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Effects of Needle Size and Sewing Thread on Seam Quality of Traditional Fabrics

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ABSTRACT

The role of fabric properties in sewing performance and seam quality is essential, therefore, it is crucial to understand the effect of different parameters on traditional fabrics' sewability properties. This study aimed to evaluate the seam quality of traditional fabrics produced from silk, cotton and linen fibres and their blends in terms of seam strength, seam slippage, seam efficiency and fabric sewability and determine the optimum sewing thread and sewing needle size for the sewing process of these fabrics. The samples were sewn using two different sewing needle size (75 Nm and 90 Nm) and sewing thread (100% mercerised cotton and 100% polyester corespun). Based on the obtained results, it can be concluded that sewing thread and fabric type had significant effect on seam strength, seam slippage and seam efficiency. The samples sewn with polyester corespun sewing thread had higher seam strength than other. The sewing needle significantly affected the needle penetration force values and the silk fabric had lowest sewability values both in warp and weft direction.

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Traditional fabrics, seam strength, seam efficiency, fabric sewability, needle penetration force

1. INTRODUCTION

Textile and fashion industry has quite inconvenient features from an ecological point of view, with parameters such as the raw material, energy and water consumption, the intense chemical process content in the production process, mass production capacity, and the potential for waste after production [1, 2]. For this reason, the effects of the concept of sustainability in industrial production are also observed in textile and fashion industry. The solutions such as adopting the slow fashion trend, using cyclical production methods, and turning to recycling raw materials are applied to the textile industry [2, 3]. In addition, local fabrics produced traditionally and ecologically attract the attention of the fashion industry and their use creates a new dimension in terms of sustainability in textile [4, 5].

The traditional shirts made of natural fibres, which are also the subject of this study, are preferred also in daily life. The materials used in these shirts generally depend on the characteristics of the region such as the climate of the region, the availability of raw materials, the production techniques, etc. [6]. The traditional fabrics made of natural fibres, namely silk, linen, cotton and their blends were evaluated in this research. Especially silk is one of the most important natural fibres due to its unique properties such as specific gravity of 1.25-1.3 g/cm and diameter of 12 µm [7]; whereas cotton has 1,54 g/cm specific gravity and10-27 µm diameter, flax has 1,4 g/cm specific gravity and15-20 µm diameter [8].

It is crucial to know the quality of the end product before commercializing. Seam quality is one of the outstanding parameter that effects the overall quality of a garment. The seam quality could be characterized as functional (strength, elasticity, durability, stability) and aesthetic (the proper appearance) [9-11]. Many researchers were studied on seam characterization both in functional and aesthetic aspect [9-25]. Data et al. (2017) evaluated the effect of stitch density and the linear density of sewing thread on seam efficiency of a woven linen men shirt's production. It was found out that, the most suitable stitch density is 13-13,5 stitch per inch and the sewing thread is 40 Tkt number spun polyester [10]. Malek et al. (2018) developed a regression model to predict the seam quality through studying sewing performance by measuring the seam efficiency, slippage and puckering of 18 denim fabrics [11]. Abou Nassif (2013), investigated the effect of needle size, stitch density,

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sewing thread tension and sewing direction on the seam tensile strength, seam elongation and seam efficiency of cotton woven fabric. It was obtained that the sewing machine parameters have a certain influence on the seam quality [12]. Choudhary and Goel (2013) analysed the effect of blend composition (3 varying in the blend composition of polyester and cotton components), sewing thread size, and sewing needle parameters on seam strength, seam efficiency, seam puckering, seam stiffness, and drape coefficient and stated that seam efficiency is higher and the seam puckering is lower in the 100% cotton structure of fabric. The low seam strength efficiency was observed for the polyester fabric due to polyester's high extensibility and tenacity [13]. Gribaa et al. (2006) investigated the influence of the sewing thread, the stitch type, the stitch density, the needle size and the edge of the seam on tensile behaviour of a plain weave cotton/polyester fabric. It was demonstrated that the sewing thread, the stitch density, the edge of the seam as well as the sewing direction have a significant effect on seam strength [14]. Rogina-Car and Kovacevic (2021) analysed the damage caused by the needle piercing the cotton fabric during sewing. The specimens were prepared using three types of needle point shapes and four needles. It was obtained that the samples sewn with SUK-designated needles creates larger holes, whereas SES-designated needles give the best results [15]. In the research performed by Gurarda and Meric (2005), the effect of elastane feeding ratio, pre-setting temperature and finishing process on needle penetration force was examined. 12 cotton/elastane woven fabrics were produced and tested using L&M sewability tester, same as used in the present research; the obtained results showed that treating the elastic fabric with silicone during the finishing process helps to prevent the fabric damage [18]. In the study conducted by Carvalho et al. (2020), the sewability of towels were determined by quantifying the needle penetration force. Different sewing needles were used with different sizes, points, and coatings. The effect of needle size on needle penetration force was significant, however the effect of needle point is not clearly demonstrated [20]. Karypidis (2018) as well tested the sewability properties of rigid structures in their natural, washed and softened states, which are higher mass per square metre fabrics known to be problematic in the sewing stage. It was found out that washing and softening fabric treatments decreases the needle penetration force [23]. Pamuk et al. (2011) investigated the sweability properties of six lining fabrics using L&M sewability tester and found out that yarn count and density have a significant effect on the sewability values of lining fabrics [25].

In this study, the seam quality of traditional shirt fabrics was evaluated in terms of seam strength, seam slippage, seam efficiency and fabric sewability. Seam strength is the strength of a sewn seam by applying a force perpendicular when seam finally ruptures [26]. Seam efficiency is another parameter that demonstrates seam performance defined as the seam carrying capacity of a fabric itself [17] and is measured by the ratio of sewn and unsewn fabric strengths [27]. Furthermore, seam slippage (opening) is a mode of failure evidenced by yarn movement at either side of the seam creating a gap or opening [8]. Seam slippage is affected by fabric characteristics such as weave, type of weaving yarn, coefficient of friction between yarns, fabric density, and so on [28, 29].

There are many factors affecting the seam strength, seam slippage and seam efficiency; the properties and the construction of fabric, sewing thread, sewing needle size, sewing needle point type, stitch density, seam type and sewing machine parameters. The seam strength and so the seam efficiency increases with the sewing thread linear density. Islam et al. (2018) evaluated the effect of sewing thread's effect of seam strength and seam efficiency using 14 tex, 18 tex and 60 tex polyester corespun sewing thread and obtained better efficiency in 60 tex sewing thread samples [26]. A similar observation was done by Choudhary and Goel (2013); where the percentage contribution of sewing thread on seam efficiency was found out as 5% [13]. Unal and Baykal (2018) also investigated the effect of PES/CO as well as PES/PES corespun sewing threads on seam quality and come up with similar results as the higher the yarn strength, the higher the seam strength [21]. Another important factor affecting seam quality is the sewing needle, which is one of the elements used in forming the seam. To determine the proper sewing needle, the needle size and the needle point type should be chosen properly considering the fabric type. During a seam formation, the sewing needle passes between the weft and warp yarns though the fabric. The thicker needle has more possibility to coincide the conjunctions of yarns, where it has to pierce. As Rogina-Car and Kovačević (2021) stated, the greater needle size creates higher contact with the material, which creates holes with larger surface area and lowers the seam quality [15]. Abou Nassif (2013) found out a 5% decrease in seam strength when the samples prepared using 80 Nm to 100 Nm needles [12]. The approach to explain this situation is the possibility of breaking the fabric yarn when using a needle with a greater diameter [31].

A good fabric sewability is related with a proper seam forming without fabric damage and a desired seam appearance. It is mainly evaluated by measuring needle penetration force (NPF). NPF is the quantitative measure of the friction between the fabric and the sewing needle and the damage which appears in the garment due to sewing process [18, 23]. Several authors studied the subject of measuring the NPF since decades, in 1976, Hurt and Tyler measured NPF in a lockstitch sewing machine by placing a tensiometer [22]. In 1973, Leeming and Munden were developed the L&M sewability tester and they obtained the patent in 1976 [31]. In the recent studies conducted by Carvalho (2004) and Carvalho et al. (2009), new technique was developed including a piezoelectric force sensor inserted into the needle bar of an industrial sewing machine [32, 33]. Measuring the NPF is essential to evaluate the fabric sewability; the lower NPF indicates the higher fabric sewability [23].

The objective of the study was to identify the optimum sewing thread and sewing needle size for the sewing process of traditional shirting fabrics produced from silk, linen and cotton, and their blends. Some existing researches in the literature focused on evaluating the seam performance of silk fabrics [34, 35], linen fabrics [10], cotton fabrics [18, 19, 22, 24, 36] and comparing silk and cotton fabrics' seam quality [37]; however, there was no systematic study focusing on silk, linen and cotton fabrics and their blendes systematically. Therefore, the focus of this research was to examine the effects of determined parameters on the seam strength, seam slippage, seam efficiency and fabric sewability. As the literature review reveals, there are limited researches on evaluating the seam quality of traditional shirting fabrics, especially produced from silk, linen and cotton, and their blends. Findings of this research contributes to fill this gap in the literature. Moreover, this study could help apparel manufacturers to understand the seam quality of traditionally woven fabrics from silk, linen and cotton materials, to determine the optimum sewing thread and sewing needle size, and therefore to manufacture the products with higher overall quality.

2. MATERIAL AND METHOD

2.1 Material

2.1.1. Fabric properties

The traditional fabrics produced from silk, linen and cotton raw materials and their blends, to be used in shirt manufacturing in the Izmir region were procured. The construction of the all fabrics was plain weave structure and they have not been subjected to any dyeing or softening process. In Table 1, the yarn counts and fabric parameters are given.

2.1.2. Sewing thread

To assess the effect of sewing thread on seam quality, 100% polyester corespun and 100% mercerised cotton sewing threads were selected. The main reason for choosing them was that the sewing threads used in the garment industry are generally produced from cotton and polyester fibres [30]. Especially polyester corespun sewing threads dominate the market due to their very high yarn strength property [21] and are suitable for the production of normal clothing products thanks to their versatile structure [10]. Table 2 presents the properties of commercial sewing threads (Coats Group plc, Uxbridge, UK) used in the study.

2.1.2. Sewing parameters

All samples were sewn using a Juki DDL-9000B high speed single needle lockstitch machine. The sewing conditions are presented in Table 3. The settings of the sewing machine were done before the sewing process and the other parameters such as lower and upper thread tensions kept constant.

The sewing needle, one of the seam forming elements, is essential to ensure good seam quality. Especially choosing the right needle size and needle point is one of the most important parameters in the production of garments' joints [11, 14, 30, 38]. As the existing literature proves the significant effect of needle size on seam quality, the thicker needles decrease the seam strength, seam efficiency and seam elongation, whereas increase the force required to pierce the needle through the fabric [12, 15]. Two needle sizes were used in this study, namely 75 Nm and 90 Nm considering the fabric characteristics as well as the recommendations of the sewing thread company.

Table 1. Fabric properties

Fabric composition	Weft yarn count (Ne)	Warp yarn count (Ne)	Weft yarn density (threads/cm)	Warp yarn density (threads/cm)	Fabric weight (g/m^2)	Fabric thickness (mm)
100% Silk	100/2	100/1	38	34	58.4	0.13
100% Linen	12/1	12/1	20	18	165.9	0.47
100% Cotton	30/1	30/1	22	34	119.9	0.37
25% Silk /75% Linen	40/1 (linen)	100/1 (silk)	26	36	98.6	0.22
30% Silk / 70% Cotton	18/1 (cotton)	100/1 (silk)	38	36	66.5	0.21
25% Cotton / 75% Linen	22/1 (linen)	100/1 (cotton)	26	36	101.5	0.24

Table 2. Sewing thread specifications

Sewing thread	Linear density (tex)	Average strength (cN/tex)	Elongation % (min – max)
100% polyester corespun	24	1190	17-22
100% mercerised cotton	30	830	4-9

Table 3. The sewing specifications

Sewing type	Stitch length (mm)	Needle size (Nm)	Needle point type	Needle point shape [15]
Lockstitch (Type 301)	3	75 90	SES Light Ball Point	

Moreover, the light ball point (SES) needle type, which is most commonly used needle point type for sewing general knit fabrics and lightweight woven fabrics [39], was chosen. These needles easily penetrate through the weft and warp yarns of the fabric, produce less yarn breakages then medium ball point needle (SUK) [15]. The range of the stitch length is between 0 and 5 mm on most sewing machines [17]. In this study, the stitch length was determined as 3 mm, which is an average stitch length in apparel industry.

In a cut and sew garment, cut pieces of fabric can be sewn in both the weft and warp directions. Therefore, the examination of the sewing direction comes to the forefront in the evaluation of the sewing quality. Many researchers studied the effects of sewing direction on the seam quality and found out it has a significant effect on the seam strength [9, 12, 40, 41]. For this reason, the sewn samples were prepared for both warp and weft directions in the present study.

2.2. Experimental Design

To determine the seam quality, all seams were formed both in warp and weft directions for all specimens. Before the tests, all specimens were conditioned under standard atmosphere conditions for 24 hours maintaining the temperature at 20±2ºC and the relative humidity at 65±4 %.

2.2.1. Seam strength

Seam strength is the strength of a sewn seam by applying a force perpendicular when seam finally ruptures. In this paper, it is followed ISO 13935-1 (2014) standard for sample preparation and testing to measure the seam strength and to evaluate the seam efficiency [42]. The tests were conducted using Zwick Z010 (Roell) tensile strength testing machine. Five tests were conducted consecutively in warp and weft direction for each specimen. The maximum forces only resulting with seam break that occurs by breaking seam thread were evaluated due to the fact that, the brakeage may occur for different causes. Furthermore, to determine the tear strength of fabrics, ISO 13937-2 standard was used to prepare the trouser-shaped test specimens and to perfom the tear tests [43]. The warp tear strength was measured on weft direction, whereas the weft tear strength was measured on warp direction.

2.2.2. Seam efficiency

Seam efficiency is defined as the seam carrying capacity of a fabric itself [17]. Seam efficiency is the ratio between the original and the seamed fabric strength, which is calculated as the ratio of seam strength by fabric tensile strength as presented in Equation (1) [10, 11, 17, 27, 36]. The fabric tensile strength was determined using the Strip Method according to ISO 13934-1 standard [42].

$$\text{Seam Efficiency } (\%) = \frac{\text{Seam strength}}{\text{Fabric tensile strength}} \times 100 \qquad (1)$$

2.2.3. Seam slippage

Seam slippage defines the ability of the warp yarns slip over the weft yarns, or weft yarns slip over the warp yarns near the seam. To measure the warp yarn slipping, the specimen is subjected to a given load in weft direction and the extension is observed in the warp direction. The reverse is done to measure the weft yarn slippage [44, 45]. Seam slippage values were tested using Zwick Z010 (Roell) tensile strength testing machine and five tests were performed in warp and weft direction for each specimen. ISO 13936-1:2004 stardard was followed.

2.2.4. Fabric sewability

Sewability can be defined as the ability of the fabric components to be seamed effectively without fabric damage and to provide a desired quality for the end-use performance [47-49]. Sewability is mainly related with needle penetration force (NPF), which is the friction between the fabric and the sewing needle. The NPF was measured using L&M Sewability Tester (John Godrich) (Figure 1) by monitoring the force required for a sewing needle to penetrate the fabric [50]. A total of 100 needle penetrations were performed for each test and the average force applied to the fabric in grams was recorded. The threshold value was determined as 50 gf for silk and silk blended fabrics and as 100 gf for other fabrics according to the recommended values of the L&M sewability tester catalogue considering the fabric mass area.

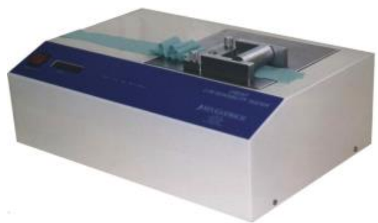

Figure 1. L&M sewability tester [46]

2.2.5. Statistical analyses

Statistical analyses were carried out by using SPSS software. The Univariate and Independent-samples t-tests were applied to examine the interaction as well as individual effects of each parameter on the seam strength, seam efficiency and needle penetration force. Post-hoc analysis were also performed by using Duncan test in order to determine which means of groups differ significantly. All test results were assessed at significant levels of 0.05.

3. RESULTS AND DISCUSSION

3.1. Seam strength

The fabrics were seamed with two different sewing needles using two different sewing threads in both warp and weft directions. Table 4 presents the seam strength, fabric tensile strength and fabric tear strength mean values.

In Figure 2, examples obtained during seam strength tests were given. In the image on the left, a clear seam break can be seen, however, fabric tear was occurred before the seam break in the image on the right side. This situation was only happened for silk/cotton fabric's warp samples however; the tensile strength of the silk fabric was similar with silk/cotton fabric. The yarn count of the warp yarns of silk fabric and silk/cotton fabric was the same, and the weft and warp densities were very similar. However, although the weft cotton yarns of the silk/cotton fabric were thicker, still the slippery were occured between the warp and weft yarns. Since the fabrics procured were produced traditionally, it was thought that the desizing process was also done traditionally. This may have affected the properties of the cotton yarn and caused the slippery. Therefore, these results were eliminated from the data used in statistical tests. The relevant data was written in bold in Table 4.

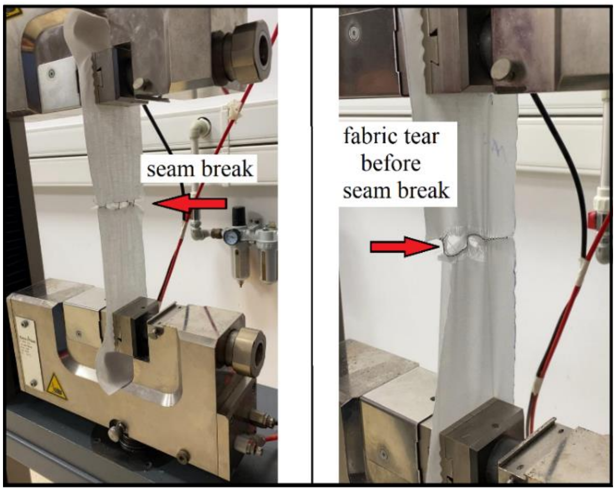

Figure 2. Some examples of images obtained during testing

Table 4. Seam strength, fabric tensile strength and fabric tear strength values

Fabric type	Sewing needle*	Sewing thread*	Seam strength (N)		Fabric tensile strength (N)		Fabric tear strength (N)	
			Weft	Warp	Weft	Warp	Weft**	Warp***
Silk	SN1	ST1	189.69	239.31	272.48	244.19	22	14.3
		ST2	169.78	205.42				
	SN2	ST1	162.40	238.53				
		ST2	201.96	225.87				
Linen	SN1	ST1	237.58	210.34	665.98	477.92	28.2	24
		ST2	234.94	246.24				
	SN2	ST1	220.62	207.00				
		ST2	263.19	263.12				
Cotton	SN1	ST1	255.45	246.59	278.86	445.91	5.27	7.9
		ST2	271.07	300.87				
	SN2	ST1	232.00	215.57				
		ST2	246.97	250.79				
Silk / Linen	SN1	ST1	180.97	208.37	707.97	245.96	35.6	16
		ST2	243.98	200.31				
	SN2	ST1	198.10	197.32				
		ST2	251.76	163.11				
Silk / Cotton	SN1	ST1	219.02	**35.96**	401.13	256.56	39.7	16.4
		ST2	291.40	**35.31**				
	SN2	ST1	214.33	**44.18**				
		ST2	216.87	**26.97**				
Cotton / Linen	SN1	ST1	183.82	148.61	810.19	248.23	40.1	17.1
		ST2	212.47	208.45				
	SN2	ST1	148.89	141.18				
		ST2	262.69	149.56				

*SN1 = 75 Nm sewing needle, SN2 = 90 Nm sewing needle, ST1 = 100% mercerised cotton sewing thread, ST2 = 100% polyester corespun sewing thread
** Tear strength values of weft yarns on warp direction *** Tear strength values of warp yarns on weft direction

The Independent Samples t-Test was performed to define the effect of individual factors on seam strength. Regarding the results, the sewing thread had statistically significant effect on seam strength values of all fabric types ($p=0.00$); whereas, it was not statistically significant for the sewing needle ($p=0.17$).

Afterwards, in order to have a better comprehending of the effects of fabric type and sewing thread values and their interactions on seam strength, the univariate analysis was applied, which is used to understand the distribution of values for a single variable. The statistical analysis of the results (Table 5) showed that the fabric type and the sewing thread had a statistically significant effect on the seam strength for both warp and weft samples ($p<0.05$). When the sewing threads used in the study were compared, the general trend was the polyester corespun sewing thread used samples had higher seam strength values than mercerised cotton sewing thread used samples both in warp and weft direction. Similar observations were reported in the literature [10, 21, 26, 34, 51] due to polyester corespun's high yarn strength property. However, this was the opposite for the silk (warp and weft direction) and silk/linen (warp direction) fabrics. It is thought that, this may be due to the multifilament structure of silk yarns and also the fact that more silk yarns coincide within one stitch length, considering the fabric density. The cotton fabric samples sewn by polyester corespun sewing thread in warp direction showed the highest seam strength. Moreover, the interaction of parameters, namely fabric type and sewing thread, did not have statistically significant effect on weft samples (p=0.085) as it had a high observed power very close to "1" (Table 5). However, the interaction effects were statistically significant on warp samples (p=0.005). The reason for this situation could be interpreted as the interaction was moved to a significant level with fabric type's dominant effect (obs. power = 1).

Although the silk fabric was the thinnest among all fabrics and had prominently lower fabric tensile strength than cotton as well as linen fabrics (Table 4), the seam strength values were close to each other especially in warp direction (Figure 3). Furthermore, the general trend in seam strength values was, the values of the weft samples were higher than those the values of the warp samples.

In both warp and weft samples, the seam strengths among fabric types were statistically significant, therefore four subsets were formed for each direction (Table 6). As it was mentioned before, silk/cotton fabric results in warp direction were eliminated due to fabric tearing occurred prior to the seam break. As seen from the mean values, some results overlapped, still it was clear that cotton had the highest seam strength in both directions. Unlike the cotton and linen fabrics, cotton/linen fabric was in the first subset group in both weft and warp direction, which were the groups had the lowest seam strength values. The fabric thickness nearly doubled that of cotton/linen fabric, with cotton fabric also having the highest fabric weight.

Table 5. The univariate analysis results

Sewing direction	Source	F	Sig.	Observed power
Weft samples	Fabric type	9.029	0.00	1
	Sewing thread	24.687	0.00	1
	Fabric type * Sewing thread	2.048	0.085	0.998
Warp samples	Fabric type	17.597	0.00	1
	Sewing thread	4.360	0.042	1
	Fabric type * Sewing thread	4.19	0.005	0.535

Figure 3. The seam strength values of samples in warp and weft direction

Table 6. Multiple comparisons of seam strength values

Sewing direction	Fabric type	N	Seam strength Subsets 1	2	3	4
Weft samples	Silk	12	180.96	-	-	-
	Cotton / Linen	12	201.97	201.97	-	-
	Silk / Linen	12	-	218.71	218.71	-
	Silk / Cotton	12	-	-	235.41	-
	Linen	12	-	-	239.08	239.08
	Cotton	12	-	-	-	251.37
Sewing direction	**Fabric type**	**N**	**Seam strength Subsets 1**	**2**	**3**	**4**
Warp samples	Cotton / Linen	12	161.95	-	-	-
	Silk / Linen	12	-	192.28	-	-
	Silk	12	-	-	227.28	-
	Linen	12	-	-	231.68	231.68
	Cotton	12	-	-	-	253.46

3.2. Seam efficiency

The seam efficiency was calculated using Equation (1), which is used to measure the loss in fabric strength caused by needle damage [27]. It is inversely proportional to fabric tensile strength; the high fabric strength lowers the seam efficiency. The highest seam efficiency both in weft direction was observed at silk fabric (Figure 4), which had lowest fabric weight (Table 1), as supporting the Cheng and Poon's (2002) [9] and Datta et al. (2017) research [10], which were indicated that the high fabric weight increased the fabric strength, which reduced the seam efficiency. In order to determine the effects of sewing thread, sewing needle and sewing direction parameters on seam efficiency, the Independent Samples t-Tests were performed. The sewing thread (p=0.451) and the sewing needle (p=0.495) did not have statistically significant effect on seam efficiency values.

In several researches, it was stated that, the high strength of sewing thread as well as the high needle size increase the seam efficiency [10, 12, 14, 19, 24]. This trend could be seen in Figure 4 as well. The corespun polyester sewing thread had higher sewing efficiency values, the exceptions were observed for silk and silk/linen fabrics similar with seam strength values. Moreover, seam efficiency values of silk, silk/linen and cotton/linen fabrics in warp direction were higher than those obtained in weft direction. It is thought that this may be caused by the warp yarns of these fabrics being thicker than the weft yarns. Vice versa, the seam efficiency of silk/cotton fabric was higher in weft direction where the yarn thickness of weft yarns was greater than warp yarns.

3.3. Seam slippage

When a seam is stretched, separation of the interface line between two sewn fabrics occurred, however if the slippage is notable, it is considered as a sewing defect [8, 28]. Table 7 presents the seam slippage results of samples in both warp and weft direction. According to the experimental results, it can be said that the lightweight fabrics were tend to cause seam slippage than others due to finer yarns used in the fabric. The silk, silk/linen and silk/cotton fabrics had similar seam slippage results on warp direction; the silk yarns used were same 100/1 Ne in warp direction and also the fabrics had similar warp yarn density.

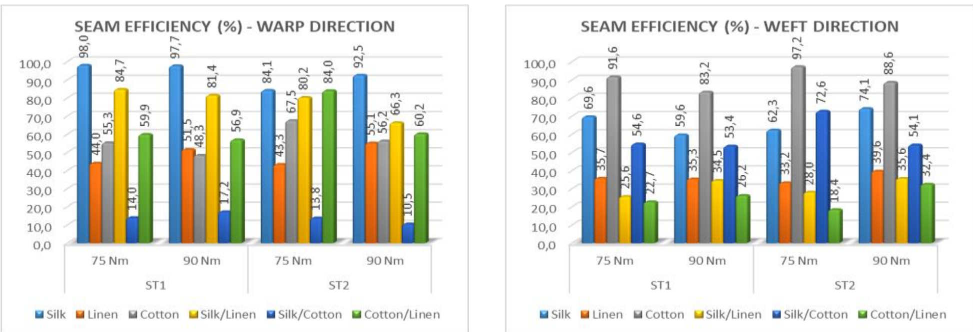

Figure 4. Seam efficiency values for both warp and weft samples

Table 7. Seam slippage values

Fabric type	Sewing needle*	Sewing thread*	Seam slippage	
			Weft	Warp
Silk	SN1	ST1	36	34.7
		ST2	39	28
	SN2	ST1	26	22
		ST2	24.5	20.2
Linen	SN1	ST1	68	54.5
		ST2	57	55
	SN2	ST1	70.5	69
		ST2	71	63
Cotton	SN1	ST1	47.5	57.8
		ST2	52.7	59
	SN2	ST1	51.5	64
		ST2	63	69
Silk / Linen	SN1	ST1	46	32
		ST2	53	36
	SN2	ST1	52	46
		ST2	45,5	36
Silk / Cotton	SN1	ST1	27	21
		ST2	25	20,4
	SN2	ST1	28.2	23
		ST2	24.9	22
Cotton / Linen	SN1	ST1	45	39
		ST2	39	30
	SN2	ST1	51.3	38.5
		ST2	34	31

Similar observations were obtained with Seif (2014) that sewing needle size and sewing direction had significant influence on seam slippage (Figure 5) [29]. Pasayev et al. (2012) stated that the seam slippage values in the weft direction were higher than the values in warp direction [52]. The general trend of the obtained results confirmed this statement, however the cotton fabric had results in the opposite way it is thought to be due to the warp and weft density of the fabric.

3.4. Fabric sewability

The NPF was measured both in warp and weft direction to determine the fabric sewability. The average values of NPF and also the sewability values were presented at Table 8. There is a defined range of sewability values as 0 to 10% considered good, 10% to 20% considered fair (no great difficulties arise during sewing) and more than 20% considered poor [18, 48, 50, 53]. Regarding obtained data, the sewability values of all fabrics were considered good, only cotton fabric had highest values both warp and weft directions as 3% (Table 8).

A good sewability requires low NPF values; a high NPF may alert sewability problems [23]. As observed in the Figure 6, the test results conducted with 90 Nm sewing needle had higher NPF values than those conducted with 75 Nm sewing needle and regarding the statistical analysis, sewing needle had statistically significant effects on NPF values (p=0.002). This has been found in other studies as well, carried out by Grancaric et al. (2005), Haghighat et al. (2014) and Carvalho et al., (2020) [20, 48, 54].

Afterwards, the univariate analysis was applied to define the effects of fabric type and sewing needle values and their interactions on NPF. In Table 9, it can be seen that, the fabric type (p=0.00) and sewing needle (p=0.00) had a statistically significant effect for both warp and weft samples. As stated by Bakıcı and Kadem (2015) and Haghighat et al. (2014), the NPF of the fabrics increases with the increase in fabric weight [48, 53]. In Table 8, the lowest NPF values both in warp and weft direction were observed for silk fabric, the lightest fabric (Table 1), which means the needle passed though the silk yarns easily. Additionally, the effect of the interaction of needle size and fabric type also had a statistically significant effect for both warp and weft samples (p=0.00). It is thought that, this situation may be due to the fact that both fabric type and sewing needle parameters were very dominant (obs. power = 1).

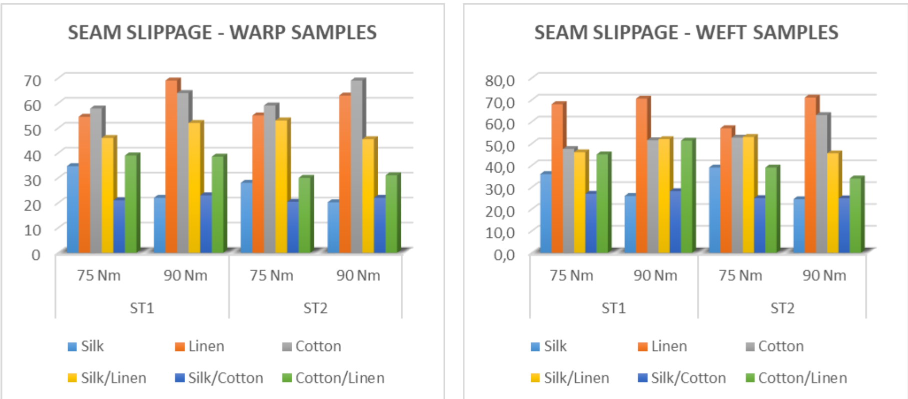

Figure 5. The seam slippage values of weft and warp samples

Table 8. The NPF and the sewability values

Fabric type	Sewing needle	NPF		Sewability value (%)	
		Weft	Warp	Weft	Warp
Silk	75 Nm	4.67	5.00	0	0
	90 Nm	15.00	12.33	0	0
Linen	75 Nm	15.67	12.67	0	0
	90 Nm	27.00	20.67	1	0
Cotton	75 Nm	17.67	25.00	0	0
	90 Nm	48.33	63.33	3	3
Silk / Linen	75 Nm	15.00	9.67	0	0
	90 Nm	22.33	15.00	1	0
Silk / Cotton	75 Nm	17.33	15.33	1	0
	90 Nm	15.00	6.67	0	0
Cotton / Linen	75 Nm	21.33	17.00	0	0
	90 Nm	23.00	19.00	0	0

The threshold values:
Silk, Silk/Cotton and Silk/Linen = 50 gf
Linen, Cotton and Cotton/Linen=100gf

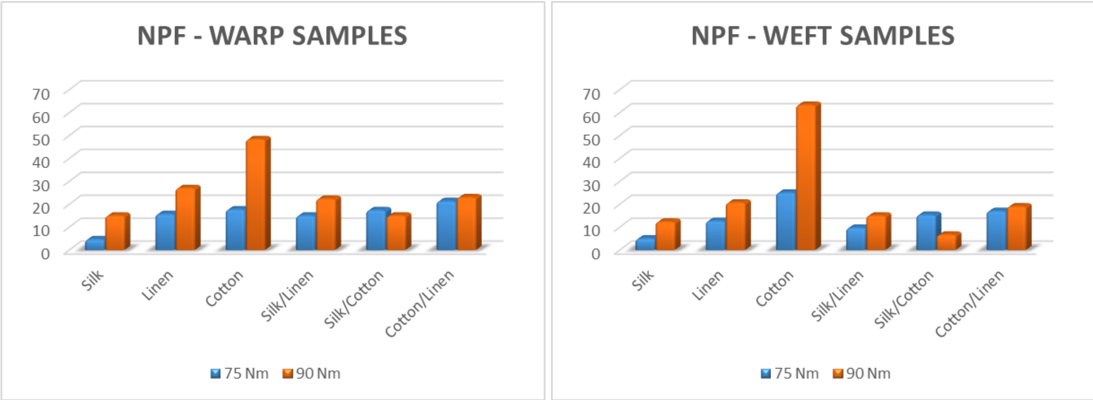

Figure 6. NPF values for both warp (left) and weft (right) samples

Table 9. The univariate analysis results

Sample direction	Source	F	Sig.	Observed power
Weft samples	Fabric type	12.485	0.00	1
	Sewing needle	30.685	0.00	1
	Fabric type * Sewing needle	6.955	0.00	0.992
Warp samples	Fabric type	71.722	0.00	1
	Sewing needle	47.955	0.00	1
	Fabric type * Sewing needle	26.019	0.00	1

Regarding the Duncan test results, three subsets were formed for weft samples; whereas, four subsets were formed for warp samples (Table 10). Similar with seam strength values, some results overlapped here as well. Only cotton fabric created a clear subset, the mean values of cotton were obviously greater than the other fabrics. In both warp and weft samples, the mean NPF values of fabrics were in same order, from smallest to greatest silk, silk/cotton, silk/linen, linen, cotton/linen and cotton.

4. CONCLUSION

Especially in last decades, the consumption cycle has become very fast in the textile and fashion industry, which is one of the oldest and largest industries in the world. The increase in the awareness of consumers has led to an increase in the importance given to sustainability. As a result of this, the manufacturers has been directed to make more sustainable production. In this context, the use of traditionally produced fabrics from natural raw materials attracts the attention of the textile and fashion industry. Considering the increasing interest, the analysis of sewing properties of Izmir region's traditional fabrics produced from natural fibres were carried out within the scope of this study.

Based on this research the following conclusions can be drawn out;

- The seam strength of 100% cotton and 100% linen fabrics was higher than the others, it was relatively lower in silk and silk-containing fabrics. Similar results were obtained by Courtney LaPere (2006) and was found out that the seam strength values of cotton fabric were higher than silk fabric [37].

Table 10. Multiple comparisons of seam NPF values

Sample direction	Fabric type	N	NPF Subsets 1	2	3	
Weft samples	Silk	6	9.83	-	-	
	Silk / Cotton	6	16.17	16.17	-	
	Silk / Linen	6	-	18.67	-	
	Linen	6	-	21.33	-	
	Cotton / Linen	6	-	22.17	-	
	Cotton	6	-	-	33.00	
Sample direction	**Fabric type**	**N**	**NPF Subsets 1**	**2**	**3**	**4**
Warp samples	Silk	6	8.97	-	-	-
	Silk / Cotton	6	11.00	-	-	-
	Silk / Linen	6	12.33	12.33	-	-
	Linen	6	-	16.67	16.67	-
	Cotton / Linen	6	-	-	18.00	-
	Cotton	6	-	-	-	44.17

- As supporting the literature [10, 21, 26, 34, 51], the polyester corespun sewing thread used samples mostly had higher seam strength values than mercerised cotton sewing thread, and it is thought this was due to polyester corespun's high yarn strength property.
- The yarn count, the fabric thickness and mass per unit area properties of the fabrics were also found as important parameters for sewing strength.
- The seam efficiency of silk fabric was higher than cotton and linen fabrics and their blends in warp direction and was similar with cotton in the weft direction. Beside other parameters, this research proves the statement that, the lower the fabric weight, the higher the seam efficiency [9, 10].
- The higher seam efficiency results of the corespun polyester sewing thread used samples support the existing literature [10, 12, 14, 19, 24] that is, the high strength of sewing thread as well as the high needle size increase the seam efficiency.
- The use of different fabric types and sewing needles in different sizes had significant effects on fabric sewability. The NPF values of silk fabrics were the lowest in both warp and weft directions, which also had the lowest fabric weight; supporting the fact that the increase in fabric weight increases the NPF [39, 44].
- Fabric properties, needle size and sewing direction had a particular effect on seam slippage of a garment, supporting the literature [29, 44].
- The results in the warp direction proved that there are some differences with the weft direction, which can be inferred as the fabric structure affects the behaviour of the sewn fabrics.

In summary, in addition to the sewing needle size, sewing thread and sewing direction parameters that important to form a seam, it was obtained that the material and physical properties of the fabrics are also effective on the sewing properties, and this study contributed to the literature in this direction. Based on the results given, the fabric properties and the joining processes can be optimised for the products to be produced from traditional fabrics. Future studies will focus on conducting wide spectrum researches involving other types of traditional fabrics and sewing parameters.

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