Improvement of dying process parameters in the production of tie and dye cotton fabric.

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Abstract
The improvement of dyeing process parameters in the production of tie and dye cotton fabrics have been studied. Desizing and mercerization operation was carried out on the cotton fabrics prior to dyeing to remove the starch or size naturally present in the cotton and for easy absorption and retention of the dye in the fabric. The cotton fabrics were dyed at different time range (5, 10, 15 and 20 minutes) and at different temperature (60°C, 70°C, 80°C, 90°C and 100°C) respectively. it was observed that increase in time, at constant temperature increases the shade of the fabric which is attributable to the fact that the fabric absorbs more dye with increase in time at constant temperature. Increase in temperature at constant time also shows a slight increase in the dye absorption by the fabrics as compared to increase in time at constant temperature. This can be attributed to the fact that reduction or vatting process starts at about 60°C and gets fully vatted at about 80°C. However at temperature range of 90°C and 100°C, there is no marked effect of the dye on the fabric, this can be attributable also to the fact that as such temperature the dye has been excessively reduced and therefore its dyeing ability becomes ineffective. The cotton fabric was also subjected to different colour fastness test especially wash and light. The results show that temperature of dyeing from 60°C to 80°C at 15 to 20 minutes gave better fastness to light and washing compared to dyeing temperature of 90°C and100°C respectively.
Key words: cotton, vat dye, colour fastness, desizing, mercerization.

1.0 INTRODUCTION

Tie and dye is a method of introducing coloured or white patterns on fabrics by tying it strongly with strings or rubber bands in various ways before immersing it in the dye bath. The colour is absorbed in all except the tied areas, and so a patterned fabric results. This is seen by untying the dyed materials, rinsing in water and drying. The process of tie-dye typically consists of folding, marbling, twisting and pleating the fabric and binding with string or rubber bands, followed by application of dye(s).

Cotton can be dyed with many natural colours extracted from natural sources and synthetic dyes (Thakare *et al*, 2006). The original vat dye is indigo, once obtained from plants but now produced synthetically (Booth, *et al* 2000).

A variety of dyes can be used in tie-dyeing, including reactive, acid, and vat dyes. (Burch, Paula, 2013). Tie-dying, particularly after the introduction of affordable dyes, became popular as a cheap and accessible way to customise inexpensive T-shirts, singlets, dresses, jeans, army surplus clothing, and other garments into psychedelic creations (Hoffman *et al*, 1999;.Pellew, Charles, 2012).

Vat dye is the most popular dye used for coloration of cotton, particularly when high fastness is required. (Philips *et al*, 1996). For the colouration of cellulose fibres about 120 000 tons of vat dyes are being used annually (Mojca Bozic and Vanja Kokol, 2008). Vat dyes is not soluble in water, but can be solubilized by reaction with a reducing agent, e.g., sodium hydrosulfite ("hydros", Na_2S_2O4) in dilute NaOH. (Bien, *et al*, 2005)

Once it has been converted to its soluble (LEUCO) form, the vat dye can penetrate into the cotton fibers.

$$\text{Vat dye (insol)} \xrightarrow{\text{pad}} \text{on fabric surface} \xrightarrow[\text{NaOH}]{\text{hydros}} \text{LEUCO form (soluble)}$$

This accounts for their excellent wash fastness. Because they can be applied, solubilized by reduction, and finally re-oxidized when inside the cotton. **(**Baumgarte *et al*, 1987).

This research intends to improve on the quality of tie and dye cotton fabrics, by improving on the dyeing process parameters and establishing standard methods of production.

2.0 MATERIALS AND METHOD

- White cotton fabrics
- Vat dyes
- Sodium Hydrosulphite
- Caustic Soda
- Stirrer
- Nose mask
- Beakers
- Hand gloves
- Weighing balance.
- Basic laboratory glass wares, such as, conical flasks, measuring cylinders, thermometer, stirring rod, and volumetric flask

2.1 METHOD

2.1.1 Fabric preparation

The cotton fabrics were obtained in its grey state, desizing and mercerization operation was carried out on the fabrics. It was then weighed and wetted out before immersion into the dye liquor.

2.2 Desizing operation:

Desizing operation was carried out on the cotton fabric. The object of desizing is to remove the size or starch naturally present in the cotton fabrics for easy absorption of dyes. If the size is not removed, the absorbency of the fabric towards water and dyes will be seriously impaired.

The cloth was impregnated with water only and stored for 48 hours at room temperature. During this period, the starch becomes degraded by enzymes naturally present in the medium, it was then washed off.

2.3 Mercerization operation:

Mercerization process was carried out by treating the cotton fabrics in a concentrated solution of 25% caustic soda for 2 minutes at room temperature. The material was then thoroughly washed in water, rinsed to remove the alkali, and dried. This increases the colour yield on dyeing and significantly increases the dye affinity of the cloth relative to that of an untreated material.

2.4 Dyeing process:

1g each of the cotton fabrics was first wetted out for 5 minutes to also improve the swelling of the pores for dye uptake and immersed in a dye bath containing 1% conc. of the vat dyes, 0.8% conc. of the sodium hydrosulphite (hydros) and 0.4% of the sodium hydroxide (NaOH) at different time range of 5, 10, 15, and 20 minutes respectively and at different temperature of 60°c, 70°c, 80°c, 90°c and 100°c. It was then washed thoroughly in water and dried.

Optimization process was carried out on the fabrics in which the time was kept constant at 5, 10, 15, and 20 minutes, while the temperature was varied at 60°c, 70°c, 80°c, 90°c and 100°c. The temperature was also kept constant at 60°c, 70°c, 80°c, 90°c and 100°c while the time was varied at 5mins, 10mins, 15mins, and 20mins respectively. It was then rinsed thoroughly and dried. This is as shown diagrammatically below;

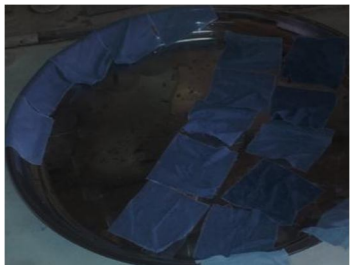

Dye preparation


fabrics immersed into the dye bath


varying time and temperature


Dyed fabric removed at specific temperature and time. Thorough washing of the dyed fabrics


Rinsing of the dyed fabric


Drying of the dyed fabrics

2.5 Colour fastness Test

An aspect of fabrics which is always of interest to consumer is how fast the colour is. This is because the beauty of a fabric is of no value unless the dye is fast under the conditions in which the fabric is to be used. The colour fastness test used for this analysis are the colour fastness to light and washing.

2.6 Colour fastness to light: The colour fastness to light was assessed by prolonged exposure of the samples to daylight. The exposure to light causes deterioration of all textile fibres and dyes to some extent, the high energy ultraviolet light in daylight being responsible. The most common effect of light on dyestuff is change in colour which is usually recognised as fading or loss of colour strength. The various samples were assessed for the degree of fading by exposing them to daylight for 72 hours, the result of the fastness test as related to the degree of fading is shown in table 1 in the discussion of result.

2.7 Colour fastness to washing:

The resistance of a dye to heat, water, soap, detergent and mechanical action, as employed during domestic laundering, is an important feature in the use of coloured textiles.

The samples were assessed to wash fastness by a series of five washing tests in severity from No. 1 which is equivalent to hand washing to No. 5 which is equivalent to machine washing at near boiling temperature. The degree of staining was assessed by stitching the appropriate undyed piece of fabric to the dyed ones. The fabrics were then dried and the degree of staining of the undyed

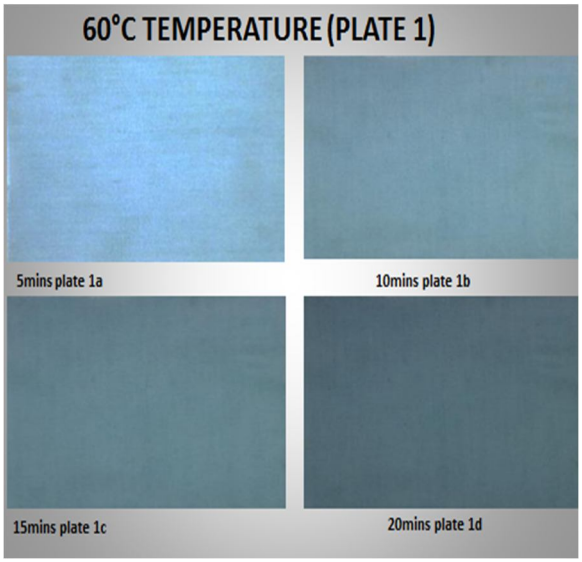
fabrics was assessed. The dyed fabrics that stains the undyed fabric more has less fastness to washing and vice versa. The results are displayed in table 2

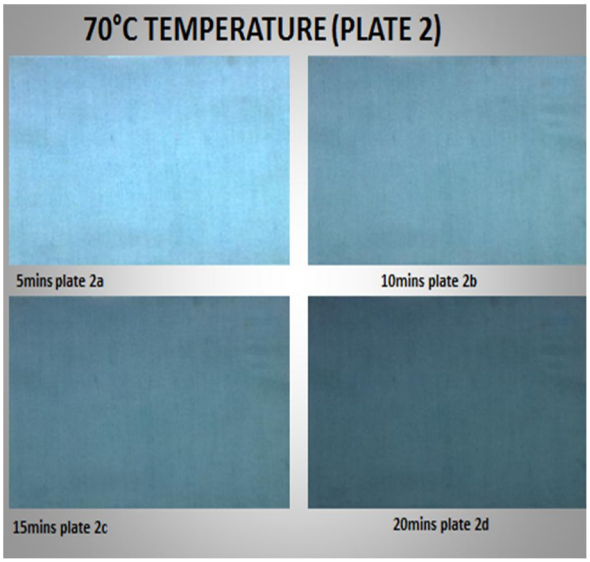
3.0 RESULTS AND DISCUSSIONS:

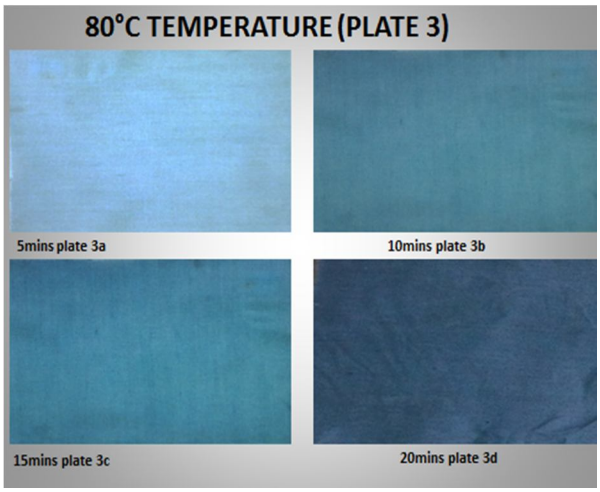
3.1 Results from the optimization of dyeing process parameters:

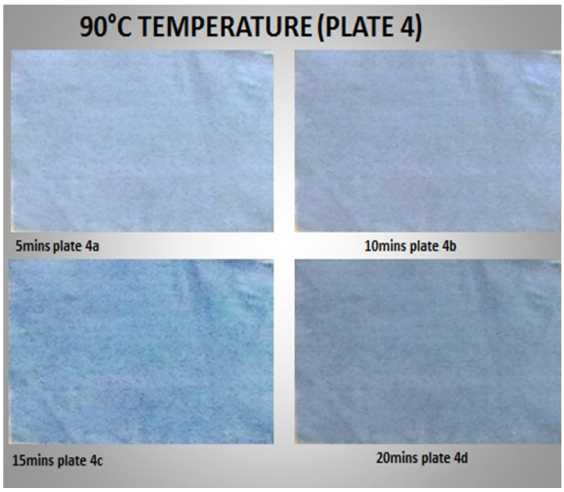
Plates 1 to 5, show the picture of the vat dyed fabric at constant temperature with varied time, it was observed that the time of dyeing had effect on the cotton fabric at constant temperatures of 60°C, 70°C, 80°C, 90°C and 100°C. Increase in time, increases the shade of the fabric which is attributable to the fact the fabric absorbs more dye with increase in time at constant temperature. During the vatting or reduction process, at constant temperature of 60°C, 70°C and 80°C, the dye penetrates the fabric easily as time increases. It can also be attributed to the fact that the reduction process makes the dye easily accessible by the fabric as time increases. However at constant dyeing temperature of 90°C and 100°C, increase in time does not show marked effect on the fabric, this can be attributable to the fact that as such temperature the dye has been excessively reduced and therefore its dyeing ability becomes ineffective.

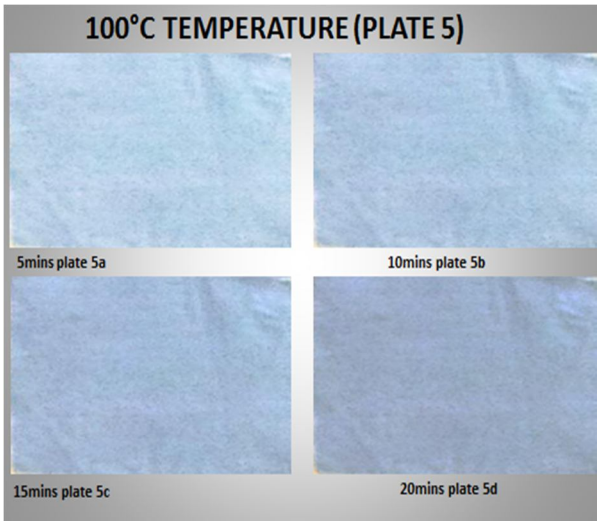
PICTURES SHOWING INCREASE IN TIME OF DYEING AT CONSTANT TEMPERATURE.







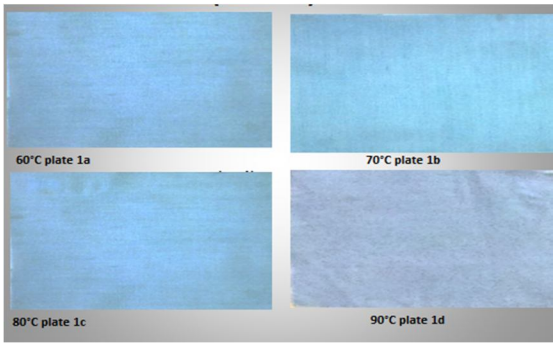




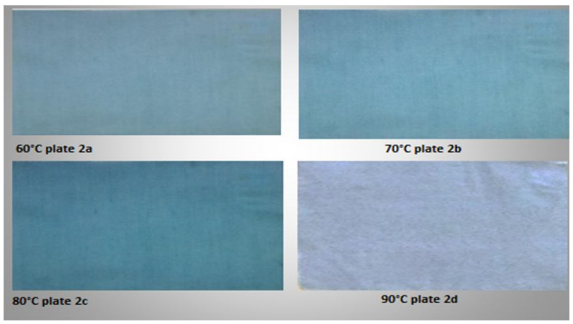
Plates 6 to 9 show the pictures of increase in dyeing temperature at constant time. It was observed that at constant time of 5mins, 10mins, 15mins and 20mins, temperature increase from 60°C to 80°C, caused a slight increase in the dye absorption by the fabric compared to increase in time at constant temperature except in plate 6 which shows almost no difference in shade which shows that at 5 minutes, the vatting or reduction process might just have commenced. This can be attributed to the fact that reduction or vatting process starts at about 60°C and gets fully vatted at about 80°C. It can be noticed that above 80°C, the fabrics absorption of the dye drastically reduces, which reduces the effect of increase in temperature at constant time. This can also be attributable to over reduction of the dye. Fabrics at a dyeing temperature of 60°C to 80°C gave a better result compared to others due to the complete absorption of the dye by the fabric at that temperature.

PICTURES SHOWING INCREASE IN TEMPERATURE OF DYEING AT CONSTANT TIME.

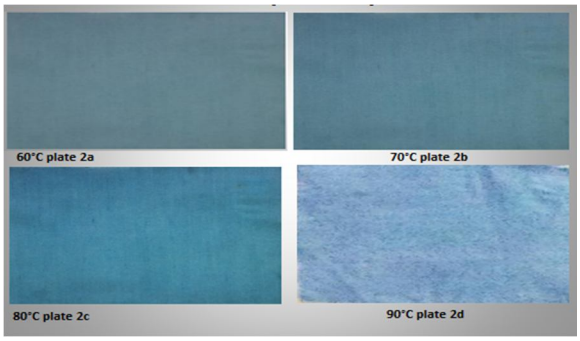
5 MINUTES (PLATE 6)



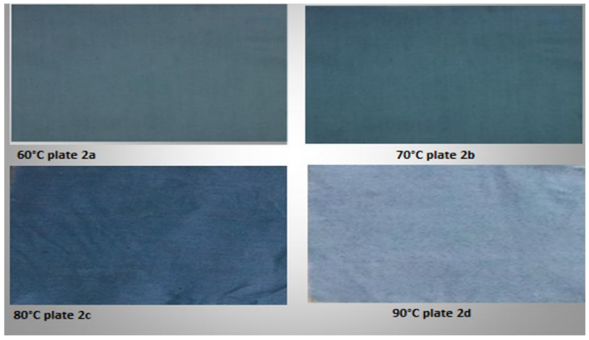
10 MINUTES (PLATE 7)



15 MINUTES (PLATE 8)



20 MINUTES (PLATE 9)



3.2 RESULTS OF COLOUR FASTNESS TEST:

Various colour fastness test carried out are: colour fastness to light, washing, rubbing and perspiration**.**

3.2.1 Results of Colour fastness to light: The results are displayed in Table 1 below:

	TIME			
TEMPERATURE	5 mins	10 mins	15mins	20mins
60°C	Low	Moderate	High	high
70°C	Low	Moderate	High	high
80°C	Low	Moderate	High	high
90°C	Low	Low	Low	moderate
100°C	Low	Low	Low	Low

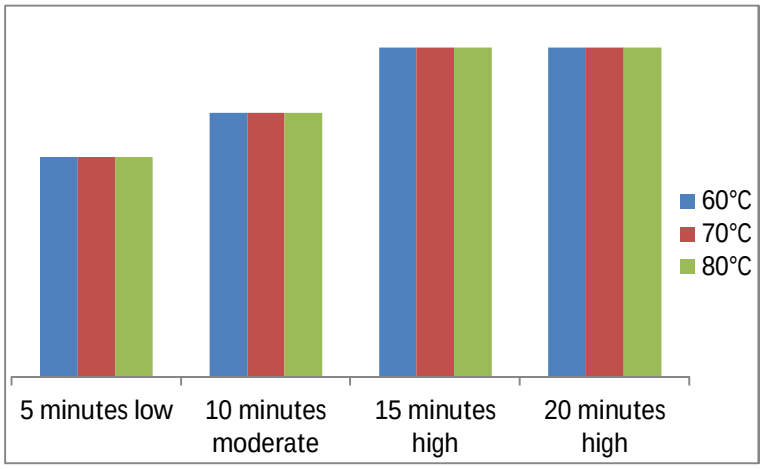


Fig 1: Graph of temperature against time at 60°C, 70°C and 80°C

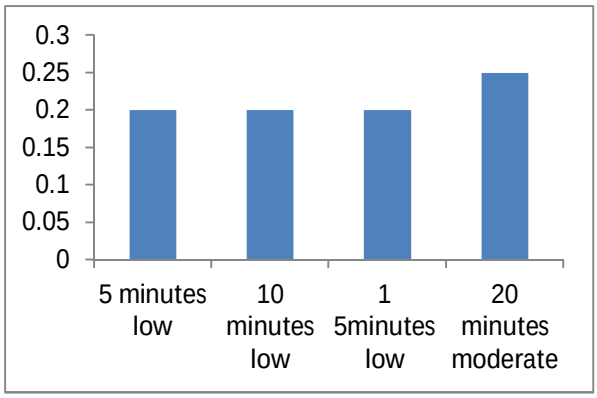


Fig 2: Graph of temperature against time at 90°C

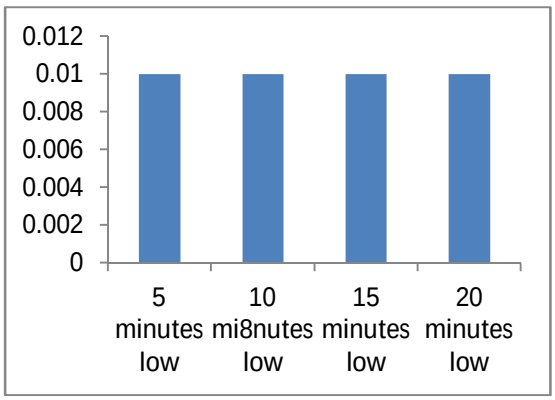


Fig 3: Graph of temperature against time at 100°C

The graph above gives the colour fastness to light result which shows that temperature range of 60°C to 80°C gave relatively better results in terms of fastness to light as seen evidently from 15 mins to 20 mins compared to 90°C and 100°C which shows less fastness ability. This is also attributable to the fact that on exposure to light, the fabrics that absorbs the fully vatted dyes i.e. 60°C to 80°C at 10mins to 20 mins, has higher resistance to fading on exposure to light compared to others.

3.2.2 Results of Colour fastness to washing:

The results are displayed in Table 2 below:

	TIME			
TEMPERATURE	5 mins	10 mins	15mins	20mins
60°C	Low	Low	High	high
70°C	Low	Low	High	high
80°C	Low	Moderate	High	high
90°C	Low	Low	Low	moderate
100°C	Low	Low	Low	Low

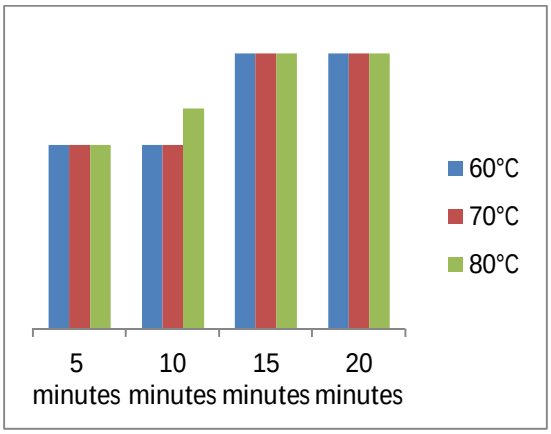


Fig 4: Graph of temperature against time at 60°C, 70°C and 80°C

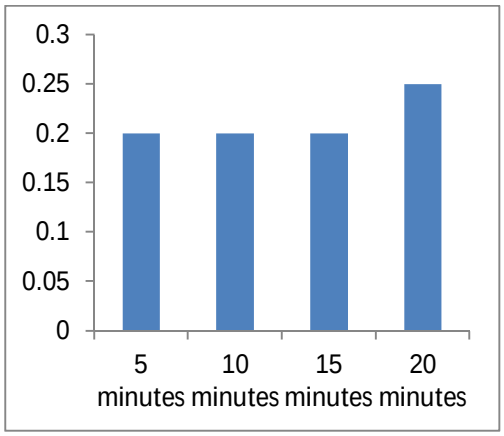


Fig 5: Graph of temperature against time at 90°C

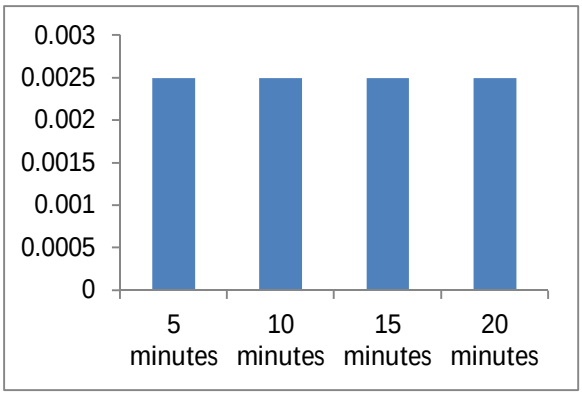


Fig 6: Graph of temperature against time at 100°C

The above result is similar to that of the colour fastness to light. Temperature range of 60°C to 80°C at 15 to 20minutes also gave a better fastness to washing compared to 90°C and 100°C on exposure to these water agencies. It is also attributable to the over reduction of the dyeing process evident from 90°C to 100°C

CONCLUSION

It was observed hitherto, that tie and dye fabrics have been experiencing challenges especially in its quality and lack of standardized method of production in terms of time, temperature, concentrations, fabric preparations and pre-treatment prior to dyeing. This research gives standard method of tie and dye production starting from the pre-treatment of the fabrics which involves mainly desizing and mercerization operation for easy absorption and retention of the dye in the fabric. The optimization process of time, temperature and concentration has been studied; it was observed that 1g of the cotton fabrics immersed in a dye bath containing 1% conc. of the vat dyes, 0.8% conc. of the hydros and 0.4% conc. of the sodium hydroxide (NaOH) at temperatures between 60°C to 80°C for 20 minutes gave better results in both dye absorption and the colour fastness test.

However, from observation, it is recommended that carrying out tie and dye at a maintained temperature of 80°C for 20 minutes with the above dyeing parameters gave a relatively qualitative tie and dye fabric with good dye absorption and high colour fastness especially to light and washing.

REFERENCES

Baumgarte, Melliand Textilber, 68 (1987) 189-276.

Burch, Paula. "About Fiber Reactive Dyes". *All About Hand Dyeing*. Retrieved 16 November 2013.

Burch, Paula. "Acid Dyes". *All About Hand Dyeing*. Retrieved 16 November 2013.
Baumgarte, Melliand Textilber, 68 (1987) 189-276.

Hoffmann, Frank W.; William G. Bailey (1994). *Fashion & merchandising fads*. New York: Haworth Press. p. 257. ISBN 1560243767.
Mojca Bozic & Vanja Kokol, Dyes Pigm, 76 (2) (2008) 299-309.

Philips D, J Soc Dyers Color, 12 (1996) 183.

Pellew, Charles E. (1909). "Tied and Dyed Work: An Oriental Process with American Variations". *Craftsman* **16**: 695–701. Retrieved 15 December 2012.
Thakare A M, Manoj Das & Brijesh Misra, Asian Dyer, April (2006) 35-36.