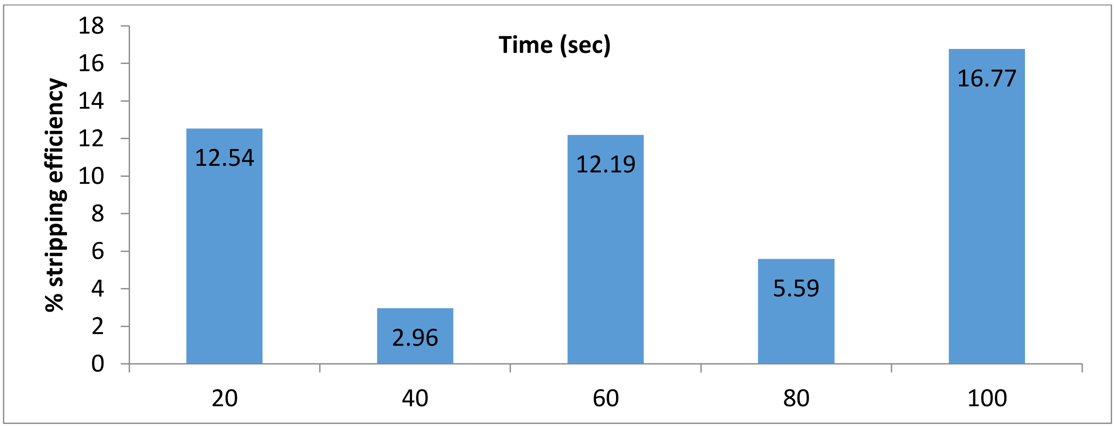

Figure 6: % Stripping of black dyed fabric using 15 g/L reductive soln. with 1:60 M: L

Inference

Following studies' K/S values showed that there was hardly any stripping. Rarely did samples have negative stripping percentages. A logical explanation for this peculiar behavior is the movement of loose colour over fabric. The percentage of stripping during this cold stripping process shows no discernable trend.

Table 7: Stripping of reactive Black dye using 15g/L reductive solution with 1:80 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
B_{11}	20	15	15	7.6898	7.1522	6.99
B_{12}	40				6.5621	14.66
B_{13}	60				7.4381	3.27
B_{14}	80				7.2664	5.50
B_{15}	100				6.8593	10.80

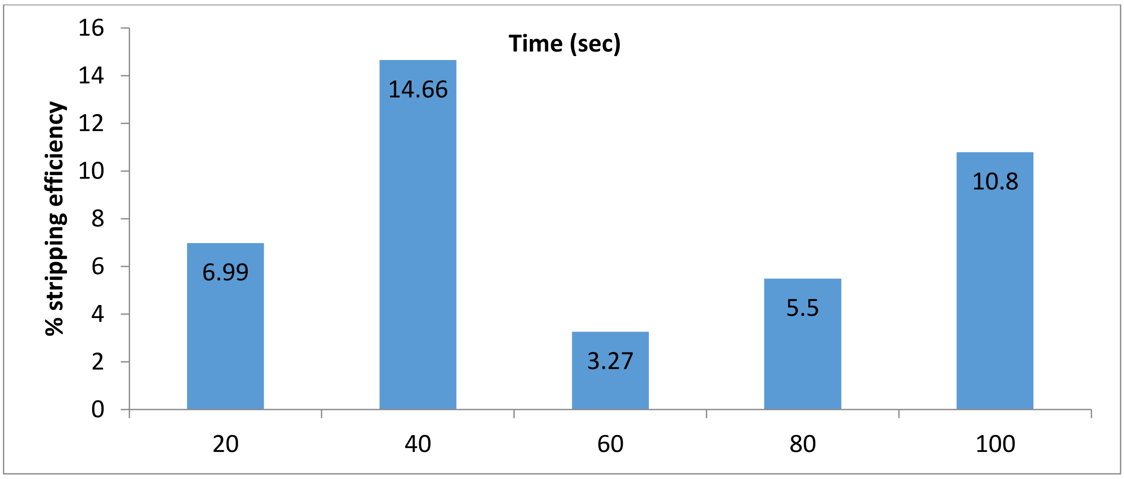

Figure 7: % Stripping of black dyed fabric using 15 g/L reductive soln. with 1:80 M: L

Inference

Using the K/S value acquired from the Spectra Flash Spectrophotometer, the effect of cold treatment on fabric was evaluated. Following studies' K/S values showed that there was hardly any stripping. Rarely did samples have negative stripping percentages. A logical explanation for this peculiar behavior is the movement of loose colour over fabric. The percentage of stripping during this cold stripping process shows no discernable trend.

Table 8: Stripping of reactive Black dye using 20g/L reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
C_1	20	20	20	7.6898	7.3415	4.52
C_2	40				6.0938	20.75
C_3	60				6.8790	10.54
C_4	80				7.2089	6.25
C_5	100				5.2405	31.85

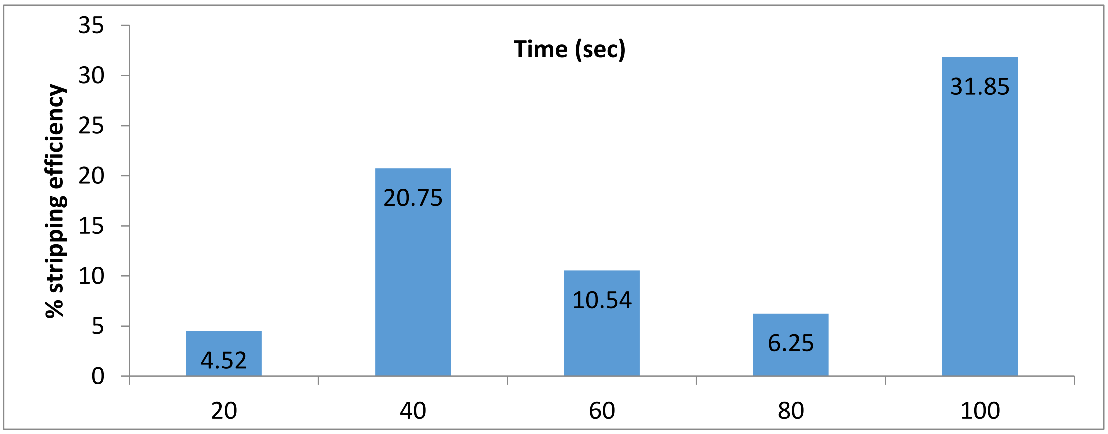

Figure 8: % Stripping of black dyed fabric using 20 g/L reductive soln. with 1:40 M: L

Inference

There is no observable effect of time on the stripping efficiency of samples. Using the K/S value acquired from the Spectra Flash Spectrophotometer, the effect of cold treatment on fabric was evaluated. Following studies' K/S values and stripping efficiency values showed that there was hardly any stripping. Rarely did samples have negative stripping percentages. The percentage of stripping during this cold stripping process shows no discernable trend.

Table 9: Stripping of reactive Black dye using 20g/L reductive solution with 1:60 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
C_6	20	20	20	7.6898	6.9331	9.84
C_7	40				6.3966	16.81
C_8	60				7.2130	6.20
C_9	80				6.8777	10.56
C_{10}	100				6.7631	12.05

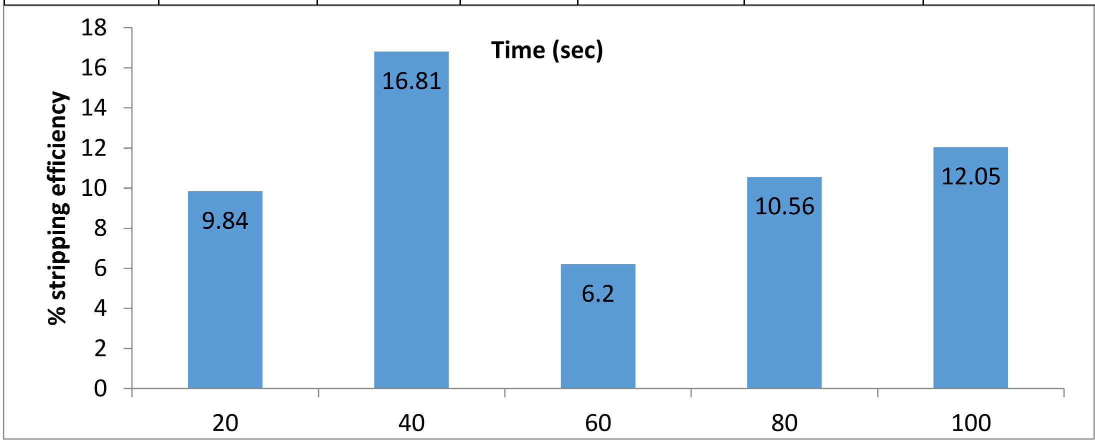

Figure 9: % Stripping of black dyed fabric using 20 g/L reductive soln. with 1:60 M: L

Inference

Using the K/S value acquired from the Spectra Flash Spectrophotometer, the effect of cold treatment on fabric was evaluated. Following studies' K/S values showed that there was hardly any stripping. Rarely did samples have negative stripping percentages. A logical explanation for this peculiar behaviour is the movement of loose colour over fabric. The percentage of stripping during this cold stripping process shows no discernable trend.

Table 10: Stripping of reactive Black dye using 20g/L reductive solution with 1:80 M: L under different time intervals in microwave

Exp. No.	Time (sec)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
C_{11}	20	20	20	7.6898	6.2972	18.10
C_{12}	40				6.7733	11.91
C_{13}	60				6.8652	10.72
C_{14}	80				7.1003	7.66

C_{15}	100				7.4800	2.72

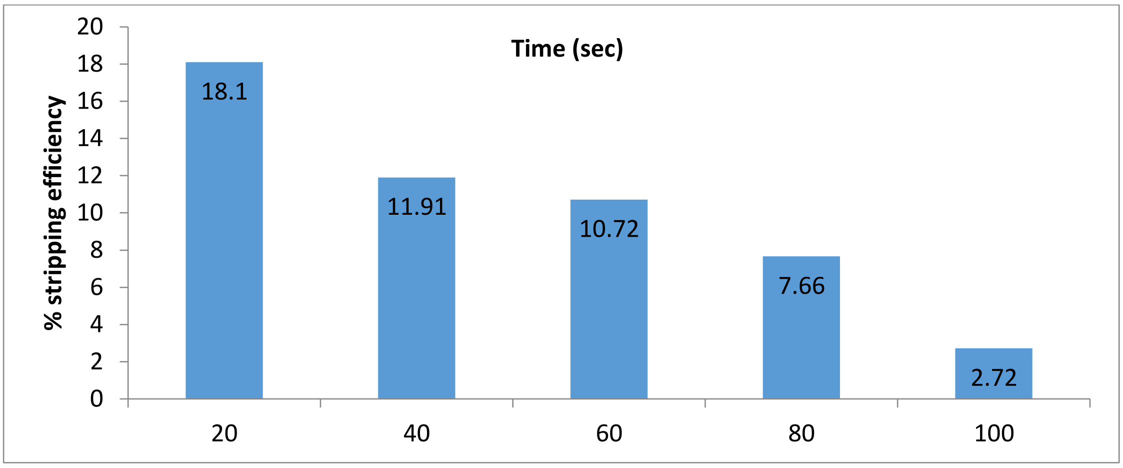

Figure 10: % Stripping of black dyed fabric using 20 g/L reductive soln. with 1:80 M: L

Inference

Each sample responded randomly to the concentration. Sample C_5 had the highest stripping efficiency out of the 45 trials that were run, and the settings for the next sample were then further chosen as the optimal conditions for further examining the outcomes of cold microwave assisted stripping.

Table 11: Stripping of reactive Black dye using 75% reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (mint.)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
F_1	3	15	15	7.6898	0.0748	99.02
F_2	15				0.079	98.90
F_3	10				0.0719	99.06
F_4	3				0.0849	98.8

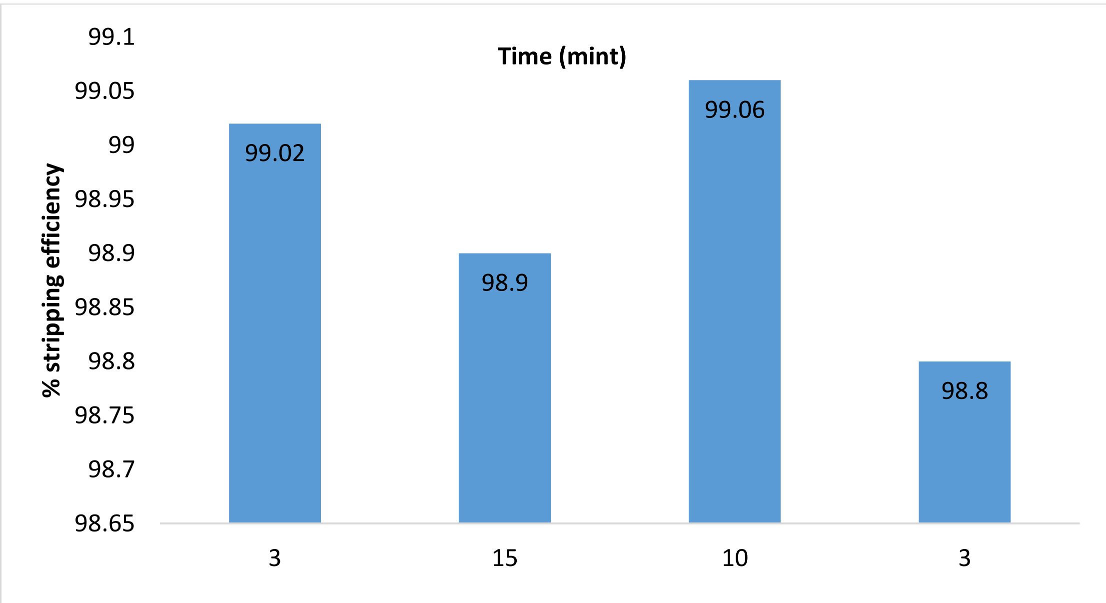

Figure 11: % Stripping of black dyed fabric using 75% reductive soln. with 1:40 M: L

Inference

A comparison of classic microwave, cold microwave, and conventional method showed that cold microwave was more effective, more affordable, and quicker than the other two methods. The quality of the cloth affects the effectiveness of stripping and the expense.

Table 12: Stripping of reactive Black dye using 50% reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (mint.)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
F_5	3	10	10	7.6898	3.9738	48.3
F_6	4				0.0931	98.7
F_7	25				0.7655	90
F_8	30				0.1025	98.6

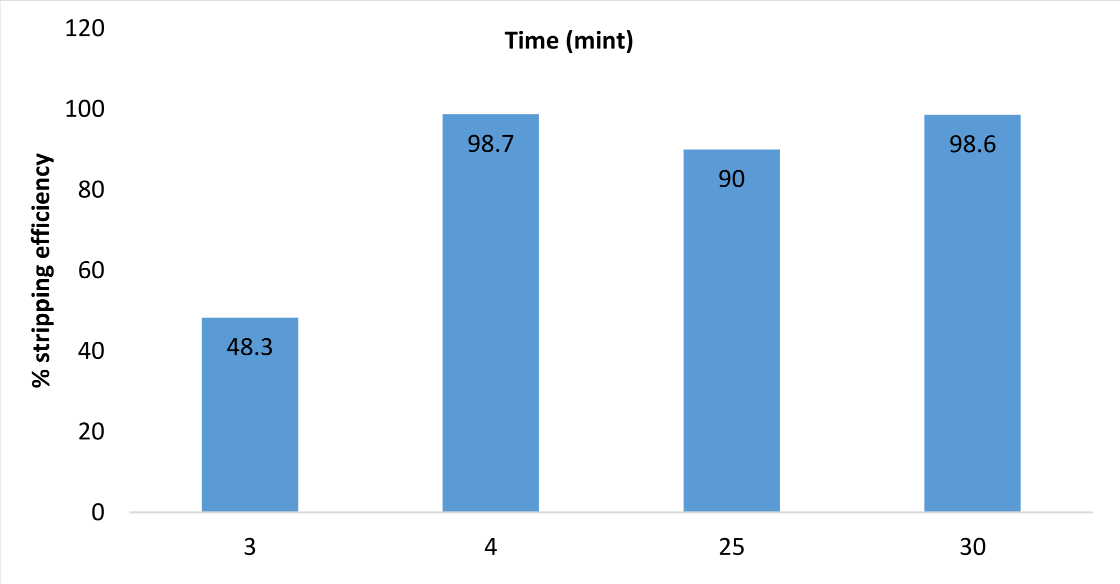

Figure 12: % Stripping of black dyed fabric using 50% reductive soln. with 1:40 M: L

Inference

The maximum stripping percentage was obtained when the pretreated fabric was treated with 50% reductive solution with 1:40 M: L ratio for 4 minutes in microwave oven. The quality of the cloth affects the effectiveness of stripping and the expense.

Table 13: Stripping of reactive Black dye using 25% reductive solution with 1:40 M: L under different time intervals in microwave

Exp. No.	Time (mint.)	Reductive stripping chemicals		k/s of dyed fabric	k/s of stripped fabric	%age Stripping efficiency
		$Na_2S_2O_4$ (g/L)	NaOH (g/L)			
F_9	3				6.0685	21.08
F_{10}	3				7.5292	2.08

F_{11}	30	5	5	7.6898	5.1464	33
F_{12}	45				0.0922	98

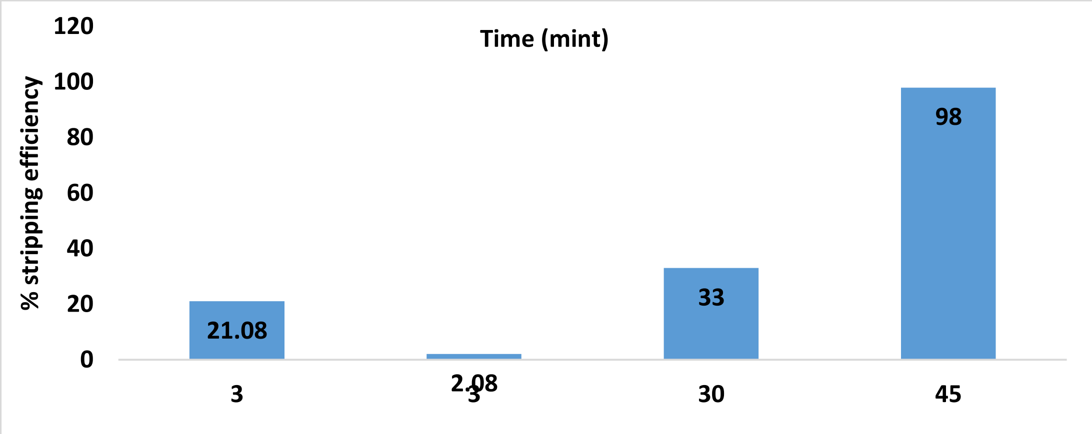

Figure 13: % Stripping of black dyed fabric using 25% reductive soln. with 1:40 M: L

Inference

Overall the results of using 75%, 50% and 25% reductive solution concentrations showed that the maximum stripping percentage was obtained by using 75% solution conc. It means that by increasing concentration of reductive solution, the stripping efficiency of fabric also increases and vice versa.

CONCLUSION

The dyed fabric was treated with cold microwave-assisted, simple microwave-assisted and conventional methods for varying lengths of time and reductive solution concentrations. To avoid the temperature rising above that of room temperature, which is 27–30°C, the period was further divided into 10-second cycles. The recorded results of 45 studies revealed that there is no obvious or fashionable improvement in response to each parameter. A comparison of classic microwave, cold microwave, and conventional method showed that cold microwave was more effective, more affordable, and quicker than the other two methods. The quality of the cloth affects the effectiveness of stripping and the expense.

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