

# The Effect of Temperature Variation on Dyeing Tie-Dye Cotton Fabrics Dyed with Reactive Dye

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**How to cite this paper:** Bristi, U. (2018) The Effect of Temperature Variation on Dyeing Tie-Dye Cotton Fabrics Dyed with Reactive Dye. *Journal of Textile Science and Technology*, 4, 117-128.  
<https://doi.org/10.4236/jtst.2018.44008>

**Received:** August 14, 2018

**Accepted:** November 13, 2018

**Published:** November 16, 2018

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## Abstract

The improvement of colorfastness properties of tie dyed cotton knit fabrics with reactive dye has been studied. Pretreated cotton knit fabric is used for dyeing for easy absorption and retention of dye. Color fastness properties of any dyed fabric are very important aspects as the end use of fabric depends on these properties. This study is to evaluate the color fastness to washing and perspiration using the method ISO 105-2CS:2002 and ISO 105-E04. The fabric is dyed with reactive dye in same concentration but in two different temperatures (30°C and 60°C) and with different amount of sodium carbonate (15 g/l, 18 g/l and 20 g/l) respectively. It is observed that the increasing temperature and using related amount of sodium carbonate the fabric absorbs more dye. In 30°C temperature the result of washing fastness is fairly good to very good where in 60°C the result is very good to excellent. Perspiration fastness result is fairly good to very good both in 30°C and 60°C temperature. The result shows very good of all washing and perspiration fastness in 20 g/l sodium carbonate. The result is concluded that the color fastness of tie-dyed samples is improved by the increasing of temperature and higher amount of sodium carbonate.

## Keywords

Tie-Dyed Cotton Fabric, Reactive Dye, Colorfastness, Temperature

## 1. Introduction

Tie-dye is an ancient process of dyeing for fabrics or garments. This method is applied on fabric by tying it strongly with ribbon or rope in predetermined design. After immersing fabric in the dye bath the color has absorbed in the fabric except the tied areas [1]; hence an irregular pattern has implemented. Most of the time tie-dye is overcome by natural dye in room temperature. But the inven-

tion of synthetic dyes like reactive dyes, it can easily apply for tie dyeing process and this dye is comparatively cheaper than natural dyes. Synthetic dyes give excellent colorfastness than natural dyes with increasing temperature. The dye absorption by cotton fabric increases linearly with temperature [2]. On the other hands synthetic dyeing is easy than any natural dyeing process. A variety of dyes can be used in tie-dyeing, including reactive and vat dyes [3]. Tie-dyeing, particularly after the introduction of affordable dyes, become popular as a cheap and accessible way to customize inexpensive T-shirt, singlet's, dresses, jeans, army surplus clothing, and other garments into psychedelic creations-[4] [5]. Colorfastness means to absorb color perfectly and retain this color of any stage such as—washing, perspiration, sunlight and any chemical process. It gives stability of any color to sustain the fabric. Good colorfastness of any fabric attracts the consumer and encourages wearing it.

[6], [7] & [8] pointed it out that reactive dyes have very good wash fastness; this is attributed to the very stable covalent bond that exists between the dye molecule and the fiber polymer. Reactive dye gives good colorfastness than any natural dye. This dye is most commonly used for cellulosic cotton fiber. Reactive dye create covalent link bond with cotton fabric with the help of sodium sulphate and sodium carbonate. This bonding becomes stronger with increasing dyeing temperature and sodium carbonate. The function of sodium carbonate is simply to increase pH. It actually makes the dye adhere chemically to the actual fiber of fabric. So sodium carbonate maintains the pH of solution and helps to dye fixation.

Reactive dyes have many properties and one of the most important properties is how well they cling to the materials and how well they stay attached in the materials. Sodium carbonate used in reactive dyeing process depends on the shade percentage. If shade percentage is increases then sodium carbonate also is increases for fixation.

The development of useful washing effect on reactive dye by tie dyeing process on cotton knit fabric where to promoted colorfastness by increasing dyeing temperature [9]. Established proper colorfastness by using sodium carbonate to obtained accurate shade percentage by increasing dyeing temperature.

## 2. Materials and Method

### 2.1. Materials

White cotton knit fabric (100% cotton single jersey), GSM 150, Reactive dyes (Remazol Red), Glauber salt ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ), sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), Dyeing auxiliaries, Stirrer, Nose mask, Beakers, Hand gloves, Weighing balance, Sample dyeing M/C, Basic laboratory glass wares, such as, conical flasks, measuring cylinders, thermometer, stirring rod, and volumetric flask.

### 2.2. Method

All the process has done before dying, like scouring bleaching for maximum ab-

sorption of dye or any kind of solution. Before dyeing all data of the fabric such as-fabric GSM, count and thickness have collected. Six samples are taken and the weight of each sample is 5 gm. Each sample is tied strongly with rope. This experiment has done by two processes, one in room temperature (30°C) and another in 60°C. All auxiliaries, chemicals and dyes are given in **Table 1** and calculated. Here dye concentration is used 4% in both experiment and amount of all auxiliaries are same. Amount of sodium carbonate used in this experiment are: 15 g/l, 18 g/l, 20 g/l in both temperatures.

After that the two dye bath has been prepared at 30°C and 60°C temperature by adding all the auxiliaries and tied fabric. Dyeing machine run for 60 minutes. After 60 minutes the dye bath has been dropped and after treatment carried on.

### 2.3. After Treatment

For better colorfastness after treatment is very important process.

After completing dyeing it was needed another treatment and it is called after treatment. After treatment chemicals are given in **Table 2**. In this step firstly rinse the dyed sample with 50°C hot water for 10 minutes. Then neutralize this

**Table 1.** Proportion of dyeing chemicals, auxiliaries and parameter of cotton fabric tie dyeing process with reactive dye.

SL	Dyeing variables	Selected proportions
1	Wetting agent (g/l)	1
2	Sequestering agent (g/l)	1.5
3	Levelling agent (g/l)	1
4	Concretion Reactive dye (%)	4%
5	Glauber salt ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ), (g/l)	60 g/l
6	Sodium Carbonate ( $\text{Na}_2\text{CO}_3$ ), (g/l)	15 g/l, 18 g/l, 20 g/l
7	Dyeing Time (minutes)	60 mins
8	Dyeing Temperature (°C)	(30°C, 60°C)
9	Dyeing pH	10 - 10.5
10	Sample weight	5 gm

**Table 2.** Proportion of after treatment auxiliaries and parameter of cotton fabric tie dyeing process with reactive dye.

SL	After treatment Chemicals	Selected proportions
1	Acetic Acid	1 g/l
2	Detergent	1 g/l
3	Soda Ash	1 g/l
4	Temperature	100°C
5	Time	10 min
6	M:L	with enough/l

sample with acetic acid at 50°C temperature. After finish acid wash it needs soap wash according to below recipe-detergent-1 gm/l, soda ash-1 g/l, temperature 100°C, time-10 min with enough water. Rinse with 90°C hot water for 10 minutes. Rinse with cold water for 5 minutes.

Textile fabric has many properties Fastness property is one of the most important properties of them. The resistance of color to fade or bleed of a dyed or printed textile material to various types of influences like water, light, rubbing, washing, perspiration etc.

Color fastness to wash is very important for dyed materials. The ability of a dyed fabric to retain its original shade during washing is called wash fastness.

#### 2.4. Wash Fastness

The recipe of wash fastness is given in **Table 3**. Sample size is 10 cm × 4 cm & Multi-fiber was also 10 cm × 4 cm. Condition has been followed by ISO C03 Method: ISO 105-2CS:2002. Detergent (ECE Non-phosphate)—4 gm/l, Sodium perborate—1 gm/l, steel ball, time—30 minutes, temperature—60°C with 1:50 water.

**Table 3.** Proportion of wash fastness chemicals, auxiliaries and parameter of cotton fabric tie dyeing process with reactive dye.

SL	Wash fastness Chemicals	Selected proportions
1	Detergent (ECE Non-phosphate)	4 g/l
2	Sodium per borate	1 g/l
3	M:L	1:50
4	Time	30 mins
5	Temperature	60°C
6	Steel ball	As per required
7	Machine	Gyro wash, Oven dry Sewing machine.

Multi-fiber fabric was attached with the dyed sample fabric by means of sewing by the white color sewing thread in the two ends. Colored fabric with the multi-fiber is treated in a wash vessel containing liquor by ECE detergent and sodium per borate. The sample was kept in 60°C for 30 minutes in gyro wash machine. After treating the sample in wash vessel it will be dried in oven. After completed washing sewing thread is unraveled for separating the sample and multi-fiber. Using color change grey scale and color staining scale appropriate rating is given. A multi-fiber fabric is given 6 color staining rating each for individual fiber.

#### 2.5. Perspiration Fastness

Perspiration can be either acidic or alkaline. Most of the tests for perspiration fastness are based on a solution containing the chemical histidine. Sample size is 10 cm × 4 cm & Multi-fiber is 10 cm × 4 cm Method: Color fastness to perspiration to E04.

### 2.5.1. Alkaline Solution

The recipe of alkaline solution is given in **Table 4**. Newly prepared containing 0.5 gm. Histidine mono-hydrochloride monohydrate 5 gm sodium chloride 2.5 gm disodium hydrogen orthophosphate per liter distilled water brought to pH 8 with 0.1 N sodium hydroxide.

### 2.5.2. Acidic Solution

The recipe of acidic solution is given in **Table 5**. Prepared containing 0.5 g histidine mono-hydrochloride monohydrate 5 g sodium chloride 2.2 g sodium di-hydrogen orthophosphate per liter distilled water brought to pH 5.5 with 0.1 N sodium hydroxide.

Properly wetted one composite specimen in the solution at pH 8 (for alkaline) at a liquor ratio of 1:50 and allow is to remain in the solution for 30 minute at room temperature. Clear excess all liquid from the specimen between two plates of per spirometer under a pressure of 12.5 kPa. This process was repeated with another composite specimen in the acid solution using a separate per spirometer. Place per spirometer in an oven at  $37^{\circ}\text{C} \pm 2^{\circ}\text{C}$  temperature for 4 hour. Remove the specimen, opened out it and allowed to dry. Both specimens are then assessed for color change of the test fabric and staining of the adjacent fabric. After complete all fastness test it was evaluated by two different scale one is color change grey scale and another is degree of staining grey scale.

**Table 4.** Proportion of perspiration fastness chemicals, auxiliaries and parameter of cotton fabric tie-dyeing process with reactive dye (Alkali solution).

SL	Perspiration Chemicals (Alkaline)	Selected proportions
1	Histidine mono-hydrochloride mono-hydrate ( $\text{C}_6\text{H}_9\text{O}_2\text{N}_3\text{HCl}\cdot\text{H}_2\text{O}$ )	0.5 gm
2	Sodium chloride (NaCl)	0.5 gm
3	Di-sodium hydrogen orthophosphate ( $\text{Na}_2\text{HPO}_4\cdot\text{H}_2\text{O}$ )	2.5 gm
4	Sodium hydroxide (NaOH)	0.1 N
5	pH	8

**Table 5.** Proportion of perspiration fastness chemicals, auxiliaries and parameter of cotton fabric tie-dyeing process with reactive dye (Acidic solution).

SL	Perspiration Chemicals (Acid)	Selected proportions
1	Histidinemono-hydrochloridemono-hydrate ( $\text{C}_6\text{H}_9\text{O}_2\text{N}_3\text{HCl}\cdot\text{H}_2\text{O}$ )	0.5 gm
2	Sodium chloride (NaCl)	05 gm
3	Sodium di hydrogen orthophosphate ( $\text{NaH}_2\text{PO}_4\cdot 2\text{H}_2\text{O}$ )	2.2 gm
4	Sodium hydroxide (NaOH)	0.1 N
5	pH	5.5

## 3. Result and Discussion

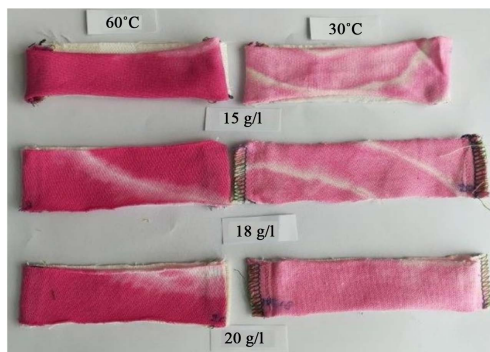
The experiment is done in two temperatures which is  $30^{\circ}\text{C}$  and another is  $60^{\circ}\text{C}$

temperature. This experiment it was observed that in same shade % dyeing temperature is increase dyeing shade also increase. Another observation is different amount of soda ash used in this experiment. It is established that 4% shade of reactive dye needs 20 g/l soda ash. But in this experiment different amount of soda ash is used which is 15 gm/l, 18 gm/l, 20 gm/l in 30°C and 60°C in both temperature. The optimum dyeing time is 60 minutes and pH is 10.5 to 11 which is standard for reactive dye.

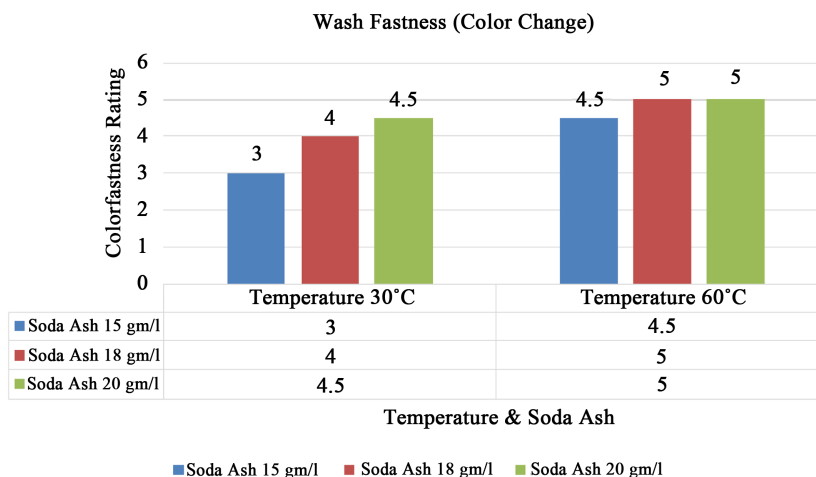
### 3.1. Wash Fastness

#### 3.1.1. Color Change

In wash fastness test the result is clear from **Figure 1**, **Figure 2** & **Table 6** which is color change test result. In this test result show that in 30°C temperature color change were fair (3) in 15 gm/l soda ash, good (4) in 18 gm/l soda ash and very good (4.5) in 20 gm/l sodium carbonate but in 60°C temperature the result of color change were very good (4.5) in 15 gm/l soda ash, excellent (5) in 18 gm/l sodium carbonate and excellent (5) also in 20 gm/l soda ash. So it observed that in 60°C temperature and 20 gm/l used sodium carbonate used the result is excellent. The results are displayed in **Table 6**.



**Figure 1.** Tie-dyed wash fastness sample.



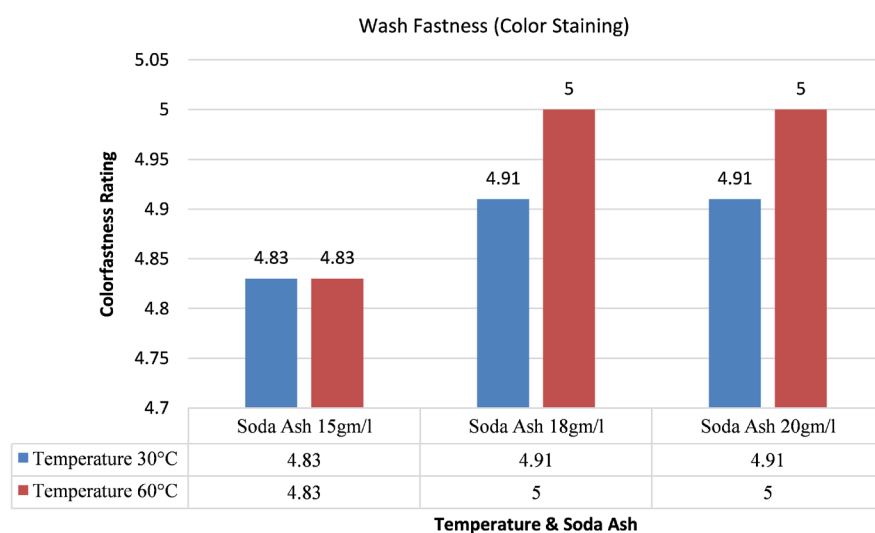
**Figure 2.** Graph of color fastness to washing (color change) temperature against of sodium carbonate at 15 g/l, 18 g/l and 20 g/l.

**Table 6.** Result of color fastness to washing (color change).

	Sodium Carbonate Temperature	
	30°C	60°C
15	3	4/5
18	4	5
20	4/5	5

### 3.1.2. Color Staining

In wash fastness test the result is clear from **Table 7** & **Figure 3** which is color staining test result. In this test result show every data in mean of multi-fiber fabric. So the result is in 30°C temperature is very good (4.83) in 15 gm/l soda ash, very good (4.91) in 18 gm/l soda ash and also very good (4.91) in 20 gm/l soda ash. In 60°C temperature the result is very good (4.83) in 15 gm/l soda ash, excellent (5) in 18 gm/l soda ash and also excellent (5) in 20 gm/l soda ash. So it observed that 60 temperature and 18 & 20 gm/l sodium carbonate given same result this experiment. The results are displayed in **Table 7**.

**Figure 3.** Graph of temperature against of sodium carbonate at 15 g/l, 18 g/l and 20 g/l (color staining result mean of multi-fiber).**Table 7.** Result of color fastness to washing (color staining).

Multi-fiber	Soda Ash 15 gm/l		Soda Ash 18 gm/l		Soda Ash 20 gm/l	
	30°C	60°C	30°C	60°C	30°C	60°C
Wool	5	5	5	5	5	5
Acrylic	5	5	5	5	5	5
Polyester	5	5	5	5	5	5
Nylon	5	5	5	5	5	5
Cotton	4	4	4/5	5	4/5	5
Acetate	5	5	5	5	5	5
Mean	4.83	4.83	4.91	5.00	4.91	5.00

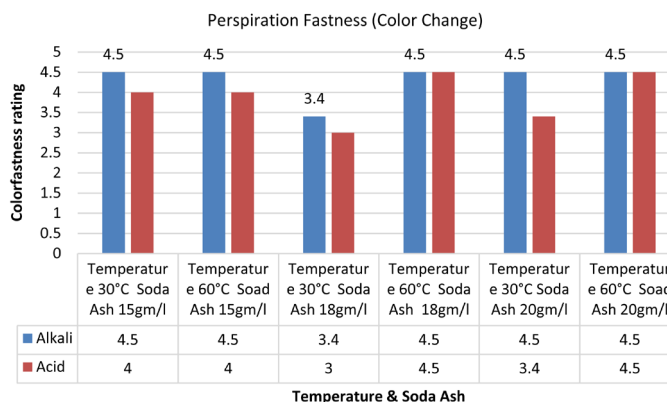
### 3.2. Perspiration Fastness

#### 3.2.1. Color Change

Perspiration fastness result is given below and the result is clear from **Figure 4** and **Figure 5** & **Table 8** that is color change result. This test result is shown in 30°C temperature of 15 gm/l soda ash in alkaline condition result is very good (4/5) and acidic condition result is good (4), 18 gm/l soda ash in alkaline condition result is fairly good (3/4) and acidic condition result is fair (3), 20 gm/l sodium carbonate given the result is very good (4/5) in alkaline condition and fairly good (3/4) in acidic condition. And also 60°C temperature the color change result in 15 gm/l is very good (4/5) in alkaline condition and good (4) in acidic condition, in 18 gm/l the sodium carbonate result is given very good (4/5) both in alkaline and acidic condition, in 20 gm/l sodium carbonate given very good (4/5) result in both alkaline and acidic condition. The results are displayed in **Table 8**.



**Figure 4.** Tie-dyed perspiration fastness sample.



**Figure 5.** Graph of temperature against of sodium carbonate at 15 g/l, 18 g/l and 20 g/l (color change).

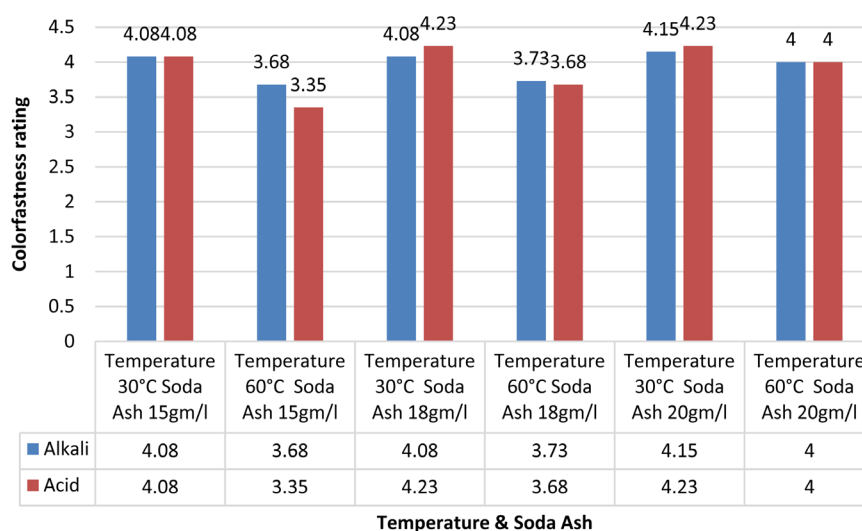
**Table 8.** Result of color fastness to perspiration (color change).

Soda Ash	Temperature			
	30°C		60°C	
	Alkali	Acid	Alkali	Acid
15	4/5	4	4/5	4
18	3/4	3	4/5	4/5
20	4/5	3/4	4/5	4/5



### 3.2.2. Color Staining

Color staining test is done by the help of multi-fiber fabric. So the results are given in mean form and show **Table 9** & **Figure 6**. This test result is show in 30°C temperature of 15 gm/l sodium carbonate result is good (4.08) both in alkaline and acidic condition, 18 gm/l sodium carbonate in alkaline condition result is good (4.08) and acidic condition result is also good (4.23), 20 gm/l soda ash given the result is good (4.15) in alkaline condition and also good (4.23) in acidic condition. In 60°C temperature the color staining result in 15 gm/l is fairly good (3.68) in alkaline condition and fair (3.35) in acidic condition, in 18 gm/l soda ash the result is given fairly good (3.73) in alkaline condition and fairly good (3.68) in acidic condition, in 20 gm/l sodium carbonate given good (4) result in both alkaline and acidic condition. The results are displayed in **Table 9**.

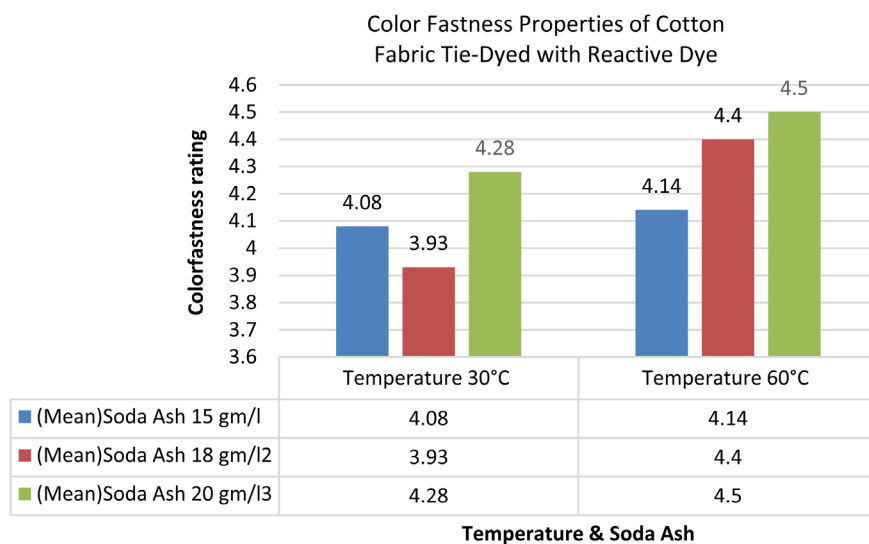


**Figure 6.** Graph of temperature against of sodium carbonate at 15 g/l, 18 g/l and 20 g/l (color staining mean of multi-fiber).

**Table 9.** Result of color fastness to perspiration (color staining).

Multi fiber	Soda Ash 15 gm/l				Soda Ash 18 gm/l				Soda Ash 20 gm/l			
	30°C		60°C		30°C		60°C		30°C		60°C	
	Al	Ac	Al	Ac	Al	Ac	Al	Ac	Al	Ac	Al	Ac
Wool	4/5	4/5	4/5	3/4	4/5	4	4	3/4	4	4	4	4
Acrylic	4	4	3/4	4	4	4/5	4	4	4/5	4/5	4	4
Polyester	4/5	4/5	4	4	4	4/5	4	4/5	4/5	4/5	4/5	4/5
Nylon	4	4	3/4	3	4/5	4/5	3/4	3/4	4/5	4	4/5	4
Cotton	3	3	2/3	2/3	3	3/4	3	2/3	3/4	3/4	3	3
Acetate	4/5	4/5	4/5	3/4	4/5	4/5	4	4/5	4	5	4	4/5
<b>Mean</b>	<b>4.08</b>	<b>4.08</b>	<b>3.68</b>	<b>3.35</b>	<b>4.08</b>	<b>4.23</b>	<b>3.73</b>	<b>3.68</b>	<b>4.15</b>	<b>4.23</b>	<b>4</b>	<b>4</b>

**Table 10 & Figure 7** is clearly identified that between the two different temperature uses in same parameter and also same percentage of dye is gives different shade in same cotton knit fabric. Where all wash fastness and rubbing fastness parameter is same. This experiment indicate that in 30°C temperature and use 15 gm/l sodium carbonate gives mean score 4.08, 18 gm/l sodium carbonate gives mean score 3.93 and 20 gm/l sodium carbonate gives mean score 4.28, and same parameter in 60°C temperature and use 15 gm/l sodium carbonate gives mean score 4.14, 18 gm/l sodium carbonate gives mean score 4.40 and 20 gm/l sodium carbonate gives mean score is 4.50. So it is establish that the increasing of temperature gives good fastness in use of 20 gm/l sodium carbonate. [7] Emphasized that reactive dyes exhibited good fastness properties which may be due to the very stable electron arrangement and covalent bond that existed between the dye molecules and fiber polymers which provide good resistance to washing and sunlight respectively [10]. The small dye particles penetrate into the fabric pores at high temperature; the bright and even shades are produced at 60°C dyeing temperature.



**Figure 7.** Graph of temperature (30°C & 60°C) against of sodium carbonate at 15 g/l, 18 g/l and 20 g/l.

**Table 10.** Result of color fastness properties of cotton fabric tie-dyed with reactive dye.

Temperature	Sodium Carbonate Ash gm/l	Wash fastness test		Perspiration Fastness				Mean Score
		C.C	C.S	C.C		C. S		
				Al	Ac	Al	Ac	
30°C	15 gm/l	3	4.83	4.5	4	4.08	4.08	4.08
	18 gm/l	4	4.91	3.4	3	4.08	4.23	3.93
	20 gm/l	4.5	4.91	4.5	3.4	4.15	4.23	4.28
60°C	15 gm/l	4.5	4.83	4.5	4	3.68	3.35	4.14
	18 gm/l	5	5	4.5	4.5	3.73	3.68	4.40
	20 gm/l	5	5	4.5	4.5	4	4	4.50

## 4. Conclusion

It was observed that the samples tied and dyed with standardized dyeing conditions of reactive red dye exhibited the excellent (5) wash fastness both in color change and color staining for the samples dyed with 20 gm/l sodium carbonate in 60 temperature and perspiration fastness is very good in color change (4.5) both in acid and alkali and good for color staining (4) both in acid and alkali. In 30 temperature in 20 gm/l sodium carbonate gives very good (4.5), (4.91) in color change and color staining of wash fastness and fairly good (3.4) and very good (4.5) in acid and alkaline condition and both are good in acid (4.23) and alkaline (4.15) in perspiration fastness. So the mean score is (4.5) that is very good in 60° temperature and (4.4) is good in 30° temperature both in 20 gm/l sodium carbonate. So it can be concluded from the study tie dyeing with reactive 60° temperature is better than 30° temperature in 20 gm/l sodium carbonate.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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## **Abbreviations and Acronyms**

C.C = Color Change

C.S = Color Staining

Al = Alkali

Ac = Acid

M:L = Material:Liquor