

PRINTING OF CELLULOSE-BASED FABRICS WITH SODIUM HYDROXIDE AND INVESTIGATING COLOR EFFICIENCY AND FASTNESS PROPERTIES OF THESE FABRICS

SODYUM HİDROKSİT KULLANILARAK SELÜLOZ ESASLI KUMAŞLARA BASKI EFEKTİ VERİLMESİ VE BU KUMAŞLARIN RENK VERİMİ VE HASLIK ÖZELLİKLERİNİN İNCELENMESİ

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ABSTRACT

In this study, it was aimed to gain printing effect on cellulose based fabrics without using dye in printing paste. Samples having different fabric weights and patterns were colored with reactive dyes by pad-batch method after they had been printed with paste containing sodium hydroxide instead of dye. Color efficiency of each printed sample was detected under different light sources and their fastness values were investigated. By this suggested method, it could be possible to gain printing effect to different fabrics. However printing accuracy was strongly related with color and fabric weight. On the other hand, fastness properties of all printed samples were generally observed in the range of 4 and 5 grades.

Key Words: Printing, Sodium hydroxide, Cellulose-based fabric, Fastness, Color efficiency.

ÖZET

Bu çalışmada, selüloz esaslı kumaşlara pat içerisinde boyar madde kullanılmaksızın baskı efekti kazandırılması amaçlanmıştır. Farklı dokuma tipine ve kumaş ağırlığına sahip numuneler, boyarmadde yerine sodyum hidroksit içeren baskı patı kullanılarak şablon baskı yöntemiyle baskılandırılmış ve sonrasında emdirme yöntemi ile renklendirilmişlerdir. Baskılı kumaşların farklı ışık kaynakları altındaki renk verimleri gözlenmiş ve haslık değerleri ölçülmüştür. Bu yöntem ile selüloz esaslı kumaşlara baskı etkisinin kazandırıldığı, baskı netliğinin kullanılan renk tonuna ve kumaş ağırlığına göre değiştiği tespit edilmiştir. Kumaşların haslık değerlerinin ise 4 ve 5 aralığında değişen değerlerde seyrettiği gözlenmiştir.

Anahtar Kelimeler: Baskı, Sodyum hidroksit, Selüloz esaslı kumaş, Haslık, Renk verimi.

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1. INTRODUCTION

Textile printing is the application of color to fabric surface in definite patterns or degradation of a colored textile surface. On the other hand, dyeing is the process of coloring whole surface of a textile material. All textile components and structures can be dyed but only textile fabrics or fabric-

like structures can be printed. After dyeing process, a unique color is available on fabric surface however printing process makes it possible to have different colors on the same kind of fabric and multi-colored structures can be obtained. Many methods are available to create printing effect but followings are commonly used in textile printing (1).

Discharge printing is one of the most important methods used for introducing design to textile fabrics. Acids, oxidizing or reducing agents, alkalis and various salts can be used to produce pattern by chemical destruction of the original dye in the printed areas. In short, it can be defined as production of a pattern by removing color on ground-dyed fabric.

Various chemical agents and thickener are available in discharge printing paste. If it is preferred to apply a colorful discharging on fabric surface, then dye can be added into this paste. Reactive dyes are suitable for this technique and they can be discharged in neutral, alkaline and acidic conditions. Generally, vat and pigment dyes are used for discharging of reactive dyes (2, 3).

Resist printing is the most versatile printing technique used in textile printing. Fabric is firstly printed with a conservative chemical which does not react with dye agent to be used after printing process. This conservative chemical known as "resisting agent" prevents printed areas from chemical and physical effects (4, 5). There is no visual difference between the appearances of resist printed and discharge printed samples. The difference is only seen on application methods of these two individual techniques. Wax or paraffin behaving as mechanical resisting agents, can be added into printing paste. In this technique, direction of chemical reaction and printing efficiency is strongly affected from chemical additives such as; acids, alkalis, salts, reducing and oxidizing agents (6, 7).

Special printing methods are applicable when a visual effect cannot be obtained by direct, discharge and resist printing techniques. Crinkle, embossed and burn-out effects are gained to fabrics by some special techniques. Emboss printing is one of the most popular techniques to create a three-dimensional image. Definite patterns are printed on fabric surface by heat treatment. It is generally applied on synthetic fabrics and crinkle effect is obtained. These fabrics are not ironed because crinkle effect is disappeared by ironing. To give crinkle effect on non-thermoplastic fabric surface, fabric surface is coated with a synthetic resin and then printing is performed with engraved cylinders (8, 9).

Screen or stencil printing is the oldest, inexpensive and high through-put printing technique. All fabric types can be easily colored by stencil/screen printing technique. Printing efficiency is strictly related with fabric type, dye used in paste, fineness of mesh,

cleanness of equipment and talent of worker. Fineness of mesh is strongly related with its composition. The fibers used for mesh production can be either multifilament or monofilament. Mesh number per unit area affects the pattern quality of printing process. Coarse mesh causes some handicaps such as lack of fixing on stencil and more paste transfer onto fabric (10).

A few studies were performed on discharge printing of fabrics constructed from protein or synthetic fibers. These fabrics were printed with paste containing a kind of reducing agent derived from calcium sulphoxylate formaldehyde. It was aimed to increase stability of paste, obtain clear patterns on fabric surface and avoid wicking and haloing problems seen on acetate and rayon fabrics during discharge printing (11).

The significant and negligible effects of different auxiliary chemical usage were identified by some researches made on resist and discharge printing. Color efficiency of fabric was determined by observing reactions between auxiliary chemicals and textile surface. These chemicals prevented crack occurrence between fiber and dyeing agent during ground-dyeing. In other words, fabric surface was colored without any deformation on printed areas. In case of using different types of these chemicals, color efficiency of fabric decreased. It was also observed that there was no visual difference between resist-printed and discharge-printed samples. Dyeing agent had an important effect on printing and dyeing efficiency (12).

It was investigated that diffused printing effect could be given to polyester, polyester blended and cellulosic fabrics. It was also suggested a novel and applicable printing method for printing of both synthetic and cellulosic fabrics. This method was based on controlling of diffused printing effect with capillary action of auxiliary chemicals. In order to give diffused printing effect, printing paste containing at least a suitable dye according to fiber type should have been consisted of suitable thickening agent, auxiliary chemical having normally capillary action and also capable of dissolving a part of dye (13).

Variable parameters of printing process were analyzed by considering printing speed, stripper type, fineness of pattern and pressure of stripper. Amount of printing paste on fabric, color efficiency, visibility from back side of the fabric and contour sharpness were separately determined for each sample. Increasing printing speed caused a decrease on color efficiency, visibility of printing from back side of fabric and quantity of printing paste transferred onto fabric surface. Visual properties of screen-printed product were seriously affected from fabric properties, finishing treatments, printing speed, surface tension of paste and stripper pressure (14).

The correlation between thickener type and obtained color were also examined. Samples were printed with different paste containing different thickener types and reactive dyes. Fixation efficiency, amount of paste used, printing accuracy and penetration were assessed. It was resulted that high color efficiency was obtained in samples printed with paste containing small amount of alginate. Most of the characteristic properties of printed samples were strongly related with dye type. Printing performance improved by means of adding combination of different thickeners. There was also meant that it was an oblique to select appropriate thickener according to dye (15).

It is known that dyed fabric is generally printed with different colors to give attractive effects. By means of this study, there is no need to dye fabric before printing to gain lighter shades of same color onto fabric surface. Lighter shades can be given by improving absorbability of desired areas on fabric surface. In this experimental study, cellulosic fabrics are printed with printing paste containing sodium hydroxide instead of dye. Their color efficiency and fastness properties are investigated by grey scale rating.

2. MATERIAL AND METHOD

2.1. Materials

Properties of cellulose based fabrics used and pre-finishing applications applied to these fabrics were given in Table 1.

Table 1. Samples and their properties

Fabric	Blend	Warp Ne	Weft Ne	Fabric weight	Pattern	Pre-finishing
Gabardine	100% Cotton	14/1 Combed-Yarn	14/1 Combed Yarn	270 g/m ²	2/2 Z Twill	Singeing-Desizing-Beaching-Mercerizing-Washing-Drying
Obeah	100% Cotton	60/1 Combed Yarn	60/1 Combed Yarn	75 g/m ²	1/1 Plain	Singeing-Desizing-Beaching-Mercerizing-Washing-Drying
Sapphire	50% Polyester 50% Viscose	30/1 Blended Yarn (Polyester&Viscose)	30/1 Blended Yarn (Polyester&Viscose)	192 g/m ²	2/1 S Twill	Washing-Oil removing-Drying-Fixation-Singeing
Axle	100% Viscose	30/1 Viscose	30/1 Viscose	144 g/m ²	1/1 Plain	Singeing-Washing-Drying

2.1.2. Reactive dyes

It is known that reactive dyes are the most versatile coloring agents used for cellulose based fabrics and reactive-dyed cellulosic fabrics have good fastness properties and lustrous appearance. In this study, two different reactive dye recipes were prepared with dyes supplied from KİPAŞ incorporated company. In order to obtain blue and khaki colors, reactive dyes marketed by Dystar Reactive Dyes and Ciba Chemical Company, currently Hunstman.

2.1.3. Alginate thickener

Alginate thickeners are the most economic thickener for reactive dye printing. They do not react with reactive dyes and wash out easily. They are compatible with cellulose-based materials. Avco-tan R330 thickener, a water-soluble and high viscous thickener, was used to improve viscosity of paste. It was supplied from Avco Chemicals.

2.1.4. Auxiliary chemicals

Appropriate auxiliary chemical selection is the key point for coloring of textile surfaces. Because these chemicals determine the efficiency and versatility of coloring process, strength of bonds between textile surface and coloring agent, time consumed for performing corresponding treatment and characteristic properties of treated textile surface. Wetting agent was added into printing paste to increase printing performance and facilitate dye adsorption. Erkantol AS, an effective wetting agent, was obtained from Tanatex Chemical. Sodium silicate and caustic soda were necessary to

prevent paste from degradation and to increase alkalinity of dyeing liquor, respectively.

2.1.5. Sodium hydroxide

It is the most commonly used strong base in textile processing, especially in mercerizing process. Mercerizing of fiber with sodium hydroxide enables greater tensional strength and constituent luster as result of strong swelling effect produced by this chemical. Adhesive characteristics of fiber surface are also improved. High-concentrated sodium hydroxide usage damages textile surface in long lasting processes. Mercerization process is performed during 60 seconds and concentration of sodium hydroxide is between 28 and 30 Be°. (16). In this study, better paste penetration and lustrous effect were obtained by sodium hydroxide having 48 Be° concentration during printing process. On the other hand, it should be considered that efficiency of sodium hydroxide will decrease in dying process because printed samples are dyed with reactive dyes after printing.

2.2. Method

2.2.1. Preparation of printing paste and printing of samples

Printing paste was prepared with sodium hydroxide instead of dye. 167, 6 g alginate thickener was added onto 254, 4 g/l soft water and this mixture was continuously stirred during 24 hours. 1000 g printing paste was prepared by adding 563, 5 g/l sodium hydroxide and 14, 5 g/l wetting agent into this mixture. It was recommended to add thickeners into printing paste in range of 40-60 % by weight (17). But

here, it was not necessary to hold a solid paste on fabric surface. The aim was to apply a little amount of sodium hydroxide onto areas to be colored for being absorbed by fibers on these areas. This application should be restricted on the areas to be printed. Therefore we did not need to prepare high viscous printing paste. As it was seen from the values given above, the printing paste was mostly consisted of sodium hydroxide with more than 50 % by weight. The amounts of thickener and chemicals used in this study were determined by trial and error method with the experiences of printers working in printing departments.

Viscosity of paste was measured as 4, 5 cm per minute by time-driven kinematic viscometer. Samples were printed by screen printing technique. Printing paste was poured on screens covered with silk gauze having 80 meshes and it was completely distributed by stripper. Stripper was used 5 times in one round for each screen. Screens were removed from fabric surface and these printed samples were dried at 120 °C during 45 seconds. After washing with 40 °C mild water, all samples were dried again. It was not possible to notice patterns on fabric surfaces after printing process.

2.2.2. Preparation of dye liquor

It was considered that all agents were compatible with reactive dyeing process. Two different recipes were prepared to obtain khaki and blue colors. For khaki color, 1 g/l wetting agent was mixed with 10 g/l caustic soda. Then 2.1 g/l Levafix Brilliant Blue E-B, 0.68 g/l Levafix Brown E-2R, 0.63

g/l Levafix Yellow E-3RL were added. To get blue color, 9,66 g/l Cibacron Blue C-R, 0,4 g/l Cibacron Red C-BL and 1 g/l Cibacron Yellow C-2R were put into 70 g sodium silicate and 2,3 g/l caustic soda solution. Dyeing recipes were prepared according to the recommendations in dyeing catalogues of Dystar and Ciba (currently Huntsman). 1 liter dyeing liquors were prepared for coloring samples by pad batch dyeing process. There was no reason to perform dyeing process with dye mixtures. These dye components were supplied from dyeing department stocks of KİPAŞ incorporated company without paying any charge.

2.2.3. Dyeing and washing

Samples were colored by pad-batch dyeing process with Mathis Laboratory Pad-Batch Dyeing Machine. Alkalinity of dye liquor was measured as 11,2 by digital pHmeter and average dwell time was kept approximately 10 seconds for all samples. Dyed fabrics were coated with gelatin and rotated during 16 hours for dye fixation and then rinsed during 2 minutes. For reactive washing of dyed samples, 1 liter washing liquor was prepared with 1 g/l Reactive W and 1 g/l Setawash SB. They were supplied from Gemsan Chemistry and Setaş Chemicals, respectively. Washing recipe was prepared according to the reactive washing methods used in fabric dyeing department of KİPAŞ

incorporated company. All samples were washed with this reactive washing liquor at 95 °C during 4 minutes. They were rinsed again and dried at 120 °C during 2 minutes in Mathis Laboratory Drying Machine.

Patterns were clearly appeared on surfaces of all samples after dyeing process. Tone-in-tone effect was observed on printed samples as if each sample had been dyed in two steps. But it should certainly tested printing efficiency and versatility of this technique by some testing methods. After sewing adjacent fabrics to the samples, resistance of samples to washing, water, perspiration, rubbing and light were tested to determine color loss and change of each sample by considering Turkish Standards.

3. RESULTS AND DISCUSSIONS

Color strength differences and fastness properties of samples were investigated. Visual properties of fabrics having different patterns were compared by investigating their percentage color strength values. Printing and dyeing efficiency could be identified by detecting color differences. On the other hand, fastness properties of dyed fabrics should be specified in order to define the strength of bonds between dye agent and fabric. Color strength differences were numerically tested by means of spectrophotometer.

In Figure 1, percentage color strength difference of gabardine fabric is lower than those of other fabrics. The wide range of difference is clearly observed under A/10 light. However a rapid increase is obtained on khaki colored-obeah fabric under different light sources. Its percentage color strength is 20% under D/65 light although it is determined as 25% under TL/84 light. It is observed that percentage color strength differences of other fabrics are linearly increased or decreased, except of obeah fabric.

Percentage color strength differences of blue colored fabrics were illustrated in Figure 2. The highest and the least differences are observed in axle and gabardine, respectively. But wide range of difference is seen on sapphire sample. On the other hand, maximum value is decreased to 30% for blue-colored fabrics.

Fastness can be defined as mechanical, physical and chemical resistance of dye on a textile surface to external factors. Fastness properties of a dyed or printed textile material determine the period of its durability and usability. Washing fastness, water fastness, perspiration fastness, rubbing fastness and light fastness tests were performed for all samples. (18-22). Obtained test results are given in Table 2, 3, 4, 5 and 6.

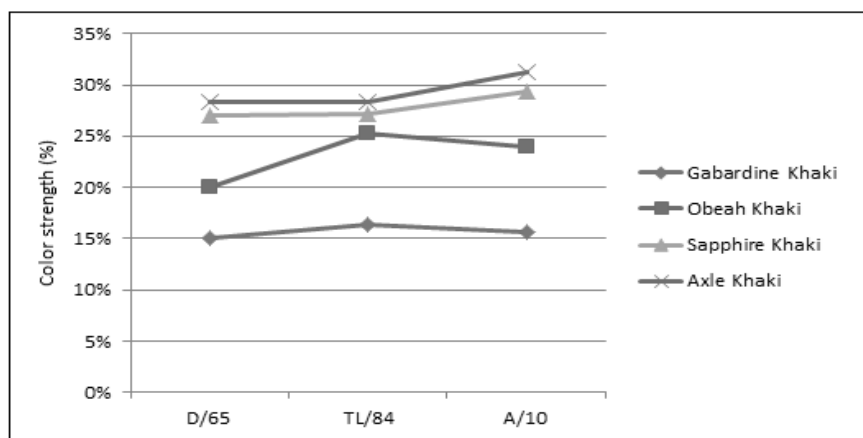


Figure 1. Percentage color strength differences of khaki-colored fabrics

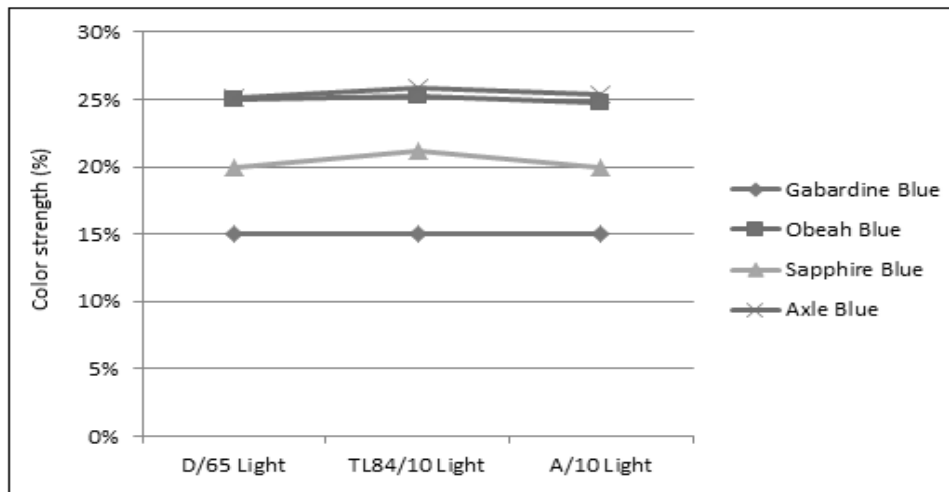


Figure 2. Percentage color strength differences of blue-colored fabrics

Table 2. Color and perspiration fastnesses of blue-colored gabardine and axle fabrics

Fastness		Acetate		Cotton		Nylon		Polyester		Acrylic		Wool	
		gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle
Color	Washing	5	5	5	4-5	5	4-5	5	4-5	5	4-5	5	5
	Water	5	5	5	5	5	5	5	5	5	5	5	5
Perspiration	Acid	4-5	5	5	5	4-5	5	5	4-5	5	5	5	5
	Alkaline	5	5	4-5	5	4-5	5	5	5	5	5	5	5

Fastness properties of gabardine and axle fabrics are nearly the same as it is seen in Table 2. 100% viscose cotton fabric exhibits very similar characteristic properties against color degradation, as like 100% cotton fabric. According to the test results, color and perspiration fastness values of viscose and cotton fabrics are higher due to strong bonds between dye and 100% cellulosic fabric.

Table 3. Color and perspiration fastnesses of blue-colored obeah and sapphire fabrics

Fastness		Acetate		Cotton		Nylon		Polyester		Acrylic		Wool	
		obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire
Color	Washing	5	5	4	5	5	5	5	5	4-5	5	5	4-5
	Water	5	5	4-5	4-5	5	5	5	5	5	5	5	4-5
Perspiration	Acid	5	5	5	5	5	4-5	5	5	5	5	4-5	5
	Alkaline	4-5	5	5	4-5	5	4-5	5	4-5	5	4-5	4-5	5

In Table 3, it is observed that blue-colored obeah fabric has better fastness properties than that of sapphire fabric. It is not a surprising result because sapphire fabric is constructed with blended yarns spun from 50% polyester and 50% viscose. Therefore, chemical bonds are weaker due to less cellulosic fiber content in sapphire fabric.

Table 4. Color and perspiration fastnesses of khaki-colored gabardine and axle fabrics

Fastness		Acetate		Cotton		Nylon		Polyester		Acrylic		Wool	
		gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle	gabardine	axle
Color	Washing	5	5	5	4-5	5	5	5	5	5	5	4-5	5
	Water	5	5	5	5	4-5	5	5	5	5	5	5	5
Perspiration	Acid	5	5	5	5	5	5	5	4-5	5	5	5	5
	Alkaline	5	5	5	5	4-5	5	5	5	5	5	5	5

Perspiration fastness value of khaki-colored gabardine fabric is similar to that of axle fabric. However washing fastness properties of axle fabric are better. It is directly related with pattern and unit fabric weight. Excess dye and sodium hydroxide absorption can be shown as reason of this phenomenon because gabardine fabric is woven with coarse yarns and 2*2 twill patterns.

Table 5. Color and perspiration fastnesses of khaki-colored obeah and sapphire fabrics

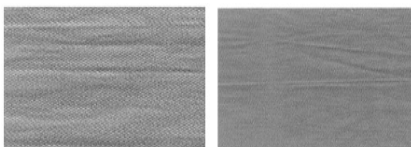
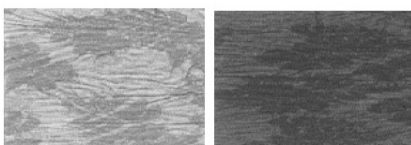
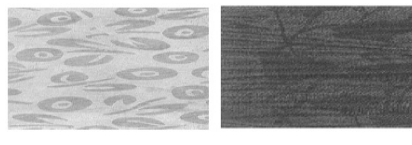
Fastness		Acetate		Cotton		Nylon		Polyester		Acrylic		Wool	
		obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire	obeah	sapphire
Color	Washing	5	5	4-5	4-5	4-5	5	4-5	5	4-5	5	5	5
	Water	5	5	5	5	5	5	5	5	5	5	5	5
Perspiration	Acid	5	5	5	5	5	5	4-5	4-5	5	5	5	5
	Alkaline	5	5	5	5	5	5	5	5	5	5	5	5

Although washing and perspiration fastness values of blue-colored sapphire fabric are poorer than those of obeah fabric, sapphire fabric exhibits better fastness properties in khaki color. Different chemical constituents of dyes must be corresponded from these conflicting test results.

Table 6. Light and rubbing fastness of all samples

		Blue				Khaki			
		gabardine	obeah	sapphire	axle	gabardine	obeah	sapphire	axle
Rubbing Fastness	Dry	5	5	5	5	5	5	4-5	4-5
	Wet	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Light Fastness		4-5	4-5	4-5	4-5	4-5	5	4-5	4-5

Obeah fabric has the highest light and fastness properties. The least values are observed in sapphire and axle fabrics. Appearances of all samples were given in Figure 3,4, 5 and 6.

**Figure 3.** Gabardine Fabrics**Figure 5.** Sapphire Fabrics**Figure 4.** Obeah fabrics**Figure 6.** Axle Fabrics

4. CONCLUSION

In mercerizing process, 100% cellulose fabrics are treated with sodium hydroxide to swell fibers, improve their liquor absorbability capacities and increase dyeing efficiency. It is known that mercerized cotton fabrics have more bulky and brighter appearance. This study is based on excellent compatibility of sodium hydroxide with cellulose fibers.

This experimental study is performed by inspiring from mercerization of cotton fabrics. But the sequences of processes applied on textile surface to obtain multi-color effect are little more different than conventional dyeing and printing processes. First of all, cellulose-based samples are printed by using paste without dye. There is no visible pattern on raw fabric after printing process. Samples are then dyed with reactive dyes. By means of detecting clear and unclear patterns on each sample, variables of corresponding processes are tried to be obtained.

Unclear printed patterns are clearly observed after dyeing due to different absorbance ability of printed surfaces. Patterns are seen darker due to high dye absorption and there is no considerable effect of using different patterns. However printing efficiency is not same for all types of fabrics. For instance, patterns are not clearly observable on gabardine fabrics although it was printed with the same printing conditions like others. This phenomenon is related with being constructed with 14 Ne cotton yarns in warp and weft directions. These thick and bulky cotton yarns absorb huge amount of sodium hydroxide and dye agent. Thereby, unclear patterns are available on this heavy fabric and the lowest printing efficiency is obtained in gabardine fabrics. This means that absorbency of gabardine fabric is same through fabric surface.

Sapphire and obeah fabrics have nearly same visual properties for two different colors. Despite of being printed with different patterns, patterns are clearly seen on these fabrics. But average of percentage color strength differences of obeah fabric is higher than that of sapphire fabric for two different colors. Although the highest color strength difference is obtained in axle fabrics for blue and khaki colors, visual and fastness properties of this

fabric are not as good as obeah and sapphire fabrics.

By means of weaving pattern, visual and fastness properties of obeah fabric are better than that of axle fabric. Light-weight fabric exhibits better performance properties. Obeah and gabardine fabrics are constructed from 100% cotton yarns. But their fabric weights and weaving patterns are different than each other. Gabardine, the heaviest fabric used in this study, was constructed from coarser and more bulky yarns. Constituents of gabardine fabric absorbed more sodium hydroxide and thereby more dye agent. Excess absorb ability of coarser yarns caused to unclear pattern occurrence. Percentage color difference of gabardine fabric is lower than that of obeah.

All fabrics used in this study have different properties by means of fabric weight, weaving pattern and fiber type. The best results are obtained in obeah fabric. It is a light-weight fabric. It is constructed from 100% cotton yarns and woven with 1×1 plain weave. Printed patterns are clearly observed on obeah fabrics. In this study, it is proved that tone-in-tone printing effect is created on fabric by using sodium hydroxide. It is necessary to apply this process onto light-weight fabrics constructed from 100% cotton yarns.

Variables of this experimental study are fabric weight, yarn count, fabric content and weaving pattern. When test results of these different samples are compared with each other, it is concluded that efficiency of printing process, percentage color strength values and fastness properties of samples are significantly influenced from following parameters.

1. *Fabric weight*: It is indirectly related with the yarn count. Heavier fabrics can be technically obtained by constructing them with coarse

yarns. Gabardine fabric, heavier in weight, absorbs more sodium hydroxide and dye liquor due to its bulky yarn content. Therefore printed patterns are not easily observable on this fabric surface.

2. *Fiber type*: Absorption capability of fiber determines the dye ability performance of a fabric. There is no problem in reactive dyeing of these fabrics because they are constructed with cellulosic fiber or its blends.

3. *Weaving pattern*: Efficiency of printing and dyeing processes change according to the period and density of contact and uniformity of surface. Due to these reasons, clearer patterns are observed in obeah and axle fabrics.

In this study, woven cellulosic fabrics are printed with paste prepared with unconventional ways. Paste is prepared with sodium hydroxide instead of dye. Sodium hydroxide is the most compatible chemical agent with cellulose-based textile materials thereby all samples are constructed from cellulosic yarns or blends. Here in, it is intended to apply sodium hydroxide by screens onto fabric surface, not to create a colorful pattern on it. Patterns on fabric surface will be visible after dyeing of printed fabrics. Printing effect is achieved on fabric surface by means of this untraditional application. Variables of this treatment are tried to be clarified by using samples with different characteristic properties, two reactive dyes and two different patterns.

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