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COLORFASTNESS TO CROCKING AND LAUNDERING OF DIGITALLY PRINTED COTTON FABRIC

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Abstract

New technologies have been used to add value to cotton and other natural fibers to increase their utilization. Coloration continues to be an important area of textile processing because the appearance of color is the most important visual aspect of fabric. Digital textile printing is a relatively new technology in the textile and apparel industry that allows for computerized designs to be instantly printed directly onto fabric. The potential for this technology in mass customization is enormous. One of the major problems associated with digital textile printing is regarding color prediction and colorfastness. There is limited information on color characteristics of digitally printed fabrics, therefore research is needed in this area. The purpose of this study was to determine the colorfastness of digitally printed cotton fabrics to crocking and laundering. Samples were subjected to three methods of laundering and to wet and dry crocking. Color change was evaluated visually and instrumentally using a spectrophotometer. Results indicated that digitally printed cotton fabric was colorfast to crocking (wet and dry). Moderate color loss occurred when the samples were subjected to hand washing and home/commercial machine washing. Accelerated washing and drying produced the greatest color loss. There was no significant difference in the color loss between hand washing and machine washing. It is concluded that digitally printed cotton fabrics do not need delicate care methods and can be safely machine-washed under normal conditions.

Introduction and Background

Cellulosic fibers such as cotton are widely used in the textile industry. Cotton is the most important of the natural cellulosic fiber (Needles, 1986). Currently, cotton is the world's best selling fiber, accounting for 61.5% of the total retail and home furnishing markets (Cotton Board, 2002). New technologies have been used to add value to cotton and other natural fibers to increase their utilization. Many such technologies are related to coloration of textile products. Applying color to a textile product is a common procedure that can occur at the fiber, yarn, or fabric stage (Hudson et. al, 1993). This can be accomplished by printing or dyeing, both of which are old crafts (Kuehni, 2002). Dyeing can be an extremely costly fabric finishing step and may not respond to fashion changes (Dickerson et. al, 1999). Conventional printing technologies such as screen printing require significant investments in screens and are designed for printing large volumes of fabrics. Digital textile printing is a relatively new technology in the textile and apparel industry that allows for computerized designs to be instantly printed onto fabric in the needed amounts (King, 2002).

Digital printing of cotton is important because it can expand the use of cotton in niche markets related to customized products. Digital ink-jet printing has gradually progressed technologically in terms of developing digital systems for low-volume production. Current technological developments of digital inkjet systems suggest and strongly support an increasing future role in the apparel industry for digital textile printing (Owens, 2001; King, 2002). Digital printing could possibly become a viable alternative to roller screen printing (George et. al, 2002). If this happens, color characteristics of fabrics would be of great concern.

The appearance of color is the most important visual aspect of fabric (Dupont et. al, 2001). Color is the primary reason why products are selected and hence consumers of textiles are drawn to them because of their color (Hudson et. al, 1993). Although color may fade with time and use, maintaining fabric color for the duration of its intended use is a major concern for the end-user of a textile product. Color changes occurring after a textile product has been created may be the result of numerous factors including the color application process, the pre and/or post treatment of the finished product, poor care of the item, unforeseen abuse, or excessive use. With the dawn of digital textile printing using inkjet and other technologies, the possibilities of fabric surface design have increased dramatically. One of the major problems with digital textile printing is regarding color prediction and colorfastness. Because of complexities of computerized color, the colors appear differently on the computer screen and on the printed fabrics because of different colors systems of computers and printers. Computers use the RGB (Red, Green and Blue) color space while the printer output is based on CMYK (Cyan, Magenta, and Yellow). Additionally, processing of the printed fabrics through steaming tends to brighten the colors and rinsing removes some colors. It is therefore important to scientifically quantify color behavior of digitally printed fabrics for facilitation of color prediction.

The process of digital textile printing involves three distinct stages. These stages are: 1) Fabric preparation, which includes pre-treatment and backing with paper if needed, 2) Printing a digital image directly on fabric using a digital fabric printer, and 3) Post-treatment of the fabric by steaming and rinsing with a rinse-aid. Steaming is essential for color penetration and for producing favorable results (Palmer, 2002).

Although this new technology has promising potential for the textile industry, changing printer technology, fabric pre-treatment, steaming, and other finishing processes are some of the variables that present a challenge in color prediction and control (King, 2002). There is need, therefore to conduct research to determine performance characteristics of digitally printed fabrics, especially colorfastness. No studies have been identified that are related to colorfastness of digitally printed fabrics. The purpose of this study was to determine colorfastness of digitally printed cotton to laundering and crocking. Specific objectives of this study were to:

1. determine the colorfastness of digitally printed fabric to crocking;
2. determine the colorfastness of digitally printed fabric to laundering.

This study provides new information that will assist scientists, businesses (small and large) and individuals to produce digitally printed fabrics that meet rigorous quality requirements of consumers.

Materials and Methods

Fabric Printing

The samples used in this study were obtained from two yards of 100% cotton sheeting. The ready to print fabric (coated and paper backed) was purchased from Jacquard Inkjet Products Inc. A print design was created using U4ia™ software and was printed on the fabric surface by the Encad® 1500 TX Digital Textile Printer using reactive dyes. After removal of paper backing, the fabric was allowed to air dry for five minutes at room temperature. The fabric was then prepared for steaming by placing it on mesh netting, rolling it around a stainless steel core, covering it with newsprint paper, and securing it at both ends with rubber bands. It was placed in a vertical fabric steamer and steamed for one hour at 245°F (120°C). Following the steaming process, the fabric was post-treated with a rinsing agent twice in warm water for five minutes and rinsing it in cold water for three minutes.

Experimental Design

A completely randomized balanced design with five replications was used. For colorfastness to crocking, there were three levels of the independent variable: wet crocking, dry crocking, and the control (not exposed to crocking). The dependent variable was the color transfer rating as determined by the AATCC 9-Step Chromatic Transference Scale. For colorfastness to laundering after laundering, there were four levels of the independent variable, namely, the control (no laundering), hand washing, home/commercial machine washing, and accelerated washing and drying. There were four dependent variables for colorfastness to laundering: L, a, b, and ΔE , where L = lightness and darkness, a = amount of red and green, b = the amount of yellow and blue, and ΔE = overall color change. To investigate staining after laundering, there were three levels of the independent variable: hand washing, home/commercial machine washing, and the control (not laundered). The dependent variable was the color transfer rating as determined by the AATCC 9-Step Chromatic Transference Scale.

Evaluation of Colorfastness

AATCC Test Method 8: 2001 (Colorfastness to Crocking: AATCC Crockmeter Method) was used to determine colorfastness. An electronic Atlas Crockmeter CM-5 was used to test five dry and five wet samples. Colorfastness to laundering was determined according to AATCC Test Method 61-2001 (Colorfastness to Laundering Home and Commercial: Accelerated) using an Atlas LHT Launder-O-Meter. Test 1A (Handwash) and Test 2A (Commercial Wash) were done. Five samples were used for each test. Colorfastness to accelerated washing and drying was determined by using the Raitech Quickwash system. Five samples were used for this test. Each sample was placed in an individual chamber and was subjected to a pre-set program that included one wash, three rinse, and three drying cycles at pre-determined temperatures and cycle times. Table 1 shows program settings used for this procedure.

Determination of Color Change

Color transfer after crocking, and staining after laundering was evaluated using AATCC Evaluation Procedure 8 (AATCC 9-Step Chromatic Transference Scale). Six trained reviewers independently completed visual assessment of samples following the crocking and laundering test procedures. The samples were evaluated at a 45° angle, underneath a north sky light source in the Variloux™ light chamber.

Instrumental assessment of color change of the laundered samples was done according to AATCC Evaluation Procedure 6:2001(Instrumental Color Measurement) using the Color Guide 45/0. Readings were taken from random locations of each sample due to the print design. For this study, the CIELAB color system was used based on AATCC standard procedures. The results of the color readings from the spectrophotometer are reported as **L, a, b** values where **L** indicates lightness or darkness with values ranging from zero (black) to 100 (white), and **a** indicates the amount of red and green in a color. Red is indicated by a positive value and green is indicated by a negative value. The **b** indicates the amount of yellow and blue with yellow having a positive value and blue having a negative value. Overall color change is indicated by **ΔE** which was determined according to the following formula: $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$.

Statistical Analysis

Data obtained by instrumental color measurement was analyzed using SPSS version 10.0 to determine if there was significant differences in **L, a, b** and **ΔE** after the treatments. The General Linear Model (GLM) procedure was used to analyze the data. A significance level of $p<0.05$ was used. The statistical model used was as follows:

$$Y_{i,j} = \mu_i + \tau_i + e_{,j(i)}$$

where
y_{ij} is the value of the dependent variable for sample *j* receiving treatment *i*,
μ is the overall mean for the dependent variable,
τ_i is the effect of treatment *i* on the dependent variable, and
$e_{j(i)}$ is the effect of j^{th} sample receiving treatment *i*.

Results and Discussion

Color Transfer (Colorfastness to Crocking and Staining after Laundering)

The samples subjected to dry crocking received an average rating of 5 on the chromatic transference scale indicating that there was no color transferred. The samples subjected to wet crocking received an average rating of 4.5 indicating minimal color transfer. The digitally printed cotton fabric had more colorfastness to dry crocking than wet crocking. Multifiber fabrics that were attached to the laundered samples were evaluated for staining using the AATCC Chromatic Transference Scale. No staining was observed in either hand washing or home/commercial machine washing.

Color Change After Laundering

Statistical analysis of color change after laundering data indicated that there were no significant differences ($p<.05$) in L for all treatments. Table 2 shows the means and standard deviations to all treatments and Table 3 shows comparison of means for all treatments. Figure 1 is the plot of **L** values for all treatments. For **a** (green – red), there was a significant difference ($p<.05$) between home/commercial laundering and accelerated washing and drying (see Table 2, Table 3, and Fig. 2). The accelerated washing and drying sample had more green color than commercial/home laundering sample. For **b** (blue – yellow), there were significant differences between the control and all the treatments (see Table 2, Table 3, and Fig. 3). The hand washed and machine washed samples had less yellow than the control and the accelerated wash/dry sample had more yellow than the control. There were significant differences ($p<.05$) between the accelerated washing and drying sample and all the other treatments. There was no significant difference between the hand-washed sample and the machine washed sample.

In evaluating overall color change the mean values for different treatments were compared. Results indicated that there were significant differences ($p<.05$) between the control and all the treatments. The accelerated washing/drying displayed the highest loss of color. There was no significant difference in color change between hand washed and home/commercial machine washed. Accelerated washing and drying produced significant differences in overall color change as compared to all treatments (see Table 2, Table 3, and Fig. 4). The **ΔE** values were converted to AATCC Gray Scale grades according to AATCC Evaluation Procedure 7 (Instrumental Assessment in the Change of Color of a Test Specimen). The hand washed and the home/commercial machine samples had a grade of 3-4 indicating moderate color loss with an increase in yellowness. The samples subjected to accelerated washing and drying had a grade of 2-3 – indicating high color loss with an increase in yellow and green hue (See Table 4).

Discussion

The anticipated color changes occurred at different stages of processing the fabric. The fabric color changed from the printing, steaming and treatment stages and throughout testing. After steaming, the color became bolder, vibrant, or more intensified. Further color loss occurred due to rinsing after steaming. Results of colorfastness testing indicated that there was overall loss of color when the fabrics were washed. The fabrics, however did not transfer color to other fabrics through staining or crocking. This means that digitally printed fabrics can be safely washed with other fabrics. The color loss due to hand-washing was not significantly different from color loss due to home/commercial machine washing although they both had moderate color loss compared to the control as indicated by the gray scale grade. These results indicate that digitally printed cotton fabrics are moderately colorfast and do not require special laundering. They can be machine washed without significant loss of color compared to other delicate methods. Accelerated washing and drying produced higher color loss than hand or machine washing. The gray scale grade of 2-3 indicates high color loss. This may be attributed to the fact that this is a more vigorous method that was based on an automated program of one wash cycle, three rinse and three drying cycles using a specialized machine (Quickwash[R] by Raitech[R]). The hand and machine washing were done using a launder-o-meter and the fabrics were hand rinsed and machine dried. The accelerated washing and drying cycle has been standardized by AATCC for shrinkage testing to simulate actual effects of washing and drying on the dimensional stability of fabrics. No studies had been done before to show the effects of washing and drying on colorfastness of digitally printed cotton fabrics. This method simulates conditions of actual laundering of fabrics and hence the effects of drying on colorfastness could be assessed. The results of this study therefore provide new information on the use of this testing method for colorfastness determination.

Conclusions

Processing of digitally printed fabrics produced definite changes in color. Steaming intensifies the color and washing causes some color loss. The results also indicated that digitally printed fabrics could be hand-washed or machine-washed with no effect on color loss. Color change increased with the intensity of washing with color loss being greater when the fabric was subjected to accelerated washing and drying. The accelerated washing test added the component of drying, which may affect colorfastness. The results of this study yielded new information on the effect of accelerated washing and drying on colorfastness of digitally printed fabrics. Digitally printed cotton fabric is moderately colorfast to commercial/home washing. More fading should be expected with machine drying. It is recommended that further studies on colorfastness and color change studies be conducted on different fibers and fabrics to determine the impact of fabric geometry and fiber content on the colorfastness of digitally printed fabrics.

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Table 1. Quickwash[R] Program Settings for Accelerated Washing and Drying Test.

Program Operation	Number of Cycles	Time per Cycle, s	Temperature, °C
Wash	1		60 °C
Agitation Time		165s	
Rinse/dry	3		60 °C
Agitation time		45s	
Spin time		35s	
Dry time		240s	
Air pressure, 3.8 bars			
Water level, 3L			

Table 2. Means and Standard Deviations of L* a* b* and ΔE for All Treatments.

Dependent Variable	Treatment	Mean	Standard Deviation	N
L	**Control**	89.24	0.25	5
	Hand Wash	89.86	1.01	5
	Home/Commercial Machine Wash	89.89	0.40	5
	Accel. Wash/Dry	89.79	0.03	5
	Total			20
a	**Control**	-7.13	0.34	5
	Hand Wash	-7.27	0.43	5
	Home/Commercial Machine Wash	-7.02	0.74	5
	Accel. Wash/Dry	-7.72	0.21	5
	Total			20
b	**Control**	48.09	0.62	5
	Hand Wash	46.56	1.08	5
	Home/Commercial Machine Wash	46.82	0.66	5
	Accel. Wash/Dry	52.13	0.98	5
	Total			20
ΔE	**Control**	0.00	0.00	5
	Hand Wash	2.59	0.34	5
	Home/Commercial Machine Wash	2.24	0.42	5
	Accel. Wash/Dry	4.51	0.93	5
	Total			20

Table 3. Multiple Comparison of Means (LSDTest) for the Effect of Laundering Method on Colorfastness of Digitally Printed Cotton Fabrics.

Dependent Variable		Control	Treatment Hand Wash	Home/Commercial Machine Wash	Accel. Wash/Dry
L	**Control**		0.102	0.089	0.145
	Hand Wash	0.102		0.942	0.841
	Home/Commercial Machine Wash	0.089	0.942		0.784
	Accel. Wash/Dry	0.145	0.841	0.784	
a	**Control**		0.666	0.709	0.067
	Hand Wash	0.666		0.424	0.146
	Home/Commercial Machine Wash	0.709	0.424		0.032
	Accel. Wash/Dry	0.067	0.146	0.032*	
b	**Control**		0.013*	0.035*	0.000*
	Hand Wash	0.013*		0.635	0.000*
	Home/Commercial Machine Wash	0.034*	0.635		0.000*
	Accel. Wash/Dry	0.000*	0.000*	0.000*	
ΔE	**Control**		0.000*	0.000*	0.000*
	Hand Wash	0.000*		0.320	0.000*
	Home/Commercial Machine Wash	0.000*	0.320		0.000*
	Accel. Wash/Dry	0.000*	0.000*	0.000*	

* $p < 0.05$

Table 4. Gray Scale Grades for Laundered Samples (Converted from **ΔE** Values)

Treatment	Gray Scale Grade	Meaning
Hand Wash	3-4 Yellower	No significant change in lightness or but change in hue in yellow direction.
Home/Commercial Machine Wash	3-4 Yellower	No significant change in lightness or but change in hue in yellow direction.
Accelerated Washing and Drying	2-3 Greener	No significant change in lightness or but change in hue in green direction.
	2-3 Yellower	No significant change in lightness or but change in hue in yellow direction.

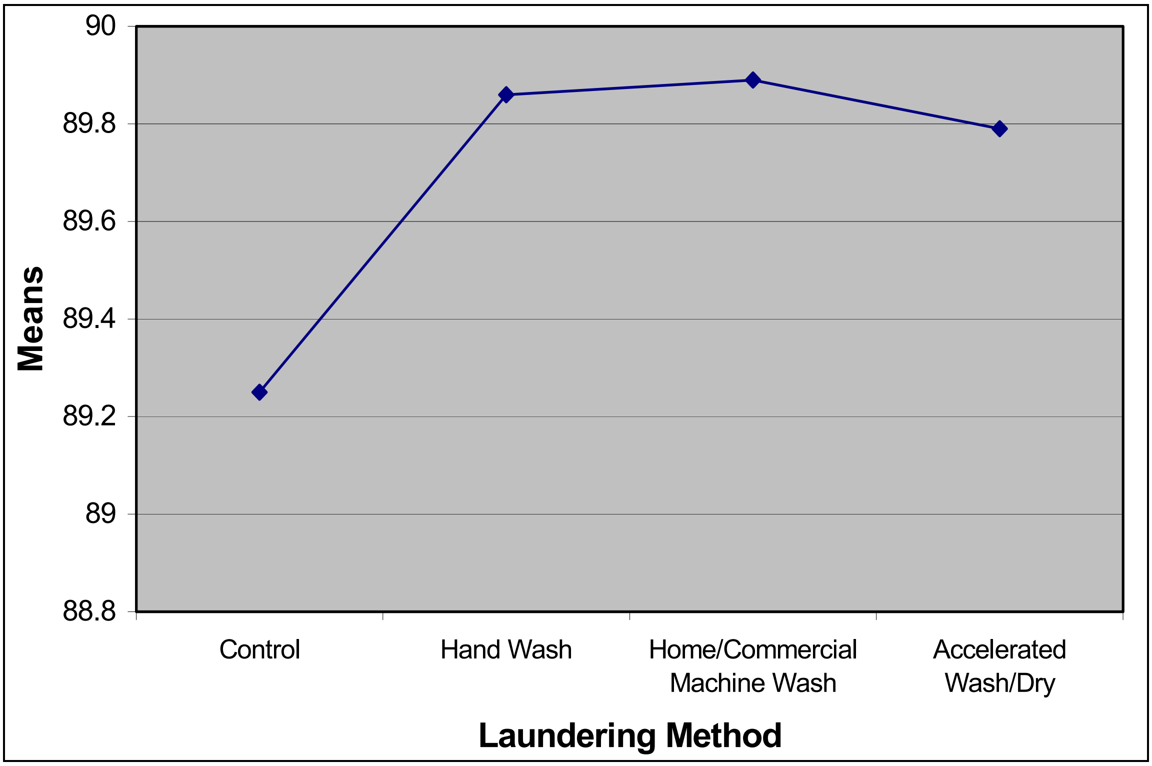

Figure 1. Changes in **L*** after Laundering.

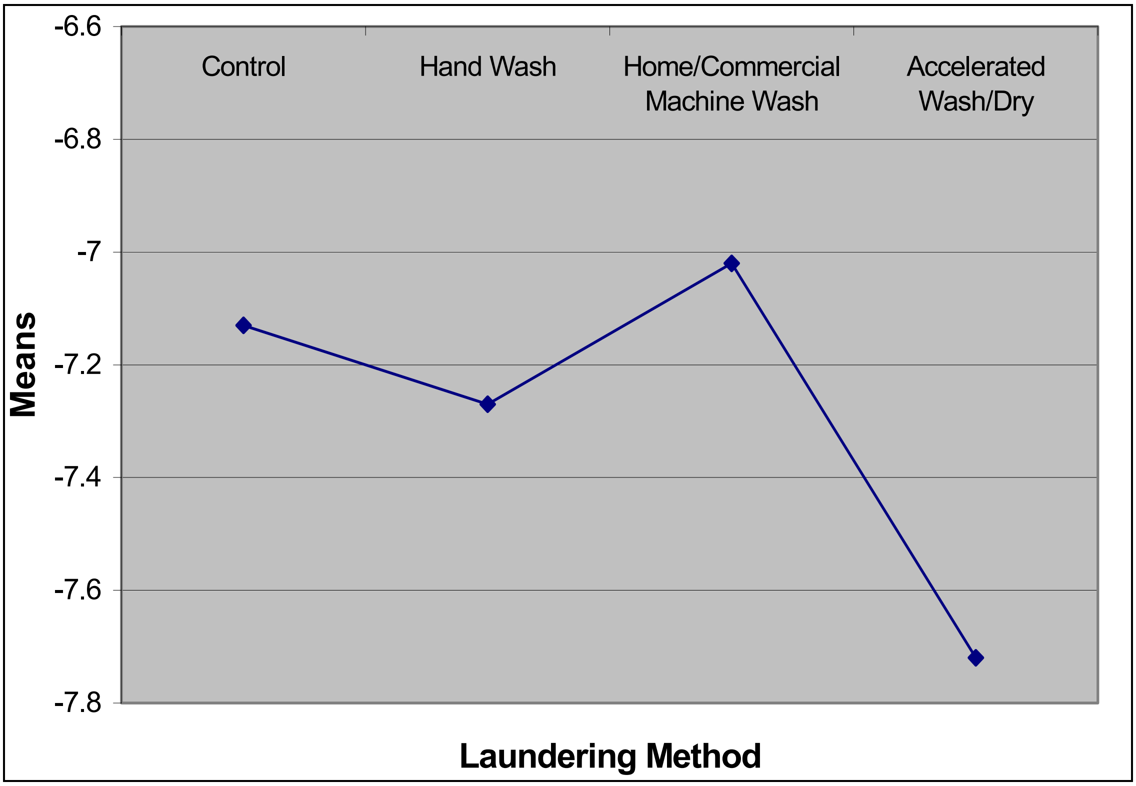

Figure 2. Changes in **a*** after Laundering.

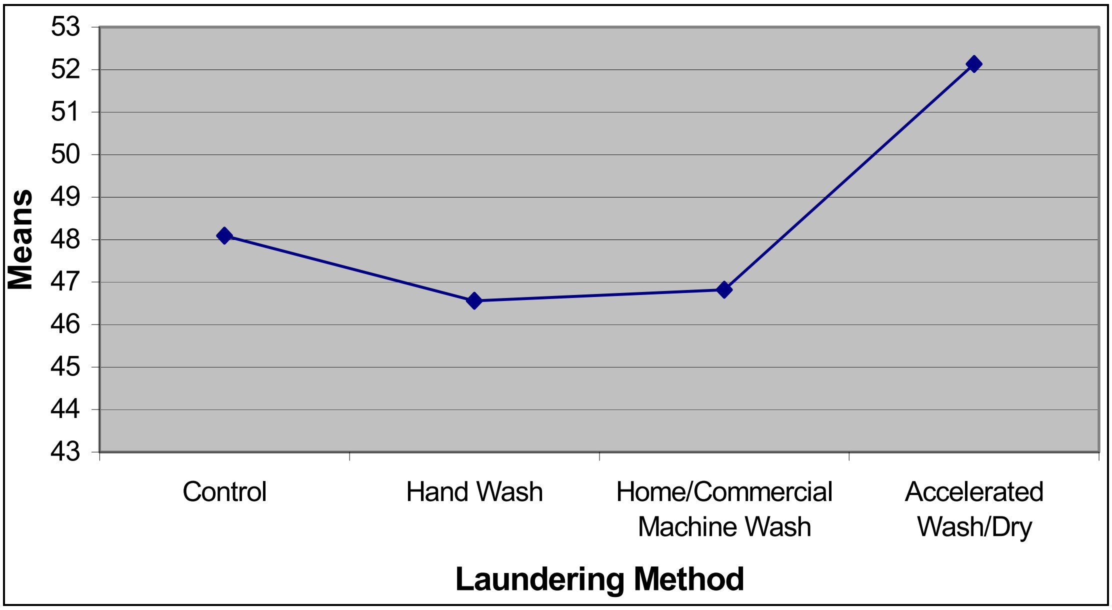

Figure 3. Changes in **b*** after Laundering.

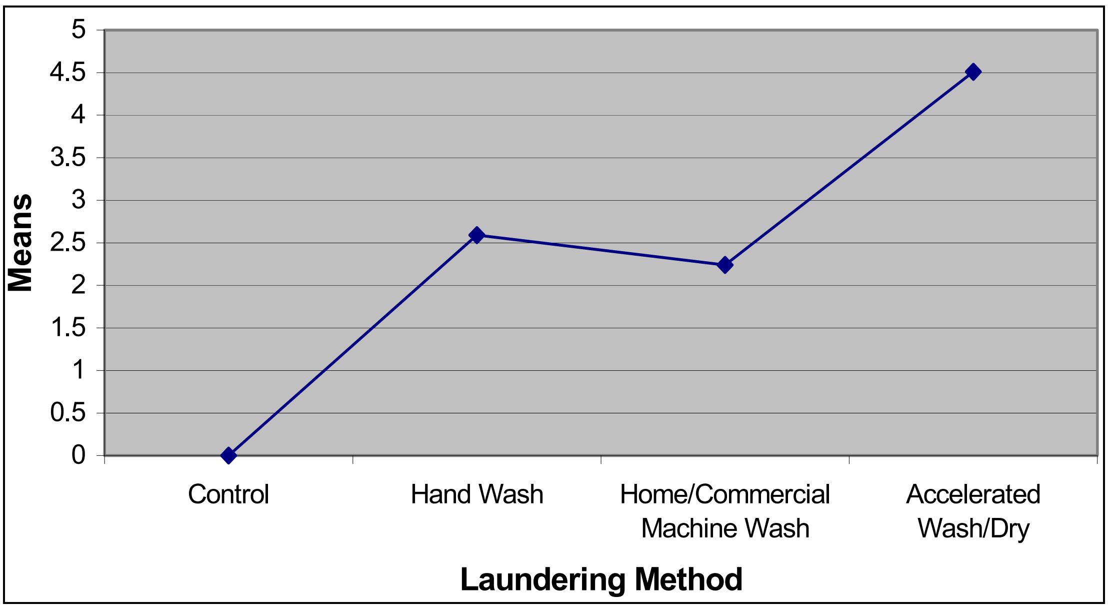

Figure 4. Overall Color Change **ΔE** After Laundering.