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Development Of Colour Changing Fabric Using Thermochromic Pigment In Combination With Coffee

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Abstract: The Thermochromic Dye In Combination With Coffee Was Applied To A Cotton Fabric Prepared By Stitching The Nichrome Wire In The Weft Direction. The Fabric Was Dyed In Isolation, In Combination With Coffee In The Ratio Of 1:1, 2:1 And 1:2 With And Without Mordant. The Nichrome Wire Was Joined To Allow The Current Flow Through The Fabric That Generates Haet In The Fabric. The Colour Changes Gradually With The Increase In Temperature And The Colour Values Were Observed At Varying Temperatures. The Wash Fastness Properties Of The Samples Were Obtained To Be Fair In All The Cases.

1. INTRODUCTION

Photochromic And Thermochromic Colorants Change The Colour Rapidly And Reversibly From Colourless To Coloured State With Ultraviolet Radiation, Temperature And Ph [1]. This Colour Changing Dyes Have Increasingly Used In The Thermochromic Coatings Which Respond Thermally To The Environment. This Thermochromic Coatings Change Their Colour From Darker To Lighter Tones With The Temperature Variation. The Colour Changing Property Of The Textile Materials Can Be Achieved Through Variety Of Dye Classes Available In The Market. In Most Of The Cases, The Colour Changing Effect Through This Material Is A Reversible Property, But Some Are Not. This Thermochromic Dye Pigment Is Manufactured And Commercialized For Different Fields Of Application [2]. This Thermochromic Dye Changes Its Colour Reversibly With The Application Of Varying Temperature. The Leuco Form Of This Thermochromic Dye Undergoes A Reversible Change From Colored State To Colourless State When Subjected To The Change In Temperature [3]. This Transition Is Achieved Through The Thermally Reversible Transformation Of The Pigment Molecular Structure That Causes The Spectral Change In Visible Colour.

This Themochromic Dye Technology Is Now Been Explored By The Textile Designers To Develop The Creative Works With A Combination Of Aesthetic And Functional Aspects. The Application Of Thermochromic Dyes Includes Medical Applications, Flexible Communicative Display For Apparels, Protective Textiles Etc. In The Field Of Medical Textiles, The Thermochromic Garments Are Used To Identify The Infections And Changes In Physiology Of The Wearer. In The Case Of Fire Fighter, It Is Used To Detect The Change In The Body Temperature At Extreme Temperature Conditions [4]. Smart Textiles That Creates A Significant Impact On The Environment Uses Thermohromic Dyes To Have

Interactive Effect With The Environement By Colour Transformation In Line With The Environment [5].
Many Research Works Has Been Carried Out In Developing Thermochromic Dyed Fabrics And Analyse Their Properties On Application. Wan Zhang Et Al Obtained A Colour Changing Polyester Fabrics Using Thermochromic Leuco Dye Loaded Silica Nanocapsules. It Was Obtained That The Thermochromic Dyed Polyester Shows Washing And Rubbing Fastness Of Grade 4 [6]. Karpagam (E) Et Al [4] Colour Changeable Printed Cotton Fabrics For Defence Applications In Combination With Turmeric Dye Pigment. The Printed Fabrics Show Better Colour Changing Performance And Wash Fastness Testing Shows Good Fixation Of The Dye Pigment Onto The Fabric. Shixiong Yi Et Al Developed A Composite Thermochromic And Phase-Change Materials And Obtained Very Good Thermal And Thermochromic Properties [7]. The Thermochromic Pigment Embedded Nylon/Spandex Sportswear Was Developed For The Detection Of Physical Exhaustion. They Obtained That The Proper Placement Of Thermochromic Panels In Construction Serves As A Warning Light For Exhaustion In Athletes [8]. In This Paper, A Thermochromic Dyed In Combination With Coffee Was Obtained And Their Colour Values Have Been Studied. The Dyed Samples Were Further Tested For Its Fastness Properties Towards Washing For Different Cycles.

Materials
Thermochromic Colorant Was Purchased From Americos Industries Inc., India. The Plain Woven Fabric Of 106 Gsm Was Used For This Work. Coffee Powder Was Purchased From Local Market. The Wetting Agent And Softners Of Laboratory Grade Were Used For The Research Work.

2. METHODS

Table 1 Shows The Recipe Of Different Colors Produced Using Thermochromic Green And Different Ratios Of Coffee Powder In The Presence And Absence Of Mordants. The Process Was Carried Out In Two Stage Method. First The Fabric Was Treated With The Coffee Powder And Then It Was Treated With The Thermochromic Dye Component.

Natural Dyeing Process:

The Bleached Cotton Fabric Was Immersed In The Distilled Water And Transferred To The Dyebath Containing The Coffee Powder And Ferrous Sulphate Mordant With The M:L Ratio Of 1:20. The Dyeing Process Was Carried Out At The Temperature 60^0C For 30 Minutes Of Time Duration At The Alkaline Ph Of 10-11 With Continuous Stirring. After Dyeing, The Dye Fixation Was Carried Out Using 4% Vinegar At 1:40 M:L Ratio By Dipping It In The Vinegar For 30 Minutes. The Samples Were Then Washed With The Distilled Water To Remove The Excess Dye Particles Present In The Surface. The Fabric Was Shade Dried Before Taking It For The Thermochromic Dyeing Process.

Thermochromic Dyeing Process:

The Natural Dyed Cotton Fabric Samples Were Then Coloured Using Thermochromic Green Pigment By Pad-Dry-Cure Technique. The Dye Pigment Dispersion Was Parepared By Dispersing The 25 Ml Of Thermochromic Pigment With 10 Ml Cationic Agent, 15 Ml Of Non-Ionic Dispersing Leveling Agent, 20 Ml Acrylic Binders And 30 Ml Of Water. The Fabric Was Padded With The Solution At Room Temperature Followed By Drying At 80^0C For 3 Minutes. The Dried Sample Was Further Cured At 140^0C For 3 Min.

Table 1 Different Ratios Of Colours Used

S.No.	Thermochromic Green	Coffee Powder	Mordant	Colour Obtained
1	1	-	No Mordant	Cadet
2	1	1	No Mordant	Raw Umber
3	1	1	With Mordant	Raw Umber
4	1	2	With Mordant	Battle Ship Grey
5	2	1	With Mordant	Khaki

Fabric Preparation:

The Fabric Was Prepared By Stitching Nichrome Wire In The Weft Direction With Ends Being Connected To The External Power Source That Actuates The Temperature. When The Current Passes Through The Circuit, Due To The High Resistance Of Nichrome, Heat Is Generated That In Turn Rises The Temperature Of The Fabric (Figure 1). The Colour Of The Samples Have Been Quantitatively Analysed By Capturing The Sample Image Using A Digital Camera And The Images Were Transferred To A PC. The Captured Images Were Analyzed For Colour Value Of The Samples Using The Colour Analysis Software. The Colour Values Obtained Were In RGB Colour Space That In Turn Converted To CIE XYZ And CIE Lab* Colour Space Value. By Plotting The Colour Density Values Against Temperature, The Colour Behavior Of The Sample Were Analysed. The Samples In Reference With The Bleached White Fabric Were Imaged To Normalize The Image Brightness To Avoid The Noise Factors Due To Light Source, Sample Holding Height And Other Variations In The Settings Of The Camera [9]. The Wash Fastness Of The Sample Was Analysed Using The Standard Of AATCC 61 And It Was Evaluated Using The Colour Fastness Tester By Pinning The Coloured Sample With The Piece Of Standard Fabric. The Sample Was Then Washed With Standard Soap Solution Followed By Rinsing And Drying. The Samples Were Then Tested For Its Colour Change And Colour Stain On To The Adjacent Fabric In Reference With The Standard Grey Scale. The Samples Were Tested For The Wash Fastness Property At Different Levels Of 5, 10 And 15 Wash Cycles.

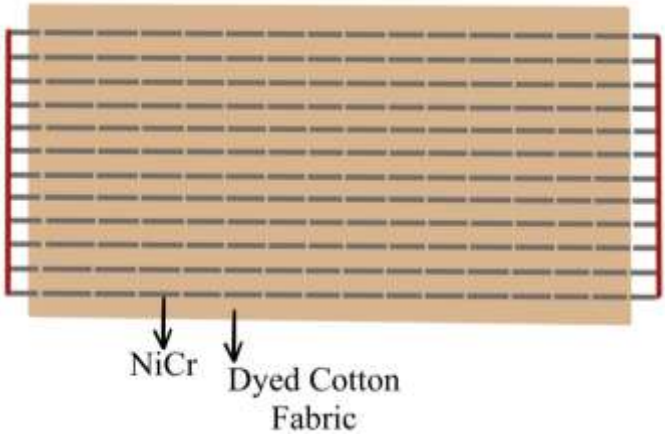

Figure 1. Electrical Connection (Parallel) Between The Wires For Current Passage

3. RESULTS AND DISCUSSION

Temperature Sensitivity Analysis

Table 2 Shows The Change In Colour Value Of The Thermochromic Dyed Fabric Subjected To Varying Heat From 21^0C To 31^0C. Figure 2 Shows The Change In Colour From Cadet To Oliver Green On Temperature Variation. From Table 2 Showing The Corresponding L* A* B* Value Of The Colours, It Is Observed That The Lightness Value Of The Fabric Dyed With Thermochromic Dye Increases With Increase In Temperature And Fabric Becomes Paler With The Increase In Temperature. The Corresponding A* And B* Value Of The Thermochromic Dyed Sample Relatively Increases With The Increase In Temperature. Thus, The Colour Of The Fabric Changes From Grayish Blue To The Olive Green With The Application Of Temperature. While Comparing The Thermochromic With Coffee In The Ratio Of 1:1 For Both With And Without Mordant, The Lightness Value Decreases Upto 25^0C And Then Increases. The Corresponding A* And B* Value Also Relatively Increases And Then Decreases. While Considering The Thermochromic With Coffee Dyed Fabric In The Ratio Of 1:2 And 2:1 Show A Considerable Increase In B* Value With The Temperature. Whereas, With Respect To The A* Value, Both 1:2 And 2:1 Samples Show A Considerable Variation By Varying The Temperature.

Table 2 Lab Value For The Thermochromic Dyed Sample

Temp.	**Thermochromic Dye**			**Thermochromic: Coffee (1:1) (Without Mordant)**			**Thermochromic: Coffee (1:1) (With Mordant)**			**Thermochromic: Coffee (1:2) (With Mordant)**			**Thermochromic: Coffee (2:1) (With Mordant)**		
	L	**A***	**B***	**L**	**A***	**B***	**L**	**A***	**B***	**L**	**A***	**B***	**L**	**A***	**B***
21	90.19	-19.24	-9.54	105.17	-3.01	-1.59	100.82	-2.76	12.26	106.40	-3.01	-1.59	106.47	-5.60	3.34
23	91.92	-12.51	-4.74	96.51	-1.96	11.07	96.38	-2.89	13.95	108.17	-6.40	0.91	109.19	-8.95	7.84
25	93.46	-13.77	-2.45	88.98	-2.16	18.24	88.98	-2.16	18.24	109.10	-0.35	7.09	110.99	-5.90	5.27
27	95.06	-14.7	-0.07	89.25	-1.94	12.37	94.24	5.34	8.92	110.49	-1.94	10.80	112.63	2.10	3.37
29	101.19	-12.21	8.56	91.45	-4.41	9.29	95.71	0.17	16.64	112.42	-0.80	18.12	114.67	2.43	11.39
31	107.43	-12.33	17.66	90.34	-1.04	6.15	95.87	-0.90	18.91	113.18	-0.66	17.67	117.20	3.96	11.43

Effect Of Temperature On A* And B* Values

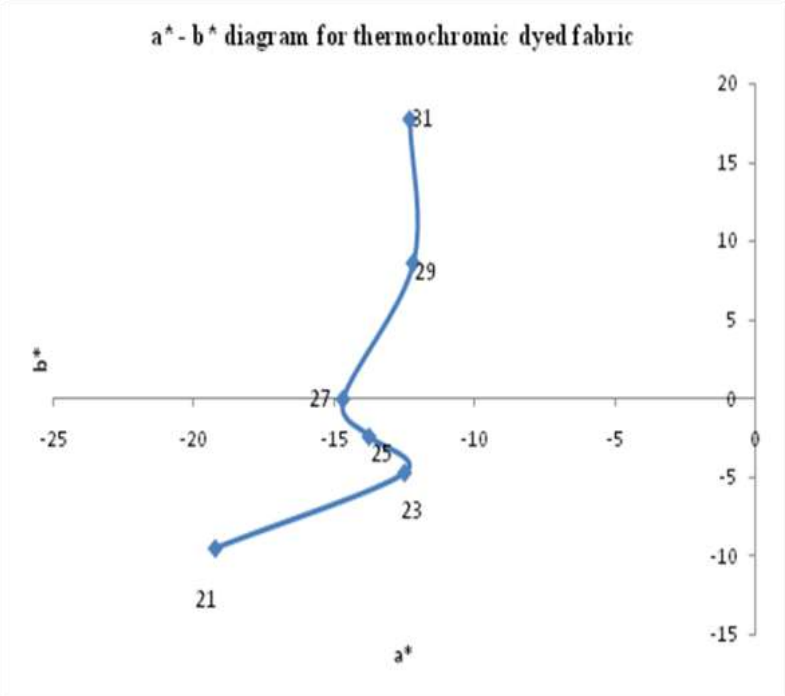

Figure 2. A* And B* Diagram For The Thermochromic Dyed Sample At Different Temperatures

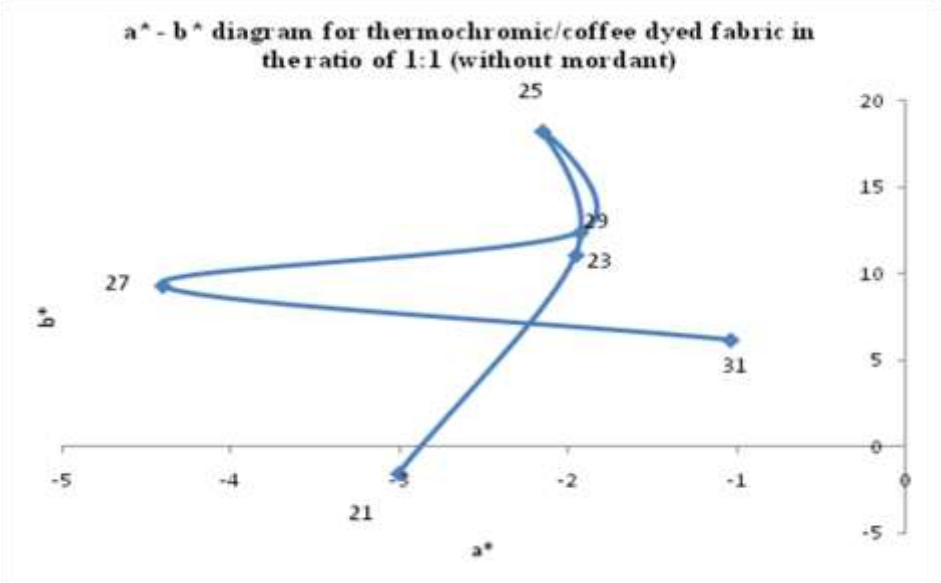

Figure 3. A* And B* Diagram For The Thermochromic/Coffee Dyed Sample In The Ratio Of 1:1 (Without Mordant) At Different Temperatures

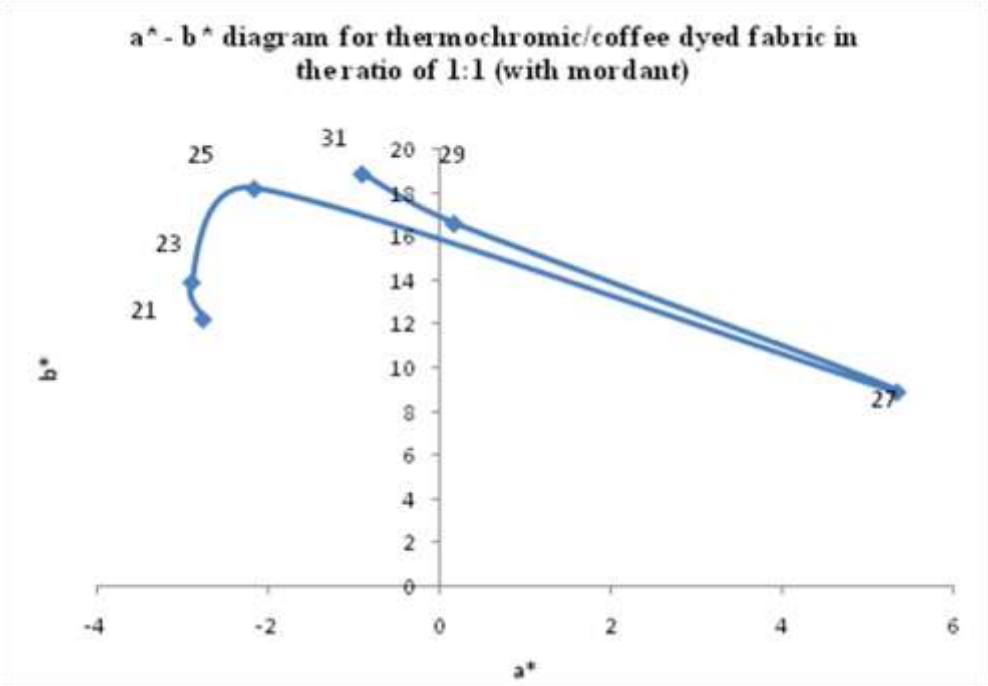

Figure 4. A* And B* Diagram For The Thermochromic/Coffee Dyed Sample In The Ratio Of 1:1 (With Mordant) At Different Temperatures

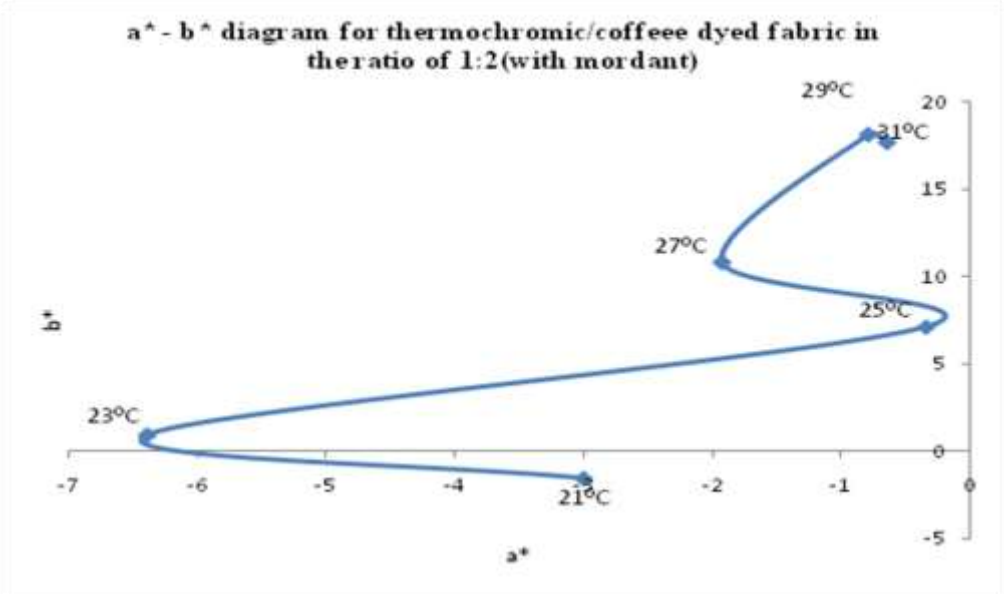

Figure 5. A* And B* Diagram For The Thermochromic/Coffee Dyed Sample In The Ratio Of 1:2 (With Mordant) At Different Temperatures

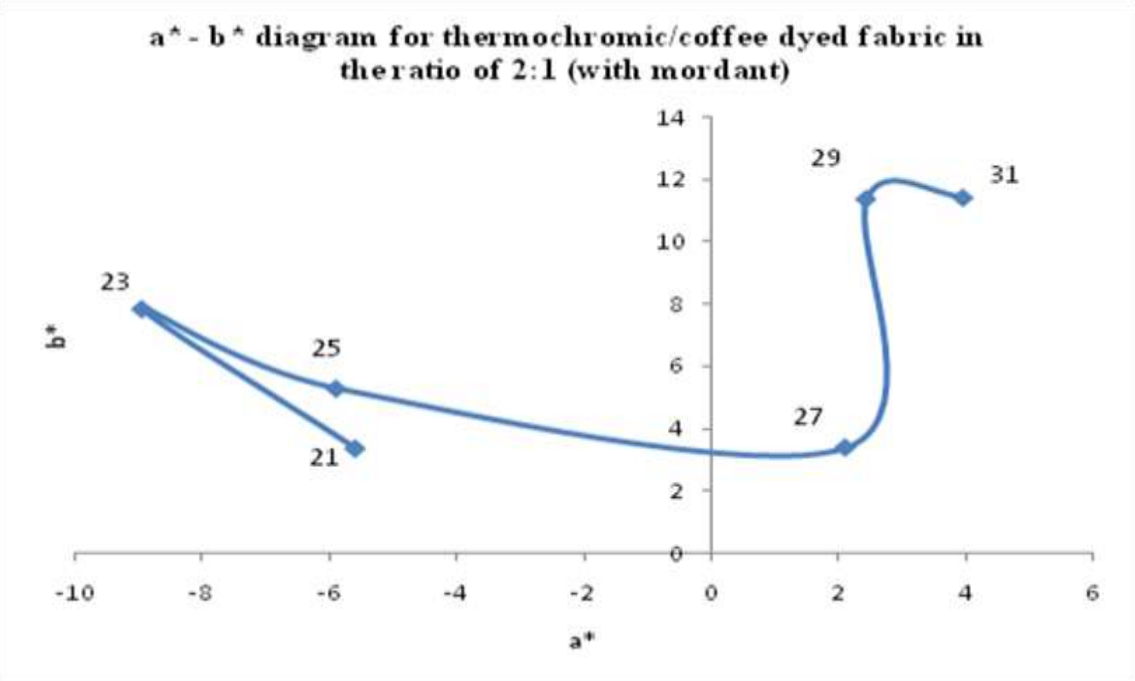

Figure 6. A* And B* Diagram For The Thermochromic/Coffee Dyed Sample In The Ratio Of 2:1 (With Mordant) At Different Temperatures

A* And B* Values Over The Temperature Range Of 21^0C To 31^0C For Different Combinations Of Thermochromic And Coffee Dyed Samples Are Shown In Figures (2-6). In The Case Of Thermochromic Dyed Sample, The Colour Of The Sample Changed To Olive Green From Grayish Blue With The Increase In Temperature. The Colour Changes Gradually With The Increase In Temperature In The Case Of Thermochromic Dyed Sample. Considering The Fabric Dyed With Thermochromic Dye And Coffee In The Ratio Of 1:1, The Colour Change From Bluish Shade To Greenish Shade Of Khaki At Lower Temperature Of 21^0 To 23^0C. It Is Also Observed That Beyond 23^0C Due To The Interaction Of Coffee, The Fabric Getting Paler As Thermochromic Dyed Sample With The Increase In Temperature Is Restricted. This Is Because The Thermochromic Pigment Fades Completely With The Higher Temperature That Creates A Possibility Of Transitions Between Different Hues By Adding The Natural Pigment With The Thermochromic Pigments [10]. Similar Trend Is Followed For The Fabric Dyed With Thermochromic And Coffee Withmordant. The Difference Obtained Between The Sample Dyed With And Without Mordant Is That The Dyed With Mordant Shows More Darker Shade Than The Other One. This Is Due To The Increased Depth Of Dyeing Due To The Presence Of Mordant In The Dye Combination.

In The Case Of Thermochromic Dyed With Coffee In The Ratio Of 1:2 With Mordant Shows A Colour Change From Khaki To Cinereous Shade With The Increase In Temperature. It Is Also Observed That The Colour Transition Occurs In The Greener Region Due To The Less Interaction Effect Of The Thermochromic Dye Of Its Less Proportion Compared To Coffee. In The Case Of Thermochromic Dyed With Coffee In The Ratio Of 2:1 With Mordant Shows A Colour Change From Khaki Green To Yellowish Khaki Shade With The Increase In Temperature. It Is Also Observed That The Colour Transition Is Wider When Compared To The Other Dyes Due To The Contribution Of The Thermochromic Dye

Towards Colour Change Of Its More Proportion And Coffee For Varying Colour Combinations Than Obtained With The Thermochromic Dye Separately.

Wash Fastness Of Samples

In This Study, Comparative Analysis Of The Thermochromic Colour Build Up On A Sample Before And After Wash At Varying Temperatures Was Measured To Understand The Wash Fastness Behavior Of The Samples (Table 3). It Was Found That Different Coloured Samples Show Different Wash Fastness Performances. The Colour Difference Among Unwashed, After 5 Wash And 10 Washes Show Better Result With Respect To Thermochromic With Coffee In The Ratio Of 2:1 Followed By Thermochromic Dye And Thermochromic With Coffee Dyed In The Ratio Of 1:2. It Is Also Observed That The Fabric Samples Dyed In The Presence Of Mordant Shows Lesser Colour Difference Between Unwashed And Washed Samples. This Is Mainly Due To The Increased Fixation Of The Dyes With The Presence Of Mordant.Thus It Can Be Inferred That The Thermochromic In Combination With Coffee Showed Fair To Acceptable Fastness To Washing.

Table 3 Colour Fastness Values Of The Samples After Washing

Sample	**Thermochromic Dye**	**Thermochromic: Coffee (1:1) (Without Mordant)**	**Thermochromic: Coffee (1:1) (With Mordant)**	**Thermochromic: Coffee (1:2) (With Mordant)**	**Thermochromic: Coffee (2:1) (With Mordant)**
Unwashed	-	-	-	-	-
After 5washes	2.31	22.02	4.38	3.81	0.24
After 10 Washes	7.00	22.73	7.61	6.99	5.24

4. CONCLUSION

The Fabric Was Dyed Using Thermochromic And Coffee Combination And The Coloured Samples Were Converted From One Chromatic State To The Other State By Increasing The Temperature By Passing The Current Through The Conductive Fabric. A Rise In Temperature Lead To A Gradual Shift In The Reflectance Values Of The Coloured Sample. It Was Analysed By The L, A* And B* Values Of The Dyed Samples. The Wash Fastness Properties Of The Dyed Samples Were Analysed And It Was Found To Be In A Fair Acceptable Level Under Repeated Washing Cycles. Hence, Through This Study It Is Found That The Thermochromic In Combination With Coffee Dyed Sample Can Change Colour In Response To The Change In Current Passing Through It. Thus, We Can Make A Camouflaging Textile Material With The Thermochromic And Natural Agent Through Which Different Colour Changing Effect Achieved Apart From The Transition Occurred Through The Thermochromic Dye Alone. As The Colour Changing Effect Is Controlled By The Circuit, The Camouflaging Effect Can Be Activated In Need.

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