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Effects of Weight, Dyeing and the Twist Direction on the Spirality of Single Jersey Fabrics

Abstract
This paper investigates the effect of fabric weight on the spirality of single jersey fabrics. For this aim, ten knitted fabrics with different weights were knitted with 100% cotton and Tt 19.7/1 combed ring spun yarn, carded S ring spun yarn and carded Z ring spun yarn to investigate the effect of the type of yarn on spirality. Furthermore, these samples were dyed to explore the dyeing effect on spirality. After the dyeing process, the twenty fabrics produced were laundered and dried according to domestic laundering and drying test procedures. It was observed from the study that the fabric weight per m² has a significant effect on spirality for all the yarn types. Another finding obtained was that the dyeing process reduces the spirality by about half, which shows that fabrics knitted from carded S ring spun yarns give lower spirality values.

Key words: *single jersey fabric, spirality, weight, dyeing.*

Introduction

Knitted fabrics, especially ready-made knitted garments, t-shirts, underwear and lingerie are an important part of the textile sector. All people must use knitted fabrics during their life. The reasons for this usage can be explained in various ways: Firstly, it has an elastic and light structure; secondly, single jersey fabrics are easily and quickly produced; thirdly they have a lighter weight and lower production cost, and finally, because of their smooth surface, they are convenient for printing. However, besides all the advantages, these fabrics have quality problems like dimensional change and deformation. The dimensional instability of the knitted loop structure can be seen. According to the ideal model, the angle between the course and wale line must be perpendicular. However, especially cotton single jersey fabrics have a tendency for the courses and wales to skew while relaxation progresses. Spirality can be defined as a fabric condition resulting from the knitted wales and courses being angularly displaced from the ideal right angle, which is caused by yarn liveliness. It is possible to use different terms such as torque, skew and bias. Bow is fabric distortion in the course direction caused by multifeeder knitting or an uneven take-down. This displacement of the courses and wales can be expressed as a percentage or angle measurement in degrees. While the bow is almost improved by the finishing process, spirality is only temporarily improved by the same process, and after laundering, spirality recurs. Thus spirality has an important influence on both the aesthetic and functional properties of knitted fabrics and garments, and therefore the formation of spirality must be prevented by various yarn-related methods. Some of these methods include low-twist-lively yarns; balanced plied yarns can be preferred, and S-twist and Z-twist single yarns are used at alternate feeders, respectively [1].

A single jersey fabric is produced by the rotation movement of the circular knitting machine, which is in a tubular form. Single jersey knitted structures, which are widely used in knitted garments, cause some problems because of their unbalanced structures. The most important problem of the single jersey structure is fabric spirality, which affects all the fabric and creates big problems during the clothing stage as it affects the garment by displacing side seams, which causes an important quality problem. This problem is prevented during the finishing and dyeing processes by different methods [2].

There are many researches concerning spirality. Araujo and Smith investigated spirality in both dry and fully relaxed Jersey fabrics produced from a series of relaxed spun yarns. They investigated the effect of yarn treatment, yarn plying and yarn plaiting on snarl upon spirality. They used 20 different yarns with different properties, most of them being 100% cotton, a few of them - 95.5% cotton– 0.05% LMP (Low Melt Polyester), and one of them was 100% acrylic. In that study they observed that untreated yarns exhibited a high tendency to snarl, and fabrics knitted from these yarns had higher spirality. Furthermore, yarn dyeing, yarn steaming, yarn sizing with PVA (Polyvinilalcohol), the heat setting of yarn and the addition of LMP reduce spirality. On the other hand, they indicated that yarn plying and yarn plaiting reduce spirality [3].

In another study of Araujo and Smith, the effect of yarn spinning technology on the spirality of jersey fabrics of 100% cotton and 50/50 cotton /PES blend yarns in dry and fully relaxed states was studied. The 100% cotton yarns showed a greater angle of spirality than the 50/50 blend in a fully relaxed state. For the 100% cotton, in both a dry relaxed and fully relaxed state, the decrease in the angle of spirality was as follows: friction > ring > rotor > air-jet. For 50/50 blend yarns, both the air-jet and rotor spun yarns, which had the lowest twist multiples and tendency to snarl, had the lowest angles of spirality in both the dry relaxed and fully relaxed states [4].

To investigate the effect of yarn count, yarn twist, and fabric tightness on spirality, Tao, Dhingra and Chan produced 56 sample fabrics using 100% cotton ring spun yarns. They selected 3 yarn counts, 5 twist factors and 4 levels of the tightness factor. The study revealed that the yarn twist and fabric tightness were the most predominant factors contributing to fabric spirality. The experimental results also demonstrated the importance of relaxation treatment for fabric spirality [5].

In another study the effect of the yarn count and twist multiplier as functions of yarn parameters and fabric tightness as a function of fabric parameters were investigated by Tao, Lo and Lau. For this aim they produced 30 fabrics from 100% cotton yarn. From the experiments, they found that modifying rotor spun yarns effectively reduced yarn twist liveliness to a very low or zero level. It was confirmed that the modified rotor yarn would greatly reduce fabric spirality in all the cases studied. In the same way, fabrics made from coarse yarns had higher levels of spirality than those from finer yarns [6].

The study by Higgins et al showed the effect of different tumble drying temperatures on the shrinkage, skewness and spirality properties of 100% cotton plain, interlock and lacoste fabrics. They applied three drying conditions to the fabrics: tumble drying at 65 - 57 ºC and 22 ºC, and flat drying at 65 - 57 ºC. They observed the lowest spirality values for plain and lacoste fabrics at 65 - 57 ºC for tumble drying and 65 - 57 ºC for the flat drying processes. On the other hand, for interlock fabrics the spirality value was the lowest at both 22 ºC and 65 - 57 ºC for the tumble drying processes [7].

Chen et al investigated the relationship between the spirality of plain wool knits and production factors, such as the twist coefficient, loop length, fiber diameter and the tightness factor. They found that balanced twist factors for both ply and single yarns affect fabric spirality. They also indicated that the tightness factor has no significant effect on spirality, while increasing the loop length and fiber diameter causes higher spirality [8].

Research on the dimensional and physical properties of cotton and cotton/spandex single jersey fabrics was made by Marmaralı, in which three different types of tightness and two different types of cotton/spandex fabrics were used. At the end of the research, it was found that the spirality was greater in loose fabrics and in non-spandex fabrics. Besides the fact that the spirality values of cotton/spandex fabrics were lower than the acceptable level of 5º, cotton/spandex fabrics with spandex in every course had considerably lower spirality values than those with spandex in alternating courses [9].

In another study by Marmaralı, the spirality of single jersey fabrics knitted from two plied cotton yarns was studied. She selected 20 samples of different yarn twist and plying twist. It was observed that increasing the twist coefficient of single yarns increases spirality. In addition, the twist coefficient of folded yarns in the S direction resulted in the lowest spirality [1].

The aim of this study was to test the effect of fabric weight on the spirality of single jersey fabrics. Spirality is a common fault in the circular knitting industry, hence the causes of spirality have been investigated for many years; however, there has been limited study on the relationship between fabric weight and spirality, therefore this experimental study explores the spirality properties of 100% cotton knitted fabrics with a changing fabric weight.

Experimental

The ten different fabrics used in the experimental study were produced by a conventional textile mill. All the fabrics were knitted as single jersey with Tt 19.7/1 cotton yarns. The reasons for this choice of fabric are that they are versatile and used in t-shirt, underwear, sportswear and baby clothes due to their easy and fast production, as well as their cheapness and comfort. The production method of the yarns used to produce these fabrics is basically the conventional ring spinning method. Furthermore, the ring yarns were differentiated as carded ring yarns twisted in the S direction, carded ring yarns twisted in the Z direction and combed ring yarns. In ***Table 1***, the fiber properties used to produce combed and carded yarns are given. Characteristics of the yarns are given in ***Table 2***.

By using a Monarch 9 machine, different fabrics were produced. In addition to nine fabrics, a fabric was knitted using both carded S yarn and carded Z yarn in the same fabric. The characteristics of both carded S and carded Z yarns are same; only the twist direction is different. This type of fabric is known as S-Z in literature. In the end, there were ten different fabrics. These fabrics were produced from 19.7/1 Tt cotton on knitting machines which had 90 feeders; these machines turned at 30 r.p.m. Technical properties of the samples are given in ***Table 3***. The samples are numbered and the fabrics are determined according to these numbers.

The following properties: fabric weight per square meter, the number of stitches per unit length (1 cm) and the spirality after washing and drying were determined using equipment and devices in the laboratories of the Textile Engineering Department of Gaziantep University in accordance with the standards.

***Table 1**. Fiber properties for sample yarn types.*

Fiber Properties	Type of yarn	
	Combed	Carded
Micronaire	4.4 - 5.1	3.8 - 4.4
Length, mm	30.14	29.94
Tensile, cN/tex	33.75	33.26
Uniformity	84.4	84.0
% 25 Length, mm	29.19	29.59
% 50 Length, mm	15.17	14.22
SFI	4.4	5.0
Humidity, %	8.5	7.2

***Table 2.** Characteristics of the yarn used in knitted samples*

Yarn Characteristics	Tt 19.7/1 combed	Tt 19.7/1 carded S & carded Z
Thin places, ±50%/1,000 m	1	11
Thick places, ±50%/1,000 m	12	128
Neps per 1,000 m	23	207
Hairiness	6.6	7.2
Tensile, cN/tex	343	288
Elasticity, %	3.9	3.8
Twist, t.p.m.	791	796

The following weft knitting machine was used for the production of the fabrics: a 30” diameter single jersey machine with 90 feeders and a total number of needles of 2582; its speed was 30 r.p.m. This machine was employed for the knitting fine-

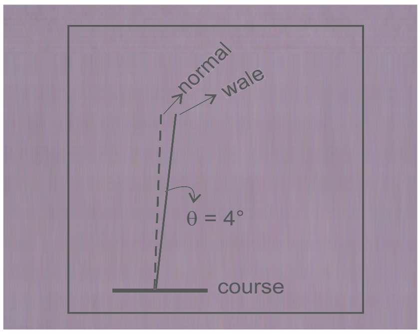

***Figure 1.** Marking the wale and course.*

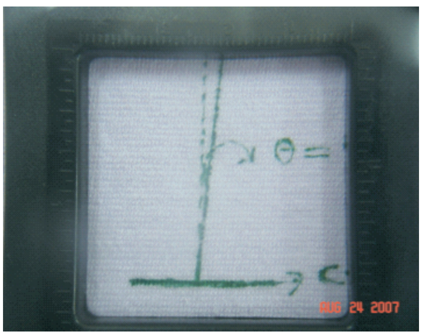

***Figure 2.**Measuring the spirality angle (θ) using a protractor.*

ness of 28 yarns. The fabrics were dyed to investigate the dying effect on spirality. The dying recipe is given in ***Table 4***.

In this study, the fabric weight was determined according to TSE EN 12127, April 1999: "Textiles-Fabrics-Determination of mass per unit area using small samples", and the number of wales and courses were determined according to TSE EN 14971, July 2006: "Textiles-Knitted Fabrics-Determination of the number of stitches per unit length and unit area." The results of the samples calculated are given in ***Table 4*** [10, 11].

Prior to marking, the samples were preconditioned and then conditioned as stipulated by ASTM Practice D 1776, Conditioning Textiles for Testing. Each specimen was conditioned for at least 4 h in an atmosphere of 21 ± 1º C (70 ± 2 ºF) and 65 ± 2% RH by laying each specimen separately on a screen or perforated shelf of a conditioning rack [12].

The last and most important procedure was laundering**.** The samples were laundered according to AATCC Test Method 179 (1996): *Skewness Change in Fabric and Garment Twist Resulting from Automatic Home Laundering.* The washing machine preferred was of the domestic type using programme B. The washing process lasted 2 hours and 15 minutes at a temperature of 60 °C. The samples washed were dried in a tumble dryer for 70 minutes at 70 ºC. These laundering properties were chosen because single jersey fabrics are generally used in under garments, and many people wash and dry such clothes in these laundering conditions. It is important to investigate the home laundering effect on spirality [13].

After laundering, the samples were dried over a perforated table in laboratory conditions. Then the spirality was measured according to the IWS 276 standard test method. This method is used to measure the angle of spirality in the structure of a plain knitted garment following relaxation in water. According to this method, 5 different places are chosen for each sample. First a wale is marked by pen, and the course linked wale is then marked, as seen in ***Figure 1***. By using a protractor, the angle different from the normal of the wale is measured, as seen in ***Figure 2*** [14].

In order to understand the statistical importance of the weight effect on spirality, a one way ANOVA was performed. To determine the relation between the spirality values of gray fabrics and dyed fabric, Pearson correlation analysis was used. For this aim, the statistical software package SPSS 8.0 was used to interpret the experimental data. All the test results were assessed at significance levels $p \leq 0.05$ and $p \leq 0.01$.

Table 3. *Production and technical properties of the samples.*

Samples	Yarn Type	Fabric surface weight, g/m²		Number of wales per cm		Number of courses per cm	
		Gray	Dyed	Gray	Dyed	Gray	Dyed
1	Carded S	113	129	12	15	16	16
2	Carded S-Z	115	147	15	15	22	17
3	Carded Z	119	130	12	15	17	15
4	Carded S	122	146	12	15	19	17
5	Combed Z	122	147	13	16	18	16
6	Carded S	130	162	12	16	21	18
7	Combed Z	130	159	13	15	21	15
8	Combed Z	132	160	12	15	20	18
9	Carded Z	136	150	12	17	22	18
10	Carded Z	142	154	12	16	22	17

Table 4. *Relevant recipes for the sample fabric*

Cooking Recipe		Dyeing Recipe		Washing Recipe	
Product	Amount, g/l (%)	Product	Amount, g/l (%)	Product	Amount, g/l (%)
Cottoclarin Ok	0.6	Syn Red Shf-Gd	(0.008)	Acetic Acid 80%	0.5
Mollan 129	0.5	Syn Blau Shf-Brn	(0.006)	Locanit Sw	0.2
Caustic	1	Mollan 129	0.5	Enbrite Cn-1	(0.35)
Hydrogen Peroxide	1	Imacol C-2G	0.3	Acetic Acid 80%	0.5
Baystabil Db-T	0.5	Sodium Sulfate	30	Belfasin Lx	2.5
Gemperaz Ahp 6	0.4	Sodium Carbonate	10	Belsoft Tv	2.5
Acetic Acid	0.5	-	-	-	-

Results and discussion

When analysing the spirality values of the samples, it was decided that the effect of the machine rotational direction and yarn twist direction are related to the effect of both the weight and dyeing on spirality. Because of the fact that these effects are similar to each other, there is no exact separation of these effects. ***Table 5*** shows spirality values of both grey and dyed samples after laundering.

Effect of fabric weight on spirality according to yarn production technology

It can be seen from ***Figure 3*** (see page 84) that increasing the fabric weight results in decreasing spirality values for all the fabrics. According to the ANOVA results, the effect of fabric weight on spirality was found to be significant ($p \leq 0.01$) at a 1% significance level.

By observing the carded Z yarn fabrics and combed yarn fabric lines in ***Figure 3*** (see page 84), it can be seen that the spirality values of these fabrics are higher than those of carded S yarn fabrics. This situation is due to the relationship between the yarn twist direction and the direction of machine rotation, the reason for which being that these yarns are Z twisted and knitted on a Monarch machine, which rotates in the same rotational direction.

Finally, it must be stated that when studying knitted fabrics, the results are never directionally proportional because the structure of knitted fabric is not stable

Table 5. *Spirality values of both grey and dyed samples.*

Samples	Spirality (degree)	
	Gray	Dyed
1	6.6	2.8
2	0	0.8
3	13.8	8.0
4	5.8	3.2
5	12.8	5.8
6	2.8	3.0
7	8.8	4.8
8	8.0	3.6
9	10.2	2.6
10	6.4	2.2

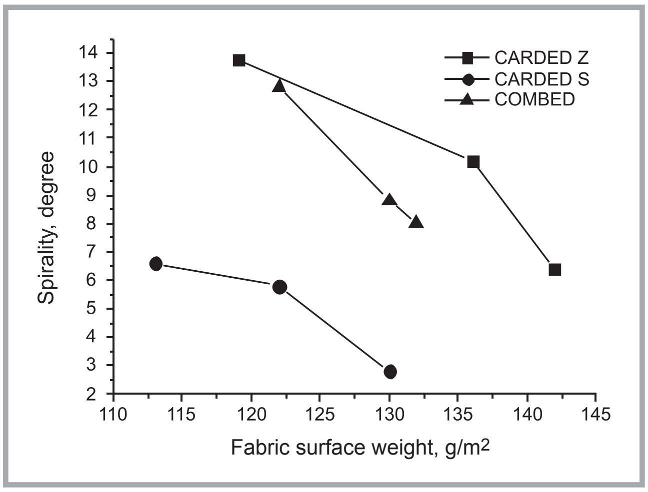

Figure 3. *Spirality of grey fabrics versus fabric weight (Machine rotates in Z direction).*

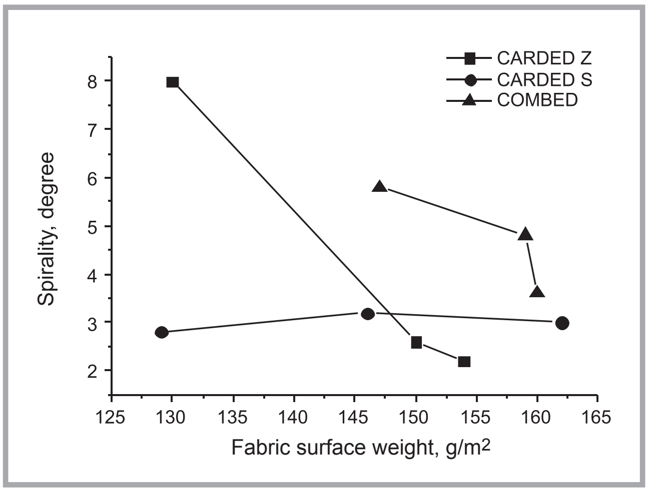

Figure 4. *Spirality of dyed fabrics versus fabric weight (Machine rotates in Z direction).*

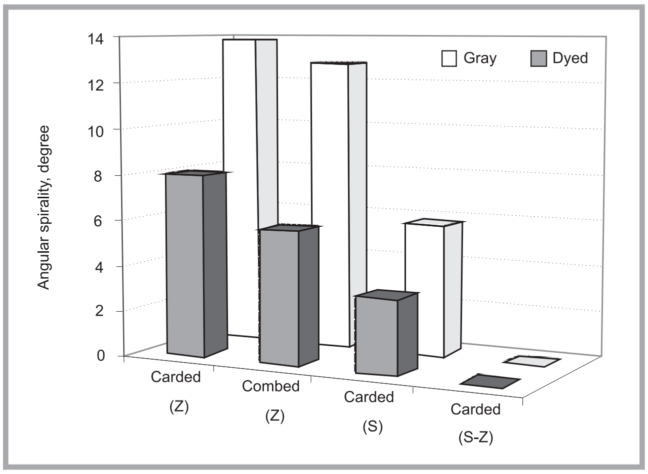

Figure 5. *Effect of the twist direction on the spirality of gray and dyed fabrics versus the machine rotation direction.*

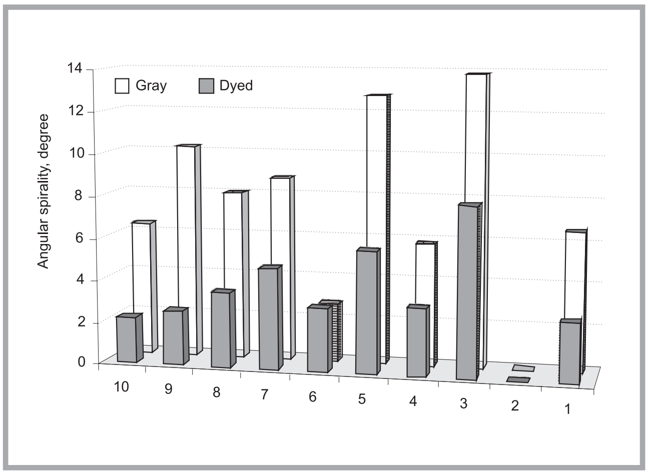

Figure 6. *Spirality of dyed fabric and gray fabric (Machine rotates Z direction); the number of sample according to Table 3.*

and spirality is measured manually with a protractor; hence spirality results vary with all altered conditions.

Effect of dyed fabric weight on spirality according to yarn production technology

When ***Figure 4*** is examined, it can be seen that there is no regular effect. By increasing the weight of carded s yarn fabric, the spirality value increases for some weights and decreases for a few other weights. Therefore, it can be said that there is no relationship between fabric weight and spirality for dyed fabrics. At the same time, ANOVA tests were applied to the spirality values of carded S yarn fabrics, the results of which show that it is not significant ($p \leq 0.05$) at a 5% significance level. However, in gray fabrics, the spirality decreases when the fabric weight increases. The only result that can be obtained from the data is that the spirality decreases by half after the dyeing process.

The combed yarn line shows that by increasing the fabric weight, the spirality values decrease. However, to investigate the statistical effect of weight, ANOVA tests were performed. From the results it can be seen that the effect of fabric weight on spirality for dyed combed fabrics is not significant ($p \leq 0.05$) at a 5% significance level. There is still a lack of information in the literature concerning the effect of fabric weight on spirality in dyed fabrics. According to Tukey Tables, the fabrics are in the same group, which means that the weight is not important for dyed combed yarn fabrics in SPSS.

The line of carded Z yarn fabric demonstrates the effect of weight clearly. At the same time, the results of the ANOVA show that the effect of weight on spirality is significant ($p \leq 0.01$) at a 1% significance level. Again when the results of the dyed fabrics are compared with those of the gray fabrics, it is evident that the dyeing process makes the spirality value decrease.

Effect of the twist direction on spirality versus the machine rotation direction

To analyse the effect of the twist direction on spirality versus the machine rotational direction, Carded S, Combed, Carded Z and Carded S-Z ring yarns were used to knit fabrics on a Monarch circular knitting machine that rotates in the (Z) direction. And to compare spirality values, samples were chosen according to whether their weight was similar to that of S-Z fabric. As seen from ***Figure 5***, for gray fabrics the lowest spirality values belong to carded S yarn fabrics, and the highest values to carded Z yarn fabrics, while carded S-Z fabrics result in zero spirality results. If carded S yarns and carded Z yarns are used course by course separately during knitting, there is no moving area for the loop, and hence spirality values are measured as zero. Finally, the results as well as the graphics and statistical analyses were examined, and it was concluded that the spirality values of carded S yarn fabrics were less than those of carded Z yarn fabrics because the machine rotation direction and twist direction of carded S yarn are opposite each other.

At the same time, ANOVA tests were applied to the spirality values of the gray fabrics. The result for a specimen is significant ($p \leq 0.01$) at a 1% significance level.

On the other hand, the spirality values of all the fabrics, including both grey and dyed fabrics, were measured and are graphically shown in ***Figure 6***. It is evident from ***Figure 6*** that the dyeing process makes the spirality value decrease; however, the decreasing ratio of the spirality values of dyed fabrics is not directly proportional to the decreasing ratio of the spirality values of gray fabrics.

It is the structure type of knitted fabrics that makes them dimensionally unstable. Knitted fabrics shrink during the dyeing process, the shrinkage ratio of which is undetermined. Therefore, due to the effect of dyeing and continual laundering processes, the spaces between loops decrease and the moving ability of the loops decreases too. In general, the swelling of all fibers are different from each other, and if the fibers used are different, the spirality values are different from each other in accordance with the effect of fibers. However, in this study the fiber used for knitting was 100% cotton, whose spirality differences do not depend on the fiber. But the yarns are different from carded S, carded Z and combed yarns. The twist direction of combed yarn is Z too.

At the beginning of this study, because of the fact that the combed yarn structure is more regular than that of carded yarn, it was thought that the spirality values of combed yarn fabrics would be less than those of carded Z yarn fabric. However, according to the results, there is no direct effect of yarn regularity on spirality. Therefore, the twist direction of yarns must be taken into account.

Conclusion

The main aim of this work was to systematically investigate the effect of fabric weight, yarn production technologies, the yarn twist direction and dyeing on the spirality of knitted fabrics. In this study, the parameters of plain fabrics made from cotton ring spun yarns were investigated. The results show that the weight of fabric is very important for all yarn production technologies for both grey and dyed fabrics. The data, graphics and statistical analysis of the spirality values showed that increasing the fabric weight decreases spirality; however, the decrease does not have the same reverse proportionality for all yarn types. When the results were investigated, it was seen that the lowest spirality values belonged to carded S yarn fabric, whereas the highest belonged to carded Z yarn fabric. We expected to find similar spirality values for carded Z yarn fabrics and combed yarn fabrics because the twist directions of both were the same; our results confirmed this.

It is apparent from the results that the dyeing process decreases spirality. The yarns have torsion, which results in spirality in a knitted fabric. If the torsion decreases the spirality decreases too. The dyeing process decreases the torsion, therefore the spirality values of dyed fabrics are less than those of gray fabrics. This decrease was up to half of the spirality values of grey fabrics. When the effect of fabric weight on dyed fabrics was examined, there was no significant effect on spirality, the reason for which may again be torsion. There is no direct relation between the decreasing values of spirality and the spaces between loops.

According to the results, the twist direction is another important parameter for spirality. The machine's rotation has an effect on the yarn tensional force, which increases spirality. When the results as well as the graphics and statistical analyses were examined, it was concluded that the spirality values of S twisted yarn fabrics were less than those of Z twisted yarn fabrics, depending on whether the machine rotation direction is Z.

Finally, it must be stated that when studying single jersey knitted fabrics, there must always be a margin of error because of the unbalanced structure of fabric.

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