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Studying the Effect of Silicone and Polyethylene Softeners on Mechanical and Sewability Properties of Woven and Knitted Fabrics

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Abstract

The research aimed to study the effects of silicone and polyethylene softeners on knitted and woven fabrics using exhaustion and pad-dry-cure methods to evaluate the functional and aesthetic performance of fabrics ,which play a crucial role in fabric manufacturing and production efficiency by tested some mechanical properties. Test results for treated fabrics compared with control fabrics showed: Both softeners improved abrasion and tear resistance for all samples by 80 %. Crease recovery had good results with polyester and blends with 94 %, while it decreased in cotton with 12 %. Pilling exhibited consistent results in cotton and improvement in polyesters by 80 %, while a decrease in blends with 74 %. Stain resistance remained consistent or decreased across all samples depending on the softener bath. Furthermore, colour fastness results indicated that wet conditions resulted lower rubbing fastness scores than dry conditions (4 or 3-4) on the grey scale, very good for acid and basic perspiration (4 or 4-5), slightly better results for washing (4 or 4-5), and stable results for light. In addition, all samples showed medium to high degrees of smoothness in the hand test by 77 %. Finally, the treated fabrics exhibited high extensibility, bending rigidity, and formability.

Keywords: Softener; Silicone; Polyethylene; Mechanical; Sewability; treatment

1. Introduction

Fabric softener is a chemical or blend of chemicals in form of liquid, used during fabric manufacture to enhance the hand, appearance, and wearability of fabrics [1]. Nearly all clothing is treated with softeners because fabric roughness and smoothness have been identified as key components of garment comfort [2][3]. Softening finishes are one of the most significant textile finishes. Textiles may obtain a soft texture, smoothness, improved drape, flexibility, and pliability by employing chemical softeners [2][4]. Additionally, softeners affect certain textile properties and frequently have a multifunctional nature, they improve tearing strength, decrease pilling, improve soiling, abrasion resistance, static protection, crease recovery, moisture absorbency, and flammability, moreover, they improve sewability, prevent sewing thread breakage, and minimize needle cutting during the sewing process [3][5].

1.1. Non-ionic softeners

Non-ionic substances are commonly utilized as finishes, both independently and as additions in highly cationic formulations; they can be applied to synthetic fibres and their blends. These softeners don't have an electric charge and don't have much of an attraction for fabric [4]. They are stable at high pH and temperatures, have excellent lubricity, and make good dispersion agents [2]. Types of non-ionic softeners: (a) Ethoxylates (b) Esters (c) Polyethylenes (d) Silicones (e) Waxes [3][4]. Since non-ionic softeners don't exhibit significant substantively, they can be easily mixed with other products or active agents. They are appropriate for finishing optically brightened white textiles since they do not cause yellowing and are resistant to high temperatures [5].

1.1.1. Polyethylene based on non-ionic softeners

Polyethylene based on non-ionic softeners, air oxidation during melt at high pressure can modify it to add hydrophilic properties (mainly carboxylic acid group). Their high lubricity (reduced surface friction) and their normal textile processing conditions make them stable to extreme pH conditions and heat [2][4][6]. They have good softening effects, low washing permanence, high antistatic effects (because of their strong ionic character), reasonable prices, and are compatible with most textile chemicals [7].

1.1.2. Silicone softeners

Even with the existence of various softeners used in commercial applications as cationic and anionic softeners, silicone softeners are the most widely used due to their exceptional specific properties and higher efficiency compared to traditional additives, they play an essential and widespread role in achieving the necessary smoothness and softness in textile yarns and fabrics [8][12]. Silicone softeners offer superior softness, a distinctive feel, high lubricity, excellent sewing ability, elastic resilience, crease recovery, abrasion resistance, tear strength, temperature stability, and durability that are great [8]. Also,

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products that form cross linked films have a high degree of permanence with a range of properties from hydrophobic to hydrophilic [2][7]. Three types of silicone softeners are available in the market according to particle size: macro, micro, and nano silicone softeners [9]. Silicone technology assists textile manufacturers in creating functional fabrics and high-performance textiles [10]. Silicone compounds exhibit a wide range of useful applications in the field of chemistry due to their intelligence. The purpose was to alter the cellulosic fabric's surface in order to enhance its characteristics, including hydrophilicity, softness, and mechanical properties. When silicone is combined with organic compounds, it imparts special properties that remain effective across a broad temperature range. Textile manufacturers worldwide have the ability to create personalized fabrics and garments using silicone technology [10][11][12]. Silicones consist of large molecules made up of a polymer backbone containing alternating silicon and oxygen atoms, with organic groups bonded to the silicone [13][14]. Methyl groups are the most important organic substituents used in commercial silicones [13]. The majority of these are polydimethyl siloxanes [13][15]. Due to the presence of a functional atom, silicones possess an ionic character, which enhances their ability to adsorb on the surface of textiles such as cotton or cotton/polyester blends [13].

1.2 Environmental impact of softeners

When selecting fabric care products, focusing on safety for the environment and people is essential. Fabric softeners, a category of these products, are experiencing a significant rise in worldwide usage yearly and have a crucial move towards sustainability due to their biodegradability [16][17][18].

Non-ionic softeners can be considered more eco-friendly compared to some other types of softeners such as cationic softeners, but their environmental impact depends on their chemical structure [21]. The majority of softening chemicals, such as hydrocarbon waxes and fatty esters are considered harmless, furthermore, some of the raw ingredients utilized by softener makers are low-risk for the environment and human health, such as polyethylene, triglycerides, fatty acids, fatty alcohols, and long-chain fatty amines [19][4]. Moreover, the way silicones are used, their physical condition, and their distribution method all significantly affect the environment, high molecular weight compounds are essential in industrial and domestic uses, whereas low molecular weight compounds are used in personal care products, additionally, silicones show good effectiveness at very low concentrations; these low concentrations will reduce ecological and environmental consequences [10].

2. Experimental (Materials and Methods)

The research relies on an Experimental and analytical study. Experimental through performing laboratory experiments, and analytical through analyzing test results.

2.1 Fabrics

Different types of commercial knitted construction fabrics - cotton 100% (Milton, pique, rib, and interlock) and woven fabrics with two different constructions - plain 1:1 (cotton 100% - polyester 100%), and twill gabardine (cotton-polyester 65:35 - polyester 100%). All used fabrics were purchased from Cairo, Egypt's local market.

2.2 Chemicals

Silicone softener—non-ionic/weakly cationic (Evo Soft SMA) and polyethylene softener—non-ionic (Evo Fin APE Conc.) were kindly taken from Dye Star Company. Acetic acid was purchased from Gomhoriya Company in Cairo, Egypt.

2.3 Methods

Exhalation and pad-dry-cure techniques were used to treat the fabrics with the two types of softeners in accordance with the data sheet.

In the exhaustion application for silicone softener, the sample was impregnated in a treatment bath containing 2% Evo Soft SMA softener, 1 g/L acetic acid, pH = 6, L: R (1:50), at 40 °C for 20 minutes, then dried in a laboratory oven at 150°C.

In pad–dry–cure application for silicone softener, the sample was impregnated in a treatment bath containing 25 g/L Evo Soft SMA softener, 1 g/L acetic acid, pH = 6, L: R (1:50), at room temperature, then the sample was squeezed using a laboratory padder to get 100% wet pick up; after that, dry and cure at 160 °C for 60 seconds using a laboratory oven.

In the exhaustion application for polyethylene softener, the sample was impregnated in a treatment bath containing 2 g/L Evo Fin APE Conc. softener and 1 g/L acetic acid, pH: 6, L: R (1:50), at 40°C for 25 minutes, then dried at room temperature.

In a pad–dry–cure application for polyethylene softener, the sample was impregnated in a treatment bath containing 20 g/L Evo Fin APE Conc. softener, 1 g/L acetic acid, pH = 6, L: R (1:50), at room temperature, and then the sample was squeezed using a laboratory padder to get 100% wet pick up; after that, dry and cure at 170 °C for 60 seconds using a laboratory oven.

2.4 Fabric testing

Eight types of fabric samples treated with two different types of softeners using two different treatment methods (32 samples), in addition to control samples (8 samples), were tested for mechanical tests such as abrasion resistance, tear resistance, wrinkle recovery, pilling, stain resistance, and colour fastness (friction, washing, perspiration, and light) at the National Research Center in Cairo, Egypt. The measurement of fabric hand was performed manually by a group of people (72 people). SIROFAST was tested on the best results for eight different types of fabric samples in previous tests at the "Golden Tex Factory" in Ramadan City, Sharkia, Egypt.

3. Results and Discussion

The effects of two distinct softeners employing pad–dry–cure and exhaustion procedures on various fabrics were tested, and the following results were obtained and discussed.

3.1 Effect of two different softeners with two different methods of treatment in the abrasion resistance test

The control and softener-treated fabrics were tested for abrasion resistance using the ASTM D 3885 test method.

An increase in results is observed in all samples with 73 % compared to the control sample, and that's because the softeners enhance the resistance of fabrics to abrasion due to two main reasons. Firstly, they create a film over the fibres and yarns, acting as a protective barrier that increases abrasion resistance. Secondly, softeners provide a lubricating effect on the fabric, which decreases friction between the fabric and any abrasive materials and enhances the flexibility of the fibres and yarns. Reduced friction and improved flexibility lead to increased abrasion resistance, and also because of their easy ability to infiltrate the inner parts of the fibres [20].

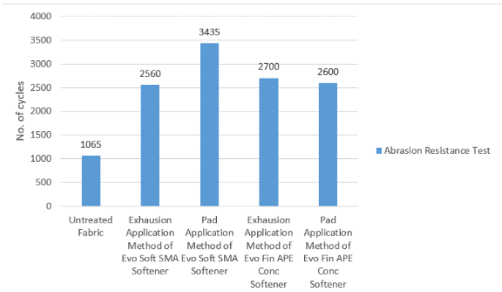

Fig. 1a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the abrasion resistance test.

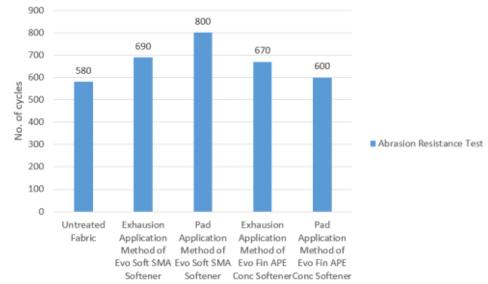

Fig. 1b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the abrasion resistance test.

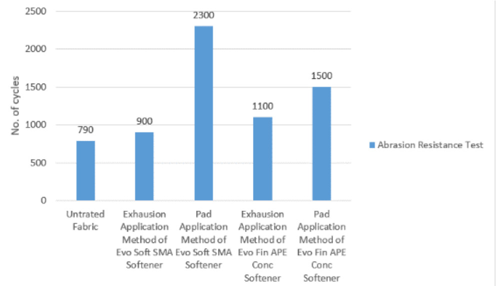

Fig. 1c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the abrasion resistance test.

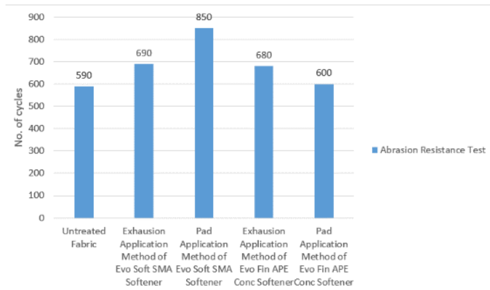

Fig. 1d. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/interlock (cotton 100%) in the abrasion resistance test.

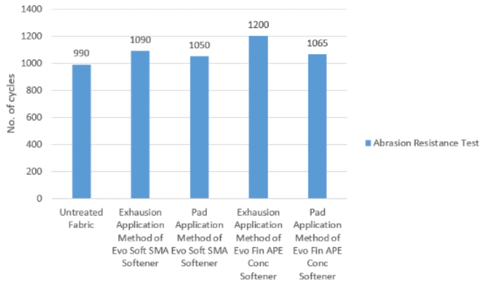

Fig. 1e. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the abrasion resistance test.

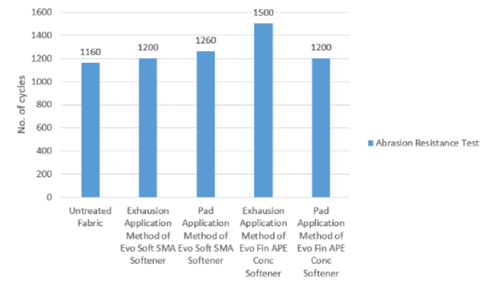

Fig. 1f. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the abrasion resistance test.

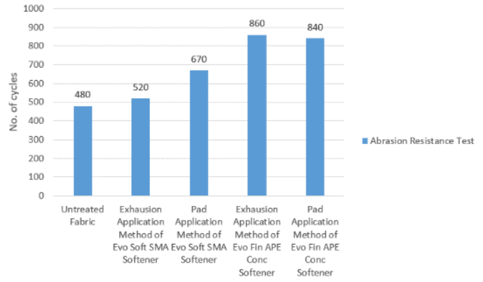

Fig. 1g. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the abrasion resistance test.

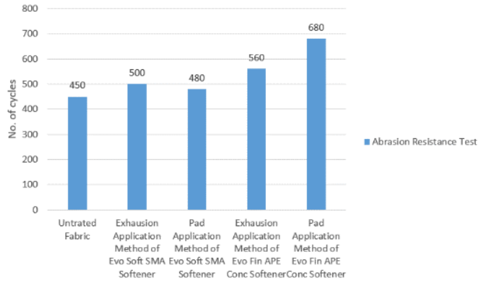

Fig. 1h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the abrasion resistance test.

3.2 Effect of two different softeners with two different methods of treatment in the tear resistance test.

Tear resistance was tested according to the ASTM D 1424 test method. All treated samples show good results in the tear resistance test with 86 % compared to the control sample by easing the movement of yarns and fibres and enhancing the tear strength of textiles, making them more adaptable. The degree of improvement in tear strength varies based on the type of interactions, both chemical and physical, between the softener and the material, as well as the quantity of softeners applied. Amino-functional siloxanes offer superior lubrication, create a coating on the fibre surface, and strongly interact with the negatively charged hydroxyl groups present in cellulose. Softeners typically show a greater enhancement in strength before washing. Non-ionic polyethylene softeners can also generate films and provide lubrication to the yarns, leading to improved strength retention [21].

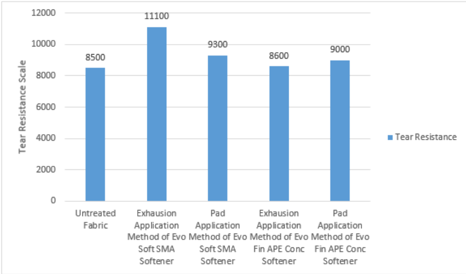

Fig. 2a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the tear resistance test.

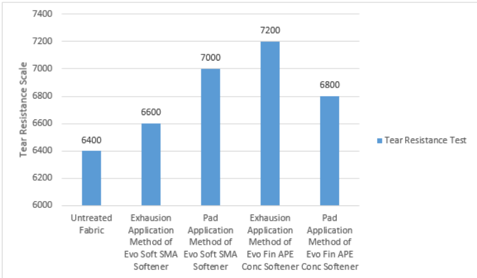

Fig. 2b. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the tear resistance test.

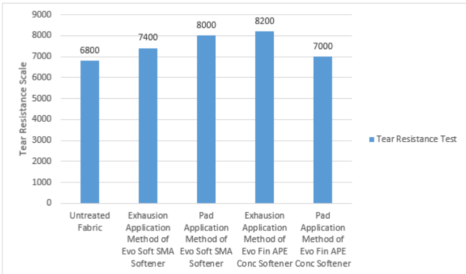

Fig. 2c. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the tear resistance test.

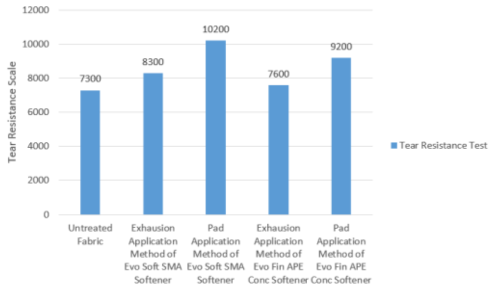

Fig. 2d. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the tear resistance test.

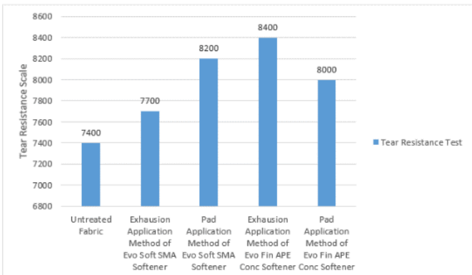

Fig. 2e. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the tear resistance test.

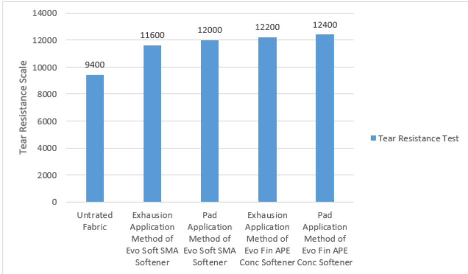

Fig. 2f. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the tear resistance test.

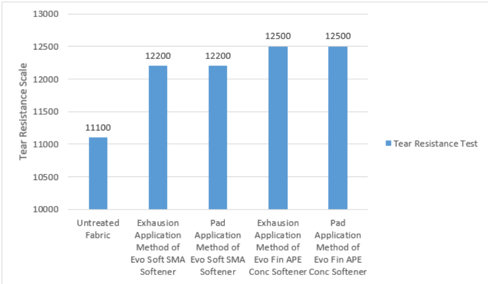

Fig. 2g. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the tear resistance test.

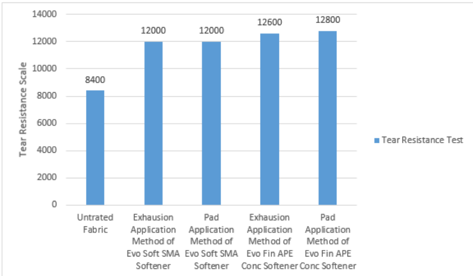

Fig. 2h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the tear resistance test.

3.3 Effect of two different softeners with two different methods of treatment in the crease recovery test.

The crease recovery angle was measured using the AATCC 66-2008 test method. Figures 3a, 3b, 3c, 3d, and 3e show a decrease in results with the two softeners by pad-dry-cure and exhaustion methods with 12 % compared to the control sample. That's due to the nature of cotton fibers, which have poor recovery from deformation, which means that they wrinkle easily in both dry and wet states and exhibit inferior crease retention [22]. When cotton fibre is compressed, it will not return to its shape [23]. In addition, there are some disadvantages related to cotton fabrics, such as poor elasticity and resiliency, which create wrinkles and don't recover from wrinkling easily [35]. The inelasticity of cotton fibre is because of its crystalline system, and for this reason, cotton fibre wrinkles and creases readily [23]. In addition, silicone softeners grant water repellence to the textiles. This water-resistant feature arises from methyl groups that are oriented and bonded to the fibre via silicone linkages, the positively charged nitrogen atom interacts with the negatively charged surface of the fabric surface. The tendency of cotton fabrics to crease is influenced by the structural characteristics of the fibres [2][23].

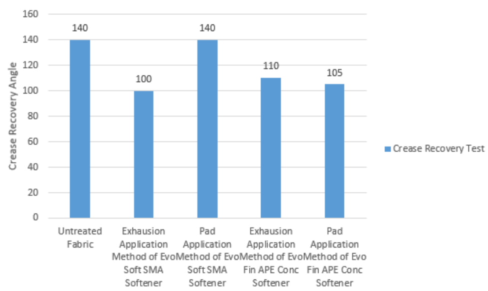

Fig. 3a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the crease recovery test.

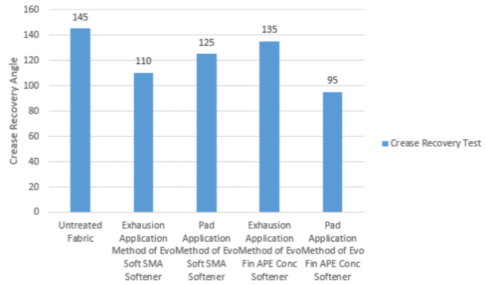

Fig. 3b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the crease recovery test.

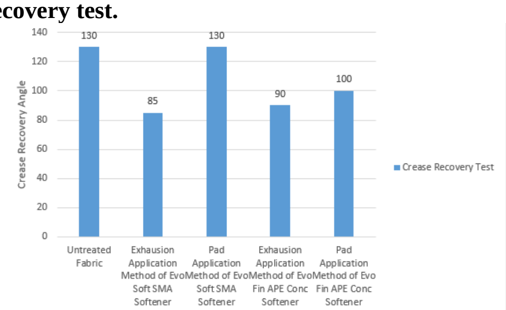

Fig. 3c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the crease recovery test.

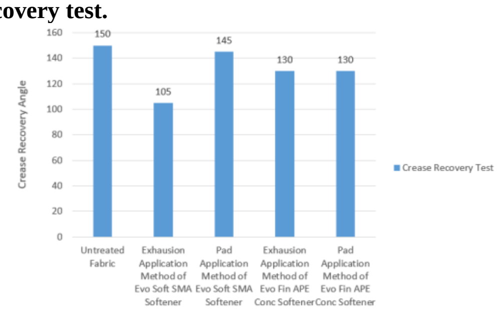

Fig. 3d. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the crease recovery test.

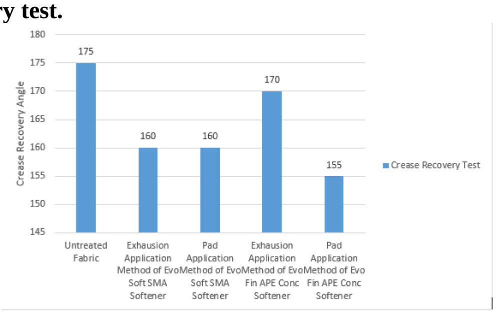

Fig. 3e. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the crease recovery test.

Figures 3f, 3g, and 3h show an increase with the silicone softener; it could be because the silicone compounds of the softener show self-condensation, which gives high molecular weight polymer and imparts permanent elastomeric properties to the surface. This reaction of the compounds gives a cross-linked network covering the surface [10].

Also, there is increasing use of polyethylene softener because of the hydrophilic character of this softener (non-ionic softener based on polyethylene) [7]. The crease recovery angle improved when treated with softeners by 94 % compared to the control sample. This improvement may be attributed to the fibre swelling in the fabric during the softening process, resulting in enhanced recovery from deformation [21]. In addition, polyester fibres have better wrinkle resistance and are highly resilient; therefore, they resist creases [25].

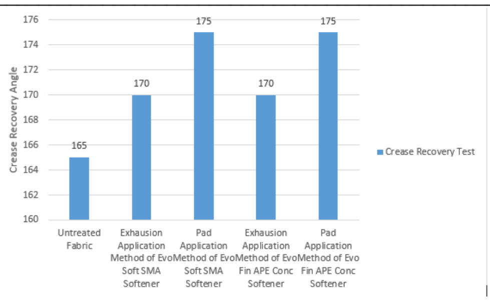

Fig. 3f. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the crease recovery test.

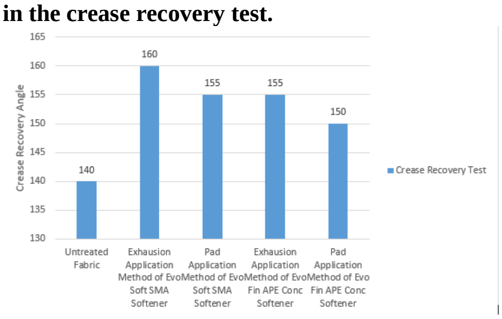

Fig. 3g. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the crease recovery test.

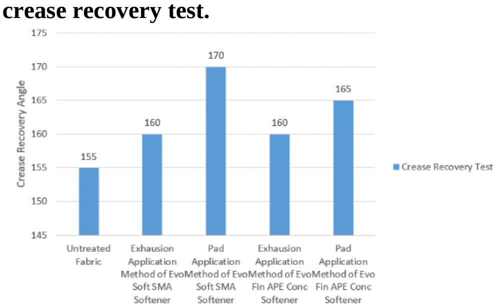

Fig. 3h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the crease recovery test.

3.4 Effect of two different softeners with two different methods of treatment in the stain resistance and pilling tests.

The control and softener-treated fabrics were tested for pilling according to BS 5811 test method. It is clear from comparing the samples treated with the softeners with the control samples that figures 4c, 4d and 4e show constancy in results except in Evo Fin APE softener with exhaustion method has decrease in results by 25 % compared to the control sample. Figure 4a shows a decrease in both softeners with the two methods with 32 %, while Figure 4b shows consistent results with the two methods; so that could be because some factors can increase pilling tendency including short staple length in the natural fibres which consist a lot of short staple fibres that protruding on the fabric surface easily [7]. Furthermore, fabrics with and without softeners perform almost identically as soon as it comes to pilling [9]. As well as the softeners' ability to reduce friction between fibres by improving the lubrication of each individual fibre makes it easier for the fibers to separate from the main structure of the fabric, which in turn causes the formation of pills [6].

Stain resistance test was measured according to AATCC 130-1990. Figures 4a and 4c show constancy in results except in Evo Fin APE softener with pad – dry – cure method has decrease in results with 50 %. Figure 4b has constant results in Evo Fin APE softener with exhaustion method and Evo Soft SMA softener by pad – dry – cure method, but show decrease in Evo Soft SMA softener by exhaustion method and Evo Fin APE softener with pad – dry – cure method by 25 %. Figures 4d and 4e have decrease in results with 30 % compared to the control sample except in Evo Soft SMA softener by pad – dry – cure method have constant result, that's due to the silicone finishes frequently accumulate and create a thin layer at the junctions between fabric and stain, affecting how they interact with both. Since silicone softeners are typically applied to the surface of fabrics, they often reside between the fabrics and stains, Silicone improved film formation and enhanced silicone structure orientation, which results greater hydrophobicity and contributed to the formation of a protective barrier on the fabric by making cross-link after application, creating a more durable and resilient film on the fabric [26]. In addition in figures 4f and 4g the constancy in the results may be because of the polyester fabric features, which don't stain easily because of its low absorbency so many stains become on the surface, Also fabrics with twill weaves don't show dust and dirt as much as the fabrics with plain weaves do and they do [23].

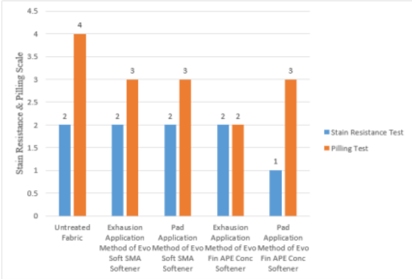

Fig. 4a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the stain resistance and pilling tests

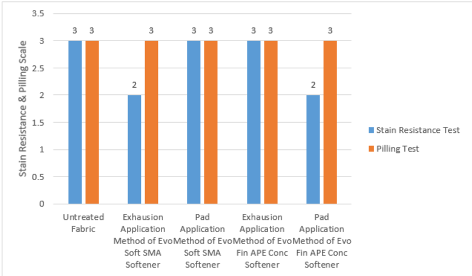

Fig. 4b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the stain resistance and pilling tests

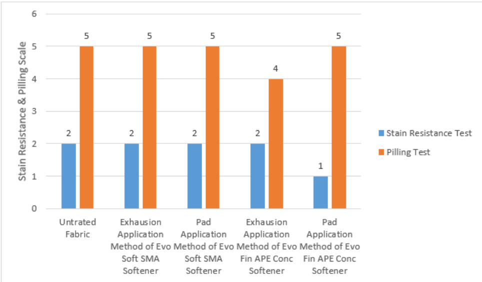

Fig. 4c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the stain resistance and pilling tests

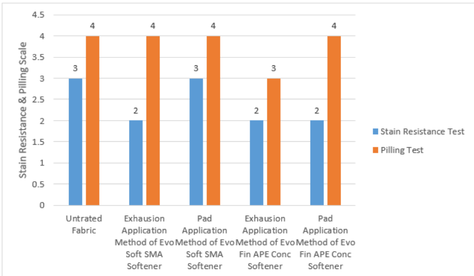

Fig. 4d. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the stain resistance and pilling tests

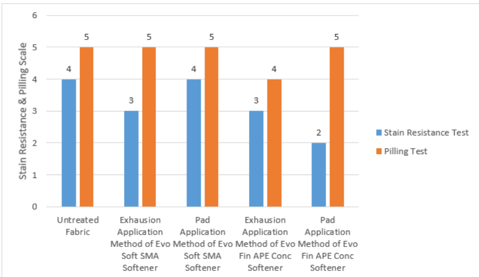

Fig. 4e. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the stain resistance and pilling tests

Figures 4f and 4g show an improvement in the results of the pilling test by 80 % compared to the control sample, and that's because of the nature of the polyester fibres, which present fair pilling and snag resistance in most textile constructions [22]. When fabrics consist of polyester, the stronger fibres are difficult to break, and the pills that are formed are not released quickly from the fabric [7]. On the other hand, it was clearly shown in figure 4h that the pilling test results were decreased by 74 % compared to the control sample, except in Evo Soft SMA softener by the exhaustion method, which shows constant results compared to the control sample. This outcome can be the result of the cotton-polyester blend; the weaker cotton fibers can be readily twisted with the stronger polyester fibers, which hold them to the fabric's surface, causing a high level of pilling [7]. Furthermore, twill weaves pill more frequently than plain weaves. Synthetic fibers like polyester have a significant pilling issue, particularly when they are blended and when they are laundered [5][9][27].

Furthermore, figure 4f shows consistent stain resistance test results when compared to the control sample, while figure 4g shows decreased stain test results for all treated samples by 25 %, with the exception of the sample treated with Evo Fin APE softener using the exhaustion method, which shows constant results.
Figure 4h shows constant results between treated samples and the control when treated with Evo Soft SMA softener by the exhaustion method and Evo Fin APE softener by the pad-dry-cure method. But was improved when treated with Evo Soft SMA softener by the pad-dry-cure method and Evo Fin APE softener by the exhaustion method with 80 % compared to the control sample. This might be due to the characteristics of polyester fabric, which cause many stains to appear on the surface due to their low absorption. Additionally, textiles with twill weaves exhibit less dust and filth than those with plain weaves [23].

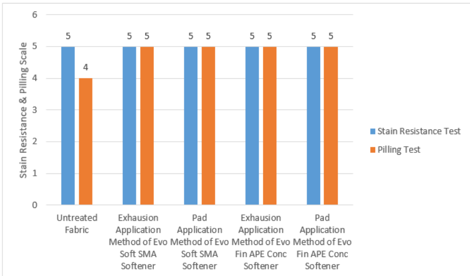

Fig. 4f. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the stain resistance and pilling tests.

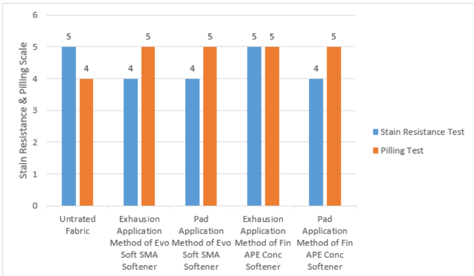

Fig. 4g. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the stain resistance and pilling tests.

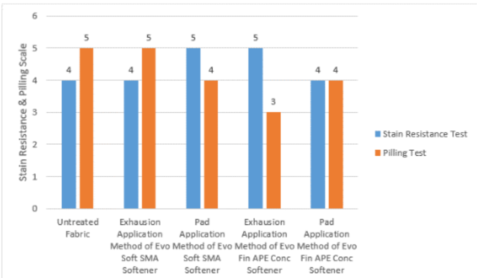

Fig. 4h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the stain resistance and pilling tests.

3.5 Effect of two different softeners with two different methods of treatment in the colour fastness (rubbing) test.

Colour fastness to rubbing was determined according to the ISO 105-X12:1987 test method. In all dry and wet rubbing results, it was observed that most of the fabrics in wet condition gave (4 or 3-4) on the grey scale, except the sample in Figure 5a, where the result was (3 or 2-3). But most of the dry test results were (4 or 4-5), except for the samples in Figures 5a and 5c, where the result was (3-4), so wet rubbing fastness got in some results worse rather than dry rubbing fastness performance because of the impact of the moisture. Wet cellulosic fibres could be partially destroyed by rubbing [7]. Applying softener to textile materials involves treating the fabric with a small amount of hygroscopic substances that can absorb moisture from the air. Adding moisture to the fabrics causes them to expand. This expansion leads to a larger surface area, which consequently results in reduced rubbing fastness [28]. The application of softener finishes helps to enhance fastness performance. Additionally, it has been established that the processes involved in softener finishing do not have a detrimental impact on colour fastness [24].

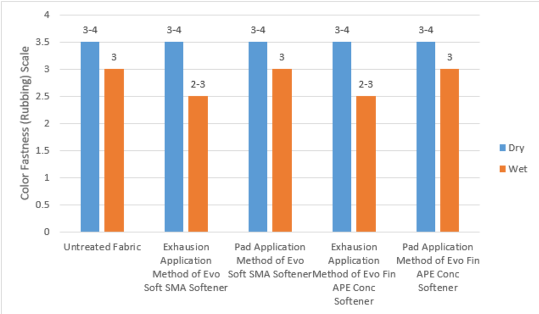

Fig. 5a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the colour fastness (rubbing) test.

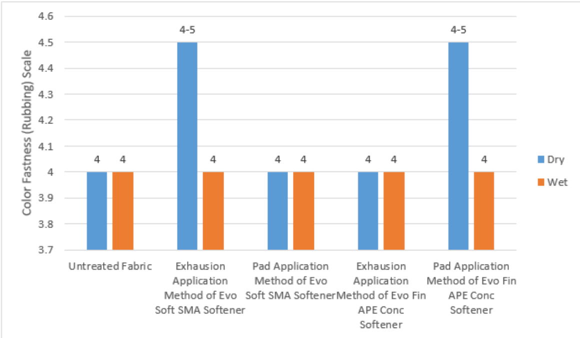

Fig. 5b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the colour fastness (rubbing) test.

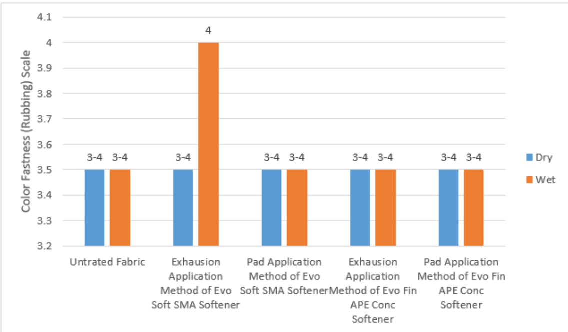

Fig. 5c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the colour fastness (rubbing) test.

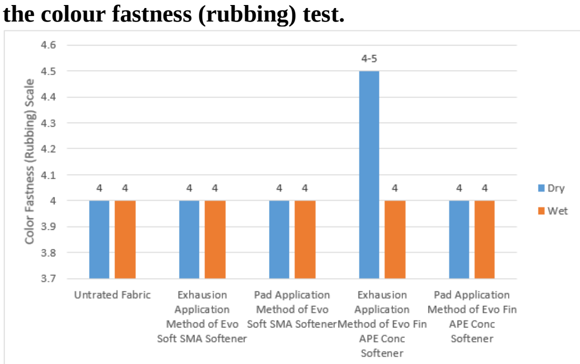

Fig. 5d. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the colour fastness (rubbing) test.

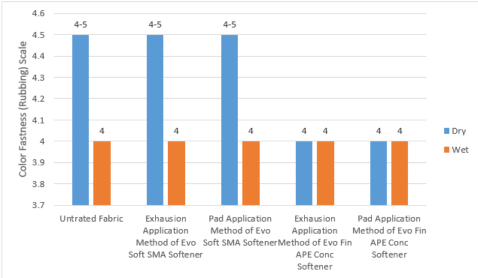

Fig. 5e. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the colour fastness (rubbing) test.

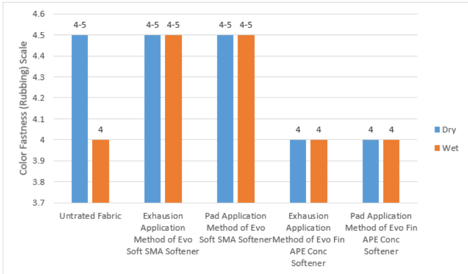

Fig. 5f. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the colour fastness (rubbing) test.

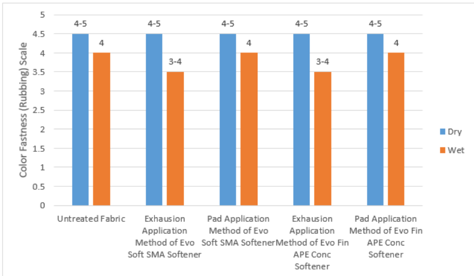

Fig. 5g. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the colour fastness (rubbing) test.

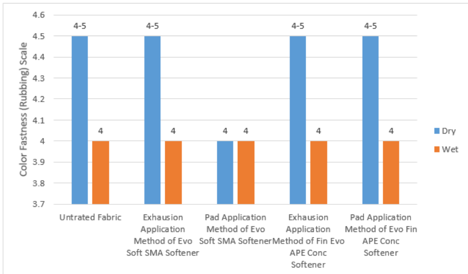

Fig. 5h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the colour fastness (rubbing) test.

3.6 Effect of two different softeners with two different methods of treatment in the colour fastness (washing) test.

The colour fastness to washing was determined according to the ISO105-C02:1989**.** It was clearly shown in all figures that slightly improved or constant results were obtained; all samples in washing results had (4 or 4-5) on the grey scale before and after treatment with softeners; the application of the softener finish did not result in significant alterations in fastness to washing [24]. After the finishing process, there was a slight difference in washing fastness properties. This reduction in fastness characteristics differs depending on the dyes used. The minimal loss in washing fastness may be attributed to the movement of dyes to the surface of the fabric when softener is present; softeners may interfere with the bonding between dyes and fibres, causing increased dye release when washed [24][28].

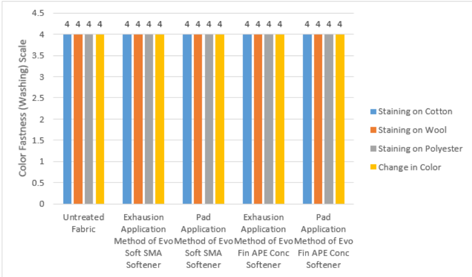

Fig. 6a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the colour fastness (washing) test.

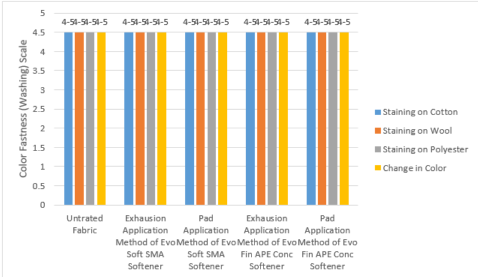

Fig. 6b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the colour fastness (washing) test.

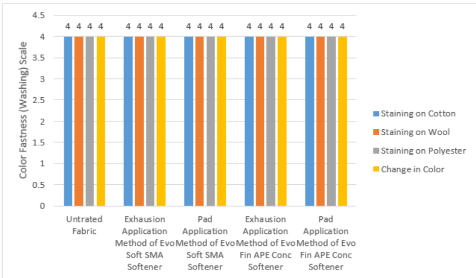

Fig. 6c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the colour fastness (washing) test.

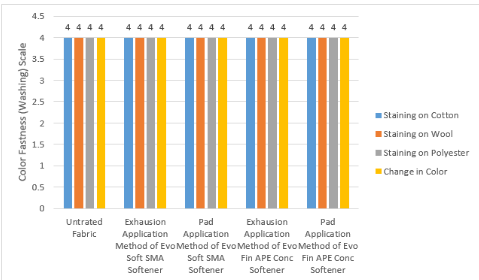

Fig. 6d. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the colour fastness (washing) test

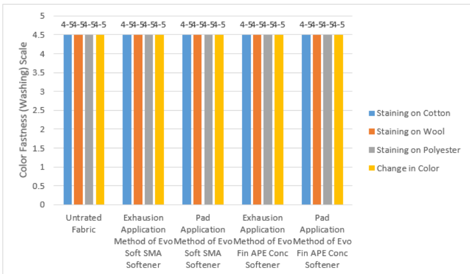

Fig. 6e. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the colour fastness (washing) test.

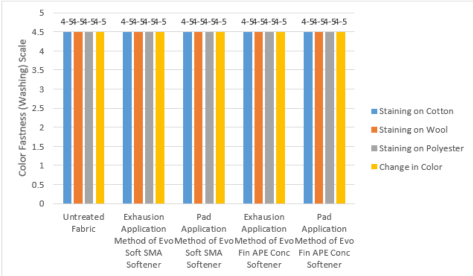

Fig. 6f. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the colour fastness (washing) test.

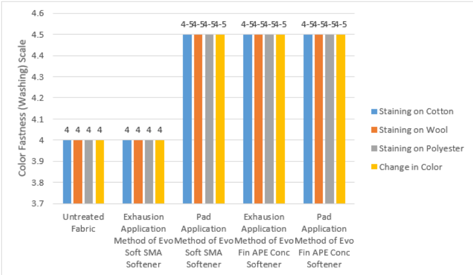

Fig. 6g. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the colour fastness (washing) test.

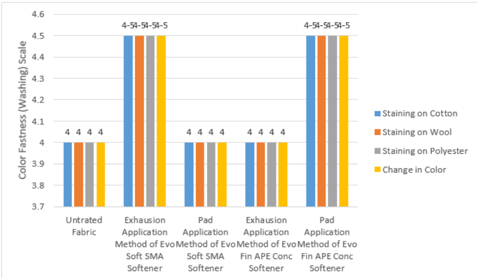

Fig. 6h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the colour fastness (washing) test.

3.7 Effect of two different softeners with two different methods of treatment in the colour fastness (acid and basic perspiration) test.

Two artificial perspiration solutions (acidic and alkaline) were prepared according to the ISO 105-E04:1989 test. All values for acid and basic perspiration fastness were very good; the results were within the range of (4 or 4-5) on the grey scale. Moreover, there is a slight change in results before and after treatment with softeners by slight increase or decrease, especially in (change in color) in acid and basic perspiration, and that's because the softener application didn't change the fastness performance of the fabrics [12][24][38]. Softeners, especially cationic ones, can react with acidic or alkaline components in perspiration. This interaction might disturb dye fixation on the fabric, leading to dye bleeding or fading when exposed to perspiration [29].

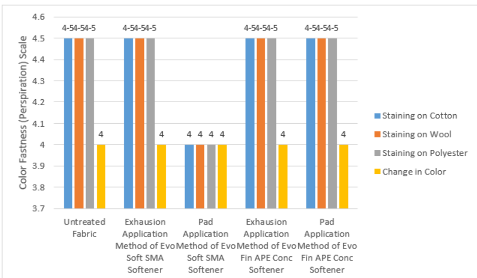

Fig. 7a.1 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the colour fastness (acid perspiration) test.

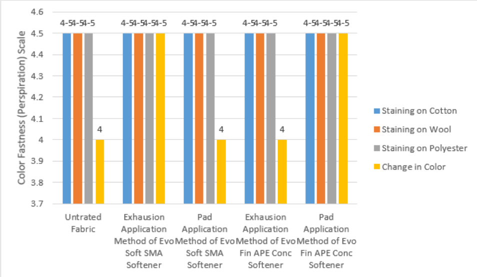

Fig. 7b.1 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the colour fastness (acid perspiration) test.

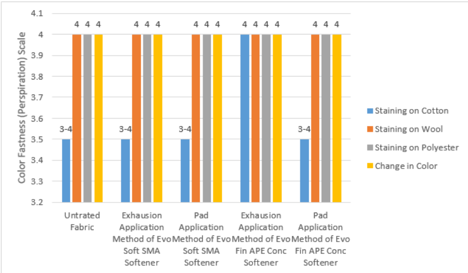

Fig. 7c.1 Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the colour fastness (acid perspiration) test.

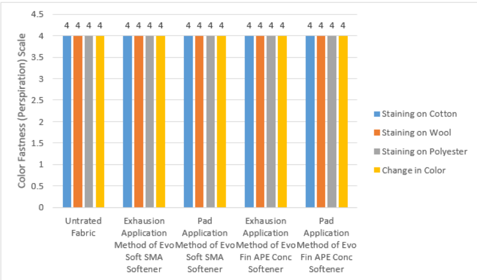

Fig. 7d.1 Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the colour fastness (acid perspiration) test.

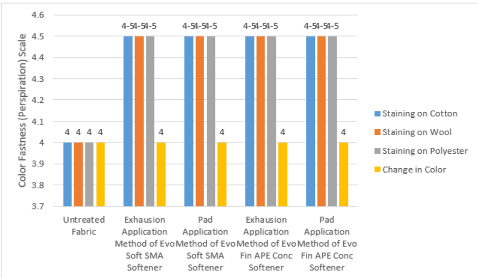

Fig. 7e.1 Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the colour fastness (acid perspiration) test

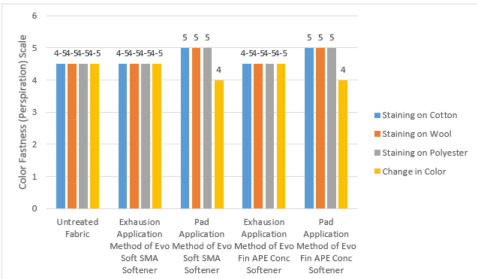

Fig. 7f.1 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the colour fastness (acid perspiration) test.

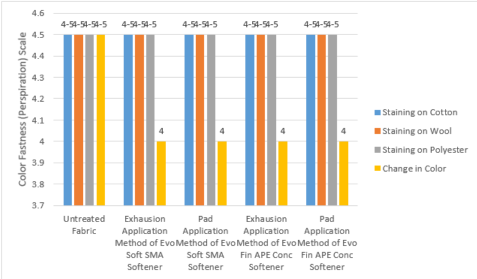

Fig. 7g.1 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the colour fastness (acid perspiration) test

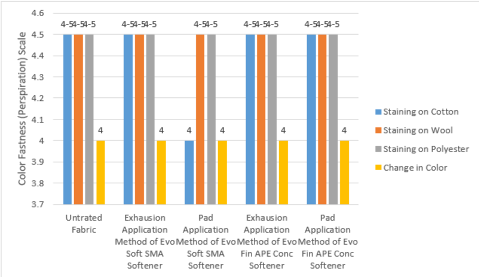

Fig. 7h.1 Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the colour fastness (acid perspiration) test.

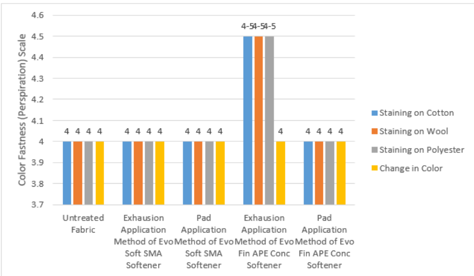

Fig. 7a.2 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the colour fastness (basic perspiration) test.

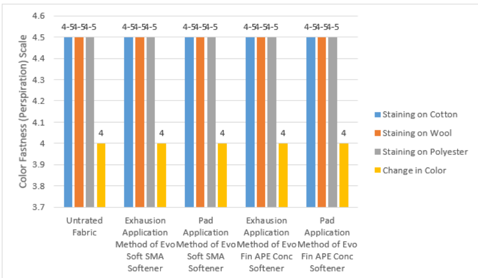

Fig. 7b.2 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the colour fastness (basic perspiration) test

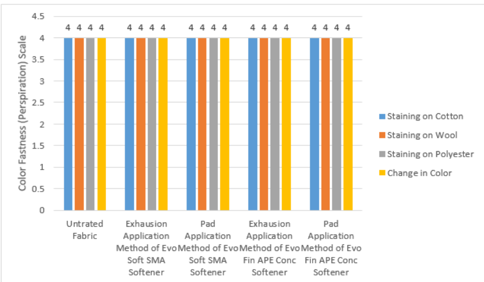

Fig. 7c.2 Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the colour fastness (basic perspiration) test

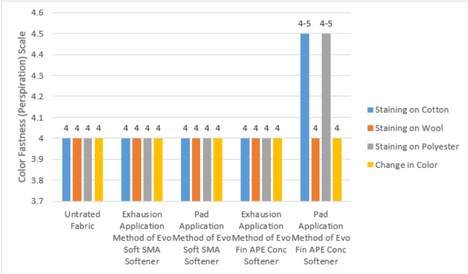

Fig. 7d.2 Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the colour fastness (basic perspiration) test.

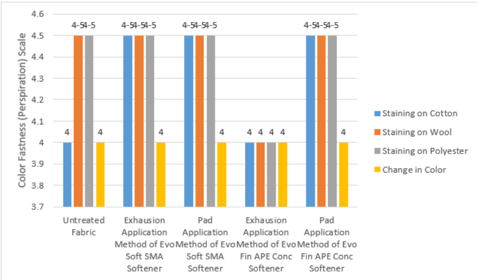

Fig. 7e.2 Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the colour fastness (basic perspiration) test.

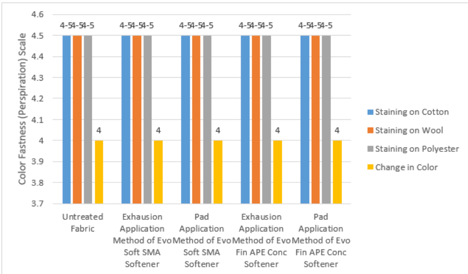

Fig. 7f.2 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the colour fastness (basic perspiration) test

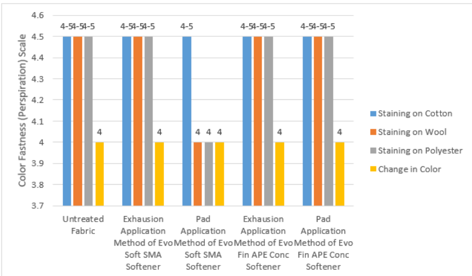

Fig. 7g.2 Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the colour fastness (basic perspiration) test.

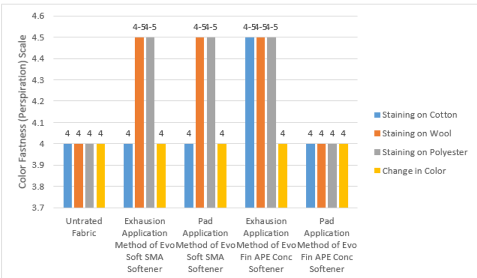

Fig. 7h.2 Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the colour fastness (basic perspiration) test.

3.8 Effect of two different softeners with two different methods of treatment in the colour fastness (light) test.

The light fastness test was carried out in accordance with the ISO 105-B02:1988 test method. It was shown that there was a decrease and constancy in all samples before and after treatment with softeners, and that's because of the type of softeners, which are not affected and didn't change the fastness performance of the fabrics softeners, especially silicone-based ones, have minimal to no effect on light fastness [12][24]. In addition to some dyes, some can undergo shade alterations when exposed to softeners due to the acidity or alkalinity of the solutions. When textiles that have been dyed are submerged in a softening bath, variations in pH levels can lead to modifications in the electron configuration of the dye molecules, which alters the colour of the dyed fabrics [24]. The interaction between softeners and surface dyes can negatively affect the fastness properties of both dyed and printed materials. Acidic conditions resulted in only a slight change in colour across all samples, while the extent of colour changes is determined by the specific types of softeners used [38].

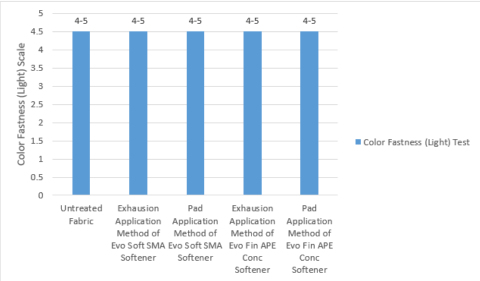

Fig. 8a. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/milton (cotton 100%) in the colour fastness (light) test

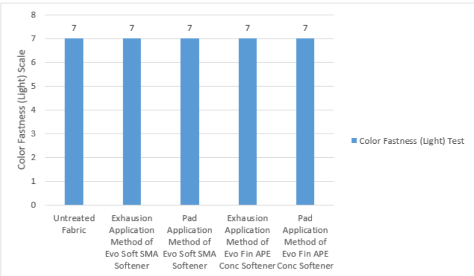

Fig. 8b. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/inter lock (cotton 100%) in the colour fastness (light) test

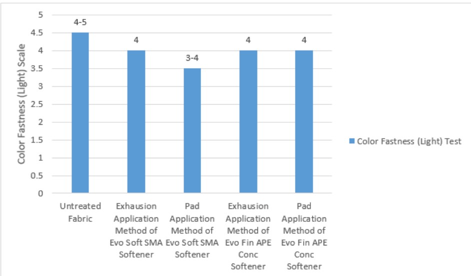

Fig. 8c. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (polyester 100%) in the colour fastness (light) test

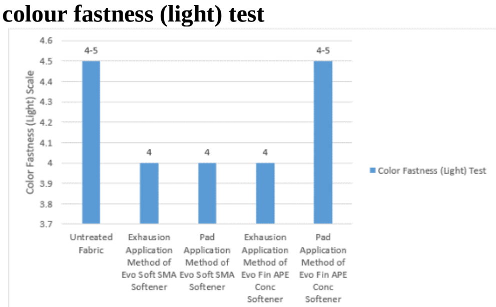

Fig. 8d. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 tergale (polyester 100%) in the colour fastness (light) test

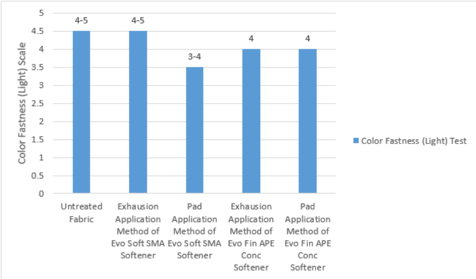

Fig. 8e. Studying the effect of two different softeners with two different methods of treatment on woven fabric/plain 1:1 (cotton 100%) in the colour fastness (light) test

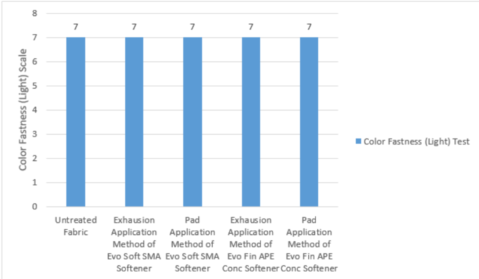

Fig. 8f. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/rib (cotton 100%) in the colour fastness (light) test

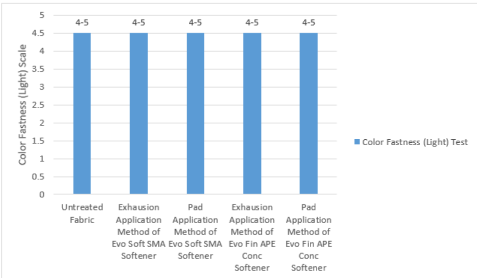

Fig. 8g. Studying the effect of two different softeners with two different methods of treatment on knitted fabric/pique (cotton 100%) in the colour fastness (light) test

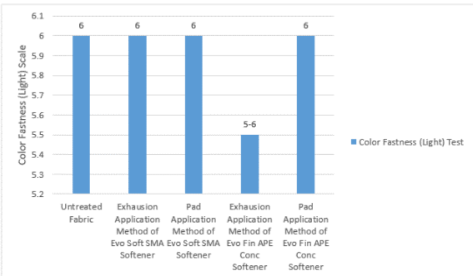

Fig. 8h. Studying the effect of two different softeners with two different methods of treatment on woven fabric/twill gabardine (cotton-polyester 65:35) in the colour fastness (light) test.

3.9 Effect of two different softeners with two different methods of treatment in fabric hand evaluation procedure.

The fabric hand was examined using the AATCC 5 (2001) evaluation procedure. The procedure was measured by 72 persons twice within five days between control, treated, and washed fabrics according to the AATCC 124-1996 test method. Tables 2, 3, and 4 show that all samples had medium and high degrees of smoothness (according to the Triple Licart Scale). The results of improving the fabric hand between the treated sample compared to the control one ranged from 70.33% (twill/cotton-polyester 65:35) to 82% (knitted fabric/pique and interlock-cotton 100%), and the results of improving the fabric hand between the washed sample compared to the treated one ranged from 65.66% (knitted fabric/pique-cotton 100%) to 81% (knitted fabric/interlock-cotton 100%). The effects of hand as a result of treated fabric with softeners are influenced not only by the chemical properties but also by their placement within the textile. If the softener mainly adheres to the exterior of the yarns, the primary effect arises from the characteristics of the chemical itself, such as feeling moist, dry, fatty, oily, smooth, rubbery, etc. Conversely, if the softener penetrates the yarn among the individual fibres, it generates a secondary handle effect known as "inner softness," which results from reduced friction between the individual fibres, Moreover, the absorbency of the softener enables the fabric to act as a lubricant that decreases both surface friction and the frictional force between the fibres. Consequently, the smoothness of the fabric treated with the softener was enhanced when touched, and also the swelling of fibres in the fabric caused by the softener offered a notably soft feel [21][30][31]. Softeners are used to achieve initial softening of the fabric. The softening effect of silicone is thought to result from the flexibility of the siloxane backbone and the ability to rotate freely around the Si-O bonds. This flexibility allows low-interacting methyl groups to be more exposed, which decreases fibre-to-fibre interactions and enhances softness for cotton and their blends with synthetic fibres [7][32].

Table 1: Samples code for the fabric hand evaluation procedure

1	2	3	4
Evo soft SMA softener with exhausion application	Evo soft SMA softener with pad application	Evo fin APE conc softener with exhausion application	Evo fin APE conc softener with pad application
A		Knitted fabric/milton (cotton 100%) with Evo soft SMA softener with exhausion application	
B		Knitted fabric/inter lock (cotton 100%)	
C		Woven fabric/twill gabardine (polyester 100%)	
D		Woven fabric/plain 1:1 tergale (polyester 100%)	
E		Woven fabric/plain 1:1 (cotton 100%)	
F		Knitted fabric/rib (cotton 100%)	
G		Knitted fabric/pique (cotton 100%)	
H		Woven fabric/twill gabardine (cotton-polyester 65:35)	

Table 2: Results and percentages of treated fabrics compared with the control fabrics

Specimens* code	Average of 2 days	Percentage %	Specimens* code	Average of 2 days	Percentage %
1A	2.27	75.66	3A	2.21	73.66
1B	2.16	72.00	3B	2.33	77.66
1C	2.32	77.33	3C	2.20	73.33
1D	2.41	80.33	3D	2.35	78.33
1E	2.45	81.66	3E	2.35	78.33
1F	2.27	75.66	3F	2.28	76.00
1G	2.46	82.00	3G	2.34	78.00
1H	2.20	73.33	3H	2.23	74.33
2A	2.35	78.33	4A	2.18	72.66
2B	2.44	81.33	4B	2.46	82.00
2C	2.30	76.66	4C	2.14	71.33
2D	2.36	78.66	4D	2.23	74.33
2E	2.17	72.33	4E	2.39	79.66
2F	2.24	74.66	4F	2.36	78.66
2G	2.36	78.66	4G	2.28	76.00
2H	2.31	77.00	4H	2.11	70.33

*****Samples code as shown in table 1.

Table 3: Results and percentages of treated fabrics compared with washed fabrics

Specimens code	Average of 2 days	Percentage %	Specimens code	Average of 2 days	Percentage %
1A	2.19	73.00	3A	2.29	76.33
1B	2.38	79.33	3B	2.32	77.33
1C	2.21	73.66	3C	2.24	74.66
1D	2.31	77.00	3D	2.16	72.00
1E	2.39	79.66	3E	2.32	77.33
1F	2.12	70.66	3F	2.21	73.66
1G	1.97	65.66	3G	1.99	66.33
1H	2.09	69.66	3H	2.24	74.66
2A	2.40	80.00	4A	2.34	78.00
2B	2.43	81.00	4B	2.36	78.66
2C	2.23	74.00	4C	2.16	72.00
2D	2.18	72.66	4D	2.20	73.33
2E	2.26	75.33	4E	2.37	79.00
2F	2.32	77.33	4F	2.08	69.33
2G	2.05	68.33	4G	2.23	74.33
2H	2.25	75.00	4H	2.09	69.66

Table 4: Percentages of treated fabrics with washed fabrics and treated fabrics with control fabrics

Specimens code	Treated fabrics with washed fabrics %	Treated fabrics with control fabrics %	Specimens code	Treated fabrics with washed fabrics %	Treated fabrics with control fabrics %
1A	73.00	75.66	3A	76.33	73.66
1B	79.33	72.00	3B	77.33	77.66
1C	73.66	77.33	3C	74.66	73.33
1D	77.00	80.33	3D	72.00	78.33
1E	79.66	81.66	3E	77.33	78.33
1F	70.66	75.66	3F	73.66	76.00
1G	65.66	82.00	3G	66.33	78.00
1H	69.66	73.33	3H	74.66	74.33
2A	80.00	78.33	4A	78.00	72.66
2B	81.00	81.33	4B	78.66	82.00
2C	74.00	76.66	4C	72.00	71.33
2D	72.66	78.66	4D	73.33	74.33
2E	75.33	72.33	4E	79.00	79.66
2F	77.33	74.66	4F	69.33	78.66
2G	68.33	78.66	4G	74.33	76.00
2H	75.00	77.00	4H	69.66	70.33

Note: All opinions of its smoothness, according to the order (totally agree=3, agree=2, do not agree=1); after that calculate the arithmetic mean (average), then determine the importance degree using "Triple Licart Scale": Small degree (1-1.66), medium degree (1.67-2.33), and high degree (2.34-3)

3.10 Testing the best results of eight different fabrics treated with softener from previous tests using fabric quality assurance using the simple test (SIROFAST).

The best softener and the best treatment bath were selected for each of the eight materials used based on the results of mechanical tests, as shown in table 5, and then the SIROFAST test was conducted on them.

Table 5: Samples code for the best samples measured by SiroFAST

Specimens code	Fabrics type	Softeners and methods used
1	Woven fabric/plain 1:1 (cotton 100%)	Evo soft SMA softener with pad application
2	Knitted fabric/interlock (cotton 100%)	Evo fin APE conc softener with exhausion application
3	Woven fabric/twill gabardine (polyester 100%)	Evo fin APE conc softener with pad application
4	Woven fabric/plain 1:1 tergale (polyester 100%)	Evo fin APE conc softener with exhausion application
5	Knitted fabric/milton (cotton 100%)	Evo soft SMA softener with pad application
6	Knitted fabric/rib (cotton 100%)	Evo soft SMA softener with pad application
7	Knitted fabric/pique (cotton 100%)	Evo soft SMA softener with pad application
8	Woven fabric/twill gabardine (cotton-polyester 65:35)	Evo soft SMA softener with exhausion application

Fabric assurance by simple testing (SIROFAST) measured compression (fabric thickness) at two loads (2 g/cm2 and 100 g/cm2), bending length, and extensibility (tensile) warp and weft at three loads (5, 20, and 100 went of width) and bias at the low load.

According to tables 6, 7, and 8, it is evident that the thickness, bending length and tensile characteristics of the fabric are apparent increases for all samples after softener application compared to the control.

The bending rigidity and formability in each fabric direction were calculated using equation (1):

$$B=W \times C^3 \times 9.81 \times 10^{-6}$$

Where W: fabric weight (g/m^2) and C: bending length (mm).

Then calculate formability, using equation (2): Formability=Bending rigidity x (Extension (20 g/cm) - Extension (5 g/cm)) / 14.7.

The roles of compression and extensibility are important. The degree of fabric compression affects the thickness of the fabric's surface layer, impacting how the cloth feels and looks. Therefore, all treated fabrics have high extensibility in warp and weft directions. This extensibility is high, so working with excessive extensibility fabrics can lead to undesired fabric distortion during cutting and sewing so, it must be treated with caution during cutting and sewing procedures [33][36].

The bending rigidity and formability results, as shown in Table 9, of all samples have increased in both directions, indicating that these fabrics are good in manufacturing and sewing because fabrics that exhibit higher bending rigidity typically do not present challenges during garment production. High-bending rigidity fabrics produce flat seams and enhance fabric formability and garment appearance. Fabric formability results are good and enhanced after treatment. The outcomes exceeded with different ranges according to the type of the fabric, indicating that the fabric possesses sufficient elasticity and bending properties, so these fabrics are good for manufacturing and have enough elastic and bending [34][36]. High fabric formability is important for a seamless garment production process and improves the production of seam puckering while sewing, and the fabric will be acceptable in manufacturing and sewing. The fabric will not buckle, and the seam will not be puckered. However, materials with low bending rigidity can lead to issues such as distortion while cutting, seam puckering during stitching, and inadequate shape retention, which affects the fit of the garment [33][34].

Table 6: SiroFAST-1 (compression meter) results

Fabric property/Sample code			1	2	3	4	5	6	7	8
Warp compression	Thickness at 2 g/cm2 (mm)	Before treatment	0.529	0.770	0.477	0.331	1.517	0.719	0.730	0.390
		After treatment	0.816	0.904	0.478	0.332	1.568	0.731	1.041	0.474
	Thickness at 100 g/cm2 (mm)	Before treatment	0.264	1.072	0.553	0.412	2.501	0.966	0.938	0.474
		After treatment	0.417	1.208	0.563	0.413	2.931	1.010	1.717	0.567
Weft compression	Thickness at 2 g/cm2 (mm)	Before treatment	0.576	0.762	0.474	0.330	1.389	0.707	0.721	0.390
		After treatment	0.792	0.907	0.480	0.339	1.444	0.740	0.759	0.477
	Thickness at 100 g/cm2 (mm)	Before treatment	0.271	1.061	0.548	0.406	2.306	0.952	0.922	0.513
		After treatment	0.426	1.202	0.557	0.421	2.396	1.017	0.946	0.579

Table 7: SiroFAST-2 (bending meter) results

Fabric property/Sample code		1	2	3	4	5	6	7	8
Warp bending length (mm)	Before treatment	16.0	14.2	15.6	15.3	14.5	12.8	13.8	22.8
	After treatment	21.0	16.2	17.5	15.7	16.3	15.5	14.0	23.0
Weft bending length (mm)	Before treatment	15.9	9.7	16	15.1	13.2	10.1	12.0	16.5
	After treatment	16.5	11.0	18.5	16.7	15.0	11.0	13.9	17.7

Table 8: SiroFAST-3 (extension meter) results

Fabric property/Sample code			1	2	3	4	5	6	7	8
Warp extension	5 g/cm	Before treatment	0.7	3.4	0.2	0.7	1.5	5.2	6.7	0.1
		After treatment	0.8	3.6	0.3	0.9	1.8	6.1	7.3	0.1
	20 g/cm	Before treatment	1.4	8.5	0.8	1.6	3.7	10.7	15.0	0.5
		After treatment	1.6	10.3	1.3	1.8	6.0	13.2	15.6	0.6
	100 g/cm	Before treatment	3.2	15.5	2.5	3.3	17.2	18.7	20.8	1.6
		After treatment	3.7	20.8	3.4	3.4	17.9	20.1	20.8	1.9
Weft extension	5 g/cm	Before treatment	0.6	16.9	0.7	0.7	1.6	20.8	6.7	0.3
		After treatment	0.8	18.9	0.8	1.0	2.8	20.8	6.9	0.4
	20 g/cm	Before treatment	3.2	20.8	1.9	1.5	4.9	21.7	16.7	0.8
		After	3.9	20.8	2.1	1.8	5.5	21.9	17.4	1.1

		treatment								
	100 g/cm	Before treatment	12.1	20.8	4.2	3.4	15.3	20.8	20.8	2.4
		After treatment	16.9	20.8	4.3	3.4	15.3	20.9	20.8	4.7
Bias extension	5 g/cm	Before treatment	1.6	1.7	2.3	2.4	2.2	2.1	1.0	0.7
		After treatment	1.7	1.9	2.5	3.1	2.6	2.5	1.3	1.7

Table 9: bending rigidity and formability results

Fabric property/Sample code			1	2	3	4	5	6	7	8
Bending rigidity	Warp	Before treatment	5.46	5.64	9.75	6.32	9.65	3.60	5.85	29.18
		After treatment	17.44	12.09	16.98	7.36	22.60	9.93	10.25	31.27
	Weft	Before treatment	5.36	1.79	10.52	6.07	7.28	1.76	3.84	11.06
		After treatment	8.46	3.78	20.06	8.86	17.61	3.55	10.03	14.25
Formability	Warp	Before treatment	0.26	1.95	0.39	0.38	1.44	1.34	3.30	0.79
		After treatment	0.94	5.51	1.15	0.45	6.45	4.79	5.78	1.06
	Weft	Before treatment	0.94	0.47	0.85	0.33	1.63	0.10	2.61	0.37
		After treatment	1.78	0.48	1.77	0.48	3.23	0.26	7.16	0.67

4. Conclusion

This study examines the effects of silicone (Evo soft SMA) and polyethylene (Evo fin APE conc) softeners using exhaustion and pad-dry-cure techniques on different fabric types: cotton, polyester, and their blends with different fabric constructions: knitted (rib,
interlock, milton, and pique) and woven (plain 1:1 and twill) to enhance the fabric manufacturing and production including sewing, cutting, production of flat seams, avoid producing of seam puckering and improve garment appearance. The 32 treated samples are compared to the 8 control samples regarding the mechanical and sewability properties of the fabrics. Through mechanical testing, such as abrasion resistance, tear resistance, crease recovery, pilling, stain resistance, color fastness (rubbing, washing, perspiration, and light), and fabric hand, the study evaluated the changes in fabric performance; then, the best softener and treatment bath were chosen for each of the eight materials based on the outcomes of mechanical tests. These eight materials were tested for sewability utilizing SIROFAST, which includes interlock, plain 1:1 polyester 100% with Evo Fin APE Conc by the exhaustion method, twill cotton/polyester 65:35 with Evo Soft SMA by the exhaustion method, and Milton, rib-pique, plain 1:1 polyester 100% with Evo Fin APE Conc by the pad-dry-cure method.

Tests of abrasion and tear resistance using exhaustion and pad-dry-cure techniques yielded positive results for all samples treated with silicone and polyethylene softeners with 73 % in abrasion resistance test and 86 % in tear resistance test compared to the control sample. By using the two techniques, crease recovery was significantly improved in polyester fabrics and cotton/polyester blends by 94 % compared to the control sample, but it decreased in cotton fabrics that were treated with silicone and polyethylene softeners with 12 %.

Pilling tests showed constant results comparing treated fabrics with the control in rib, pique, and plain 1:1 cotton 100% fabrics, except with Evo Fin APE Conc softener by the exhaustion method, which exhibited a decrease in results by 25 % compared to the control sample. Milton fabric showed decreasing results with 32 %; interlock fabric had constant results, but plain 1:1 polyester 100% and twill polyester 100% fabrics increased with silicone and polyethylene softeners by exhaustion and pad-dry-cure methods by 80 % compared to the control sample. In addition, the twill cotton/polyester blend indicated decreasing results with 74 % except with Evo Soft SMA softener using the exhaustion method, which offered constant results.

The stain resistance test showed constancy in results with Milton and plain 1:1 cotton 100% fabrics, except in Evo Fin APE softener with the pad-dry-cure method, which showed a decrease by 50 % compared to the control sample. Interlock fabric had constant results in Evo Fin APE softener with the exhaustion method and Evo Soft SMA softener by the pad-dry-cure method but showed a reduction in Evo Soft SMA softener by the exhaustion method and Evo Fin APE softener with the pad-dry-cure method by 25 %. Rib and pique fabrics had a decrease in results with 30 % compared to the control sample, except in Evo Soft SMA softener, where the pad-dry-cure method showed constant results. Twill polyester 100% fabric showed constant results with silicone and polyethylene softeners by exhaustion and pad-dry-cure methods. Plain 1:1 polyester 100% had a decrease in results by 25 % except in Evo Fin APE softener, where the exhaustion method has constant results. Furthermore, the cotton/polyester blend offered constant results in Evo Soft SMA softener by the exhaustion method and Evo

Fin APE softener by the pad-dry-cure method, but there was an increase in Evo Soft SMA softener by the pad-dry-cure method and Evo Fin APE softener by the exhaustion method with 80 % compared to the control sample.

According to the colour fastness to rubbing test, wet conditions resulted in somewhat lower rubbing fastness scores than dry conditions. Fabrics in wet conditions displayed (4 or 3-4) on the grey scale, except Milton (2-3). On the other hand, the dry fabrics displayed (4 or 4-5), except for Milton and 100% twill polyester (3-4). Nonetheless, the color fastness to washing produced excellent results; using silicone and polyethylene softeners, all samples obtained a grey scale score of 4 or 4-5 using exhaustion and pad-dry-cure techniques. Very good results were demonstrated by colour fastness to acid and basic perspiration; all values had a grey scale value of (4 or 4-5). Furthermore, all samples' color fastness to light decreased or remained stable when comparing the control with treated fabrics using silicone and polyethylene softeners using exhaustion and pad-dry-cure techniques.

The fabric hand evaluation showed that all treated samples with silicone and polyethylene softeners by exhaustion and pad-dry-cure methods achieved medium to high levels of smoothness. The improvement in fabric hand for the treated sample in comparison to the control ranged from 70.33% (twill/cotton polyester 65:35) to 82% (knitted fabric/pique and interlock-cotton 100%). Additionally, the enhancement in fabric hand for the washed sample relative to the treated one varied from 65.66% (knitted fabric/pique-cotton 100%) to 81% (knitted fabric/interlock-cotton 100%).

Furthermore, the samples exhibited good extensibility results, which is good for manufacturing and sewing, because dealing with high extensibility fabrics can lead to fabric distortion during cutting and sewing. Also, bending rigidity and formability results of all samples have increased in both directions with silicone and polyethylene softeners by exhaustion and pad-dry-cure methods, high bending rigidity fabrics produce flat seams and also enhances fabric formability and garment appearance which is important for a seamless garment production process and enhances the production of seam puckering while sewing. Finally, the future research needs to study the effect of these softeners and more types of softeners and get the best optimum condition to enhance fabric quality and manufacturing.

5. References

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