(REFEREED RESEARCH)

INFLUENCE OF YARN AND FABRIC CONSTRUCTION PARAMETERS ON DRAPE AND BENDING BEHAVIOUR OF COTTON WOVEN FABRICS

İPLİK VE KUMAŞ KONSTRÜKSİYON PARAMETRELERİNİN DOKUMA KUMAŞLARIN DÖKÜMLÜLÜK VE EĞİLME DAVRANIŞINA ETKİSİ

Nilgün ÖZDİL[1], Arif Taner ÖZGÜNEY[1], Gamze SÜPÜREN MENGÜÇ[2], Sima SERTSÖZ

[1]Ege University, Department of Textile Engineering, Izmir, Turkey
[2]Ege University, Emel Akın Vocational Training School, Izmir, Turkey

Received: 24.02.2014 Accepted: 08.06.2014

ABSTRACT

Handling characteristics such as stiffness and draping qualities have great importance for fabrics used in clothing and they could be evaluated by test devices and/ or by human judges using subjective techniques. Fabric hand is a complex phenomenon, which is influenced from the properties of fibers, yarns, fabrics and finishing treatments. Although there are numerous studies on fabric handle, it is still a contemporary subject, since it attracts the consumers' attention. In this study, effect of yarn twist level, weft density, fabric weave pattern, yarn ply and yarn count on drapeability and bending properties of cotton fabrics were investigated. The results were compared and evaluated statistically by using independent samples T-Test and variance analysis methods.

Key Words: Fabric hand, Drape, Drape coefficient, Bending, Woven fabric.

ÖZET

Sertlik ve dökümlülük gibi tutum özellikleri giysi amaçlı kullanılan kumaşlar için çok önemlidir ve test cihazları ve/ ya da subjektif tekniklerle kişiler tarafından değerlendirilebilir. Kumaş tutumu lif, iplik, kumaş ve bitim işlemlerinden etkilenen karmaşık bir kavramdır. Kumaş tutumu ile ilgili pek çok çalışma olmasına rağmen tüketicilerin dikkatini çektiği için hala güncel bir konudur. Bu çalışmada iplik bükümü, çözgü sıklığı, kumaş konstrüksiyonu, iplik kat sayısı ve iplik numarasının pamuklu dokuma kumaşların dökümlülük ve eğilme özelliklerine etkisi incelenmiştir. Sonuçlar istatistiksel olarak t-testi ve varyans analizi ile değerlendirilmiştir.

Anahtar Kelimeler: Kumaş tutumu, Dökümlülük, Dökümlülük katsayısı, Eğilme, Dokuma kumaş.

Corresponding Author: Nilgün Özdil, nilgun.ozdil@ege.edu.tr, Tel: +90 232 311 16 06

1. INTRODUCTION

Handling properties of textile materials are important, since they determine the success or failure of a textile product. Fabric hand attributes can be obtained through subjective assessment or objective measurements (1). To evaluate fabric hand objectively, the need to use instrumentation is imperative in order to measure physical and mechanical properties of the fabric (2).

There are several important factors involved in fabric hand, such as stiffness, smoothness, weight, thickness, compressibility, liveliness, ease of skewing or shearing, and cold feeling (3). However, fabric stiffness and drape were some of the earliest properties to be measured objectively (4).

Fabric stiffness and handling is an important decision factor for the end users and the degree of fabric stiffness is related to its properties such as fiber (material type), yarn and fabric structure (5). Bending rigidity is one of the most widely used parameters to judge stiffness and fabric handling.

Peirce identified fabric bending properties as a key component of hand and developed various tests to measure fabric rigidity in bending. Since this time alternative tests for fabric bending properties have been developed along with the recognition that hand is much more complex than can be predicted from bending measurements alone (2, 6).

Bending properties of the fabrics govern much of their performance, such as hang and drape, and are an essential part of complex fabric deformation analysis. The bending properties of a fabric are determined by yarn bending behavior, the weave of the fabric and the finishing treatment of the fabric, the relationship among them are highly complex (7,8).

Fabric drape is one of the important properties of flexible textile materials that directly related to the impression of appearance of a garment during wear. The role of drape in a garment is an important aspect of aesthetics (1). Fabric drapeability may be described as a degree of the deformation of fabric to orient itself into folds when the fabric partially supported by other objects (9). In another expression, drape can be defined as a property which characterizes the shape of a fabric when it is hanging down of its own weight (1). Different fabrics exhibit different drape behavior and hence the garment silhouette made of different fabrics would be different on same garment style (9).

Since the drape and bending behavior of the textile materials are attractive subjects for the consumers and researchers, there are so many studies both on subjective and objective measurement of these parameters.

Okur and Cihan (2001) investigated the relationship between the fabric drape coefficients and mechanical properties tested on the FAST system for woven fabrics. They found that, lower the drape coefficient, lower the bending rigidity (10).

Alpay and Kavuşturan (2000), studied on the bending properties of 100 % cotton woven fabrics in different yarn count and weft density. Bending length and bending rigidity values of the fabrics increases, as thicker weft yarns and more number of weft yarns were used in the structure (11).

Çelik et al. (2002), investigated the effects of the construction and weft density on properties of the PET/Viscose blended woven fabrics. Bending rigidity of plain weave fabrics were found higher than the twill fabrics and the bending rigidity value increases when higher weft density values were used in the structure (12).

Effects of weft density and weave structures on the physical and mechanical properties of fabrics, which are micropolyester woven fabrics with plain, twill and satin weave structures in five different weft densities were studied by *Abou Nassif (2012*). According to the results, it was concluded that, increasing weft density leads to an increase in stiffness. Acceleration of the weft density from 61 to 80 picks/inch leads to an increase in fabric stiffness by 30%, 58% and 48% for plain, satin and twill weaves respectively. The stiffness of micropolyester fabrics woven from plain weaves is found higher than those woven from other structures (5).

Effect of fiber cross section on bending and drape properties were investigated by *Omeroglu et al. (2010)*. For this purpose, full and hollow fibers having round and trilobal cross-sectional shapes were produced in equal manufacturing conditions and were used in the experiment. The bending rigidities of the fabrics produced from hollow fibers were found higher than the bending rigidities of the fabrics produced from full fibers. Fabrics produced from hollow round fibers have the highest bending rigiditiy values. The fabrics produced from full fibers indicate higher drapabilities than those produced from hollow fibers (13).

The effect of weft density, weft yarn count and warp tension on bending and drape properties of woven fabrics were investigated by *Süle (2012)*. Bending rigidity was found higher with thicker weft yarns and at higher weft densities. Bending rigidity in the warp direction increases when warp tension increases, however, there is not a significant change in the weft direction depending on any change in warp tension. However for the fabrics woven with thicker weft yarns, overall fabric bending rigidity increases with the increasing warp tension (14).

The aim of this study is to investigate drapeability and bending properties of cotton woven fabrics comprehensively and to determine the influence of yarn count, twist, fabric density, yarn ply and construction on the drapeability and bending properties of the fabrics.

2. MATERIALS AND METHODS

In this experiment 100% cotton yarns were spun in three different yarn counts (Ne) which are 50/1, 70/1 and 100/2. The production was performed in α_e= 3,3- 4,0- 4,8 twist coefficients for the yarns Ne 50/1, and in α_e= 4.0 for the yarns Ne 70/1. After the yarns Ne 50/1 and Ne 70/1 had been produced by the Rieter K44 Compact Machine, their windings were performed by the Murata Winding Machine. As for Ne 100/2, after the single-layer yarns were produced in Ne100/1 by the Rieter Conventional G33 Ring Spinning Machines, the winding process was performed by Schlafthorst 338 Machine. Then the single-layer yarns Ne 100/1 had been folded by the SSM Folding Machines. The winding process was performed by the Machine VTS-10 of Volkmann. The production was performed in α_e=3,3- 3,8- 4,0 twist coefficients for the yarns 100/2.

The produced yarns were woven into two different constructions which are plain weave and sateen, and three different weft densities including tight, medium and loose structures were used (Table 1).

After the production, fabrics were conditioned under standard atmosphere conditions (20 °C±2 °C temperature, 65% ± 4% RH). Afterwards, drape coefficients and bending rigidities were measured.

Drapeability of the fabrics were measured by drape meter. The fabric is placed on the sample holder which has a larger diameter, then the sample holder, the edge of the fabric sags due to its own weight. The drape of a fabric that sags due to its own weight can result in different shapes.

A fabric can be considered as fully stiff if a sample with a radius of R2 is placed on a sample holder with a radius of R1 and its projection is equal with circle that has the radius of R2 (Figure 1).

Table 1. Fabric types used in study

Fabrics	Yarn count (Ne)	Twist (α_e)	Construction	Warp density * weft density (ends/cmxpicks/cm)	Tightness
1	50/1	3,3	plain	56*31	medium
2	50/1	4	plain	56*36	tight
3	50/1	4	plain	56*31	medium
4	50/1	4	plain	56*26	loose
5	50/1	4	sateen	56*31	medium
6	50/1	4.8	plain	56*31	medium
7	100/2	3,3	plain	56*31	medium
8	100/2	3,8	plain	56*31	medium
9	100/2	4,0	plain	56*36	tight
10	100/2	4,0	plain	56*31	medium
11	100/2	4,0	plain	56*26	loose
12	100/2	4,0	sateen	56*31	medium
13	50/1	3,3	sateen	64*42	medium
14	50/1	4	sateen	64*48	tight
15	50/1	4	sateen	64*42	medium
16	50/1	4	sateen	64*36	loose
17	50/1	4.8	sateen	64*42	medium
18	100/2	3,3	sateen	64*42	medium
19	100/2	3,8	sateen	64*42	medium
20	100/2	4,0	sateen	64*48	tight
21	100/2	4,0	sateen	64*42	medium
22	100/2	4,0	sateen	64*36	loose
23	70/1	4	plain	56*36	tight

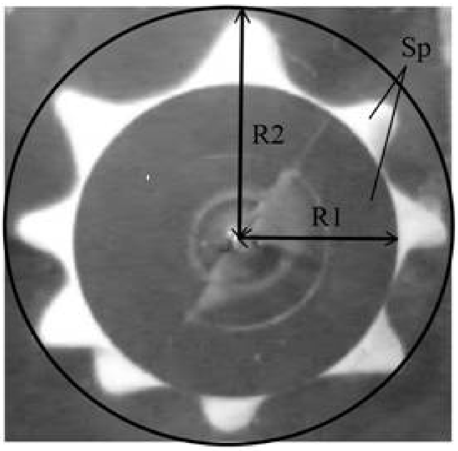

Figure 1. Projection of drape – paper ring with draped image

To calculate the drape coefficient using image processing, the following formula can be used (15).

$$CD = \frac{S_p - \pi R_1^2}{\pi R_2^2 - \pi R_1^2} * 100\ (\%)$$

where,

CD, drape coefficient (%)

Sp, area of the draped sample, including the part on the sample holder (mm^2)

R_1, radius of sample holder (mm)

R_2, radius of the non deformed sample (mm)

The stiffer a fabric is, the larger is the area of its shadow compared with the unsupported area of the fabric so the higher the drape coefficient the stiffer is the fabric.

The stiffness tester (figure 2) was used to determine the stiffness of a fabric according to ASTM D1388. A rectangular strip of fabric is supported on a horizontal platform of the stiffness tester and extended in the direction of its length, so that an increasing part overhangs and bends under its own mass. When the tip of the specimen reaches a plane passing through the edge of the platform and inclined at an angle of 41.5° below the horizontal, the bending length is read off the scale. From the bending length and the mass per unit area of the fabric, the bending rigidity can be calculated (16).

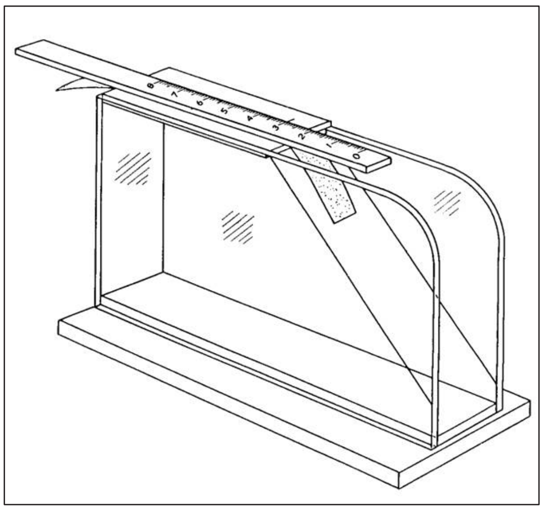

Figure 2. Shirley stiffness tester (17)

Bending rigidity in the warp and weft dirrections is calculated using the formula given below (17).

$G = 0{,}1 \times W \times c^3$

where:

G = bending rigidity, mg.cm,

W = fabric mass per unit area, g/m^2,

c = bending length, cm.

Fabric bending rigidity is calculated by the mean values of warp and weft bending rigidities.

$G_{fabric} = (G_{warp} \times G_{weft})^{1/2}$

3. RESULTS AND DISCUSSION

3.1. The Effect of Twist

The effect of the yarn twist on bending rigidity is given in Figure 3 and in Figure 4. According to the Figures and statistical evaluation results (Table 2), it can be denoted that, bending properties of the fabrics vary belonging to the yarn structure. In the case of plain fabrics, contrary to the expectations, as the yarn twist level increases, the bending rigidity decreases for the fabrics produced from single yarns (Figure 3 and Table 1). However, the difference in bending rigidities was not found statistically significant for the fabrics produced from plied yarns.

As the twist level increases, yarn diameter and fabric thickness decrease. It is thought that the lower bending rigidity is caused by the lower fabric thickness and finer the fabric lower the bending rigidity.

However, for sateen fabrics produced from single yarns, the lowest bending rigidity values were obtained at the optimum twist values (α_e= 4 for Ne 50/1) (Figure 4).

Table 2. Student-Newman-Keuls Test results for multiple comparisons (Effect of Twist)

	Fabrics	Parameters	Bending Rigidity					Drape Coefficient			
		Twist Coefficient	N	Subset			Twist Coefficient	N	Subset		
				1	2	3			1	2	3
Effect of Twist Level	Ne 50/1 - 56*31 -Plain Fabric	α_e=4,8	16	6,7			α_e=4,8	6	45,9		
		α_e=4	16	7,7			α_e=4	6	47,5	47,5	
		α_e=3,3	16		9,2		α_e=3,3	6		49,4	
		Sig.		0,093	1,000		Sig.		0,149	0,105	
	Ne 100/2 - 56*31- Plain Fabric	α_e=4	16	11,5			α_e=3,3	6	51,9		
		α_e=3,8	16	11,6			α_e=4	6	52,2		
		α_e=3,3	16	13,5			α_e=3,8	6	53,6		
		Sig.		0,200			Sig.		0,366		
	Ne 50/1- 64*42- Sateen Fabric	α_e=4	16	7,4			4	6	45,7		
		α_e=4,8	16		9,4		4,8	6	45,7		
		α_e=3,3	16			12,4	3,3	6		52,4	
		Sig.		1,000	1,000	1,000	Sig.		0,997	1,000	
	Ne 100/2- 64*42 - Sateen Fabric	α_e=3,8	16	15,1			4	6	54,6		
		α_e=3,3	16	17,1			3,3	6	56,1		
		α_e=4	16	17,6			3,8	6	56,5		
		Sig.		0,069			Sig.		0,276		

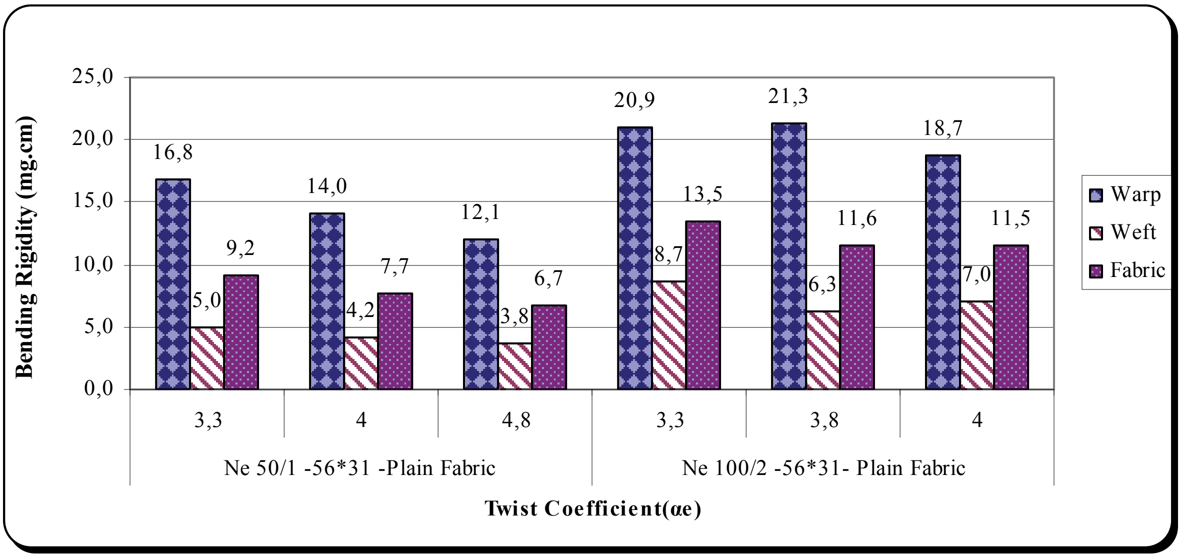

Figure 3. Bending rigidity results of Ne 50/1 and Ne 100/2 plain fabric in different twist coefficients

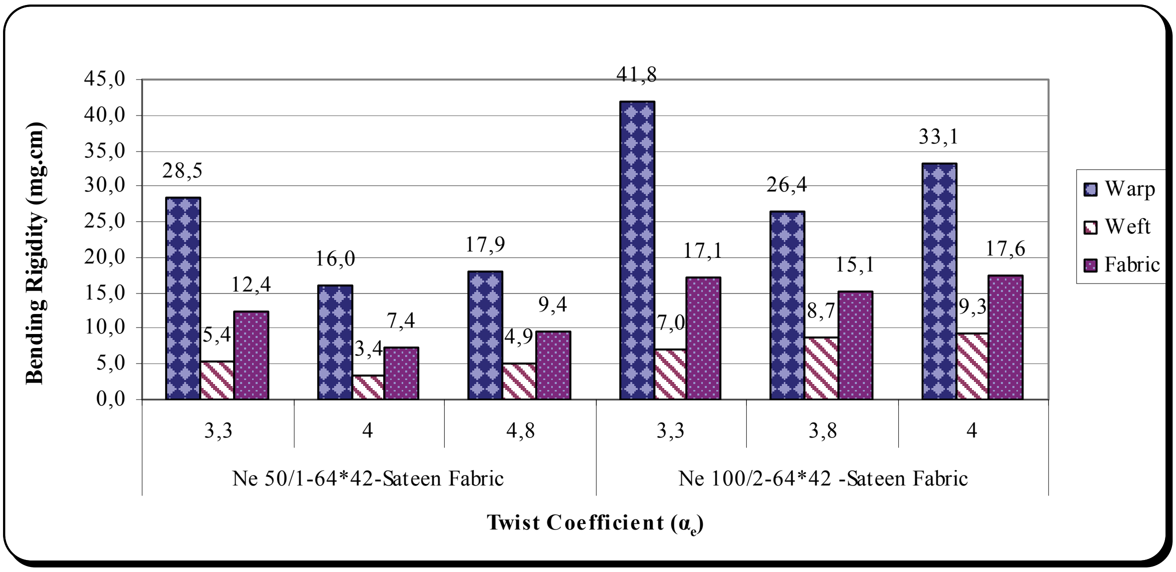

Figure 4. Bending rigidity results of Ne 50/1 and Ne 100/2 sateen fabric in different twist coefficients

Drape coefficient values are given in Figure 5 and Figure 6. Lower the drape coefficient, higher the drapeability. Drapeability of the fabrics are better for the fabrics, produced from single yarns in higher twist coefficient. On the other hand, there is not an apparent difference between the drape properties of the fabrics produced from plied yarns in different twist coefficients similar to the bending rigidity results.

3.2. The Effect of Weft Density

Bending rigidity test results are given in Figure 7 and Figure 8. According to literature as the weft density increase, bending rigidity increases too (11,12), which means that tight structures cause an increase in fabric stiffness. In both plain and sateen fabrics, bending rigity values of weft direction decrease as the weft density decreased.

In this study similar results were obtained for both plain and sateen fabric structures.

The bending rigidity values of the fabrics have some variations depending on the bending direction. However, generally fabric bending rigidity values are higher for the fabrics which have higher weft density (tight structure) for all type of the fabrics. For Ne 50/1-αe=4-plain fabric and for Ne 100/2 -αe=4-sateen fabric, difference between the results of tight and other structures were found statistically significant (Table 3).

The drapeability results of the fabrics are given in Figures 9 and Figure 10. According to test results, looser the fabric, higher the drapeability for plain and sateen fabrics produced single and plied yarns. Loose fabrics have also lower bending rigidity (as given in Figure 7 and Figure 8) that imparts lower stiffness.

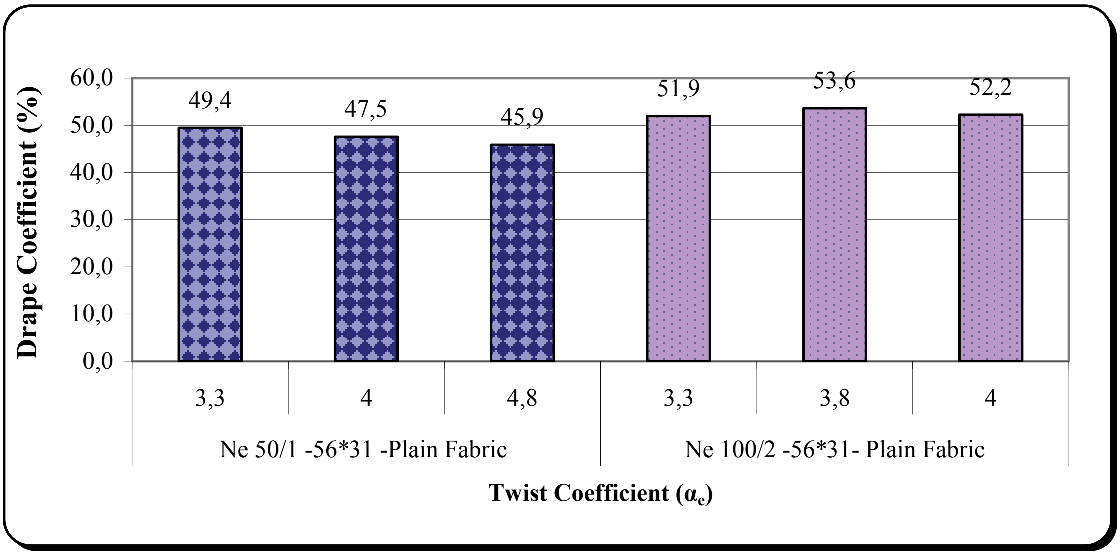

Figure 5. Drape coefficient results of Ne 50/1 and Ne 100/2 plain fabrics in different twist coefficients

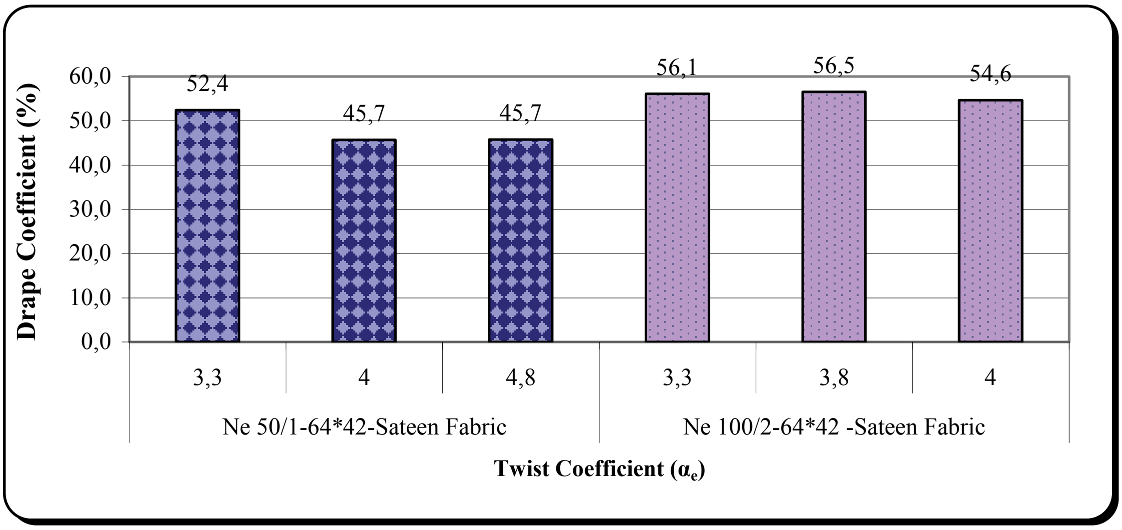

Figure 6. Drape coefficient results of Ne 50/1 and Ne 100/2 sateen fabrics in different twist coefficients

Table 3. Student-Newman-Keuls test results for multiple comparisons (effect of weft density)

	Fabrics	Parameters	Bending Rigidity						*Drape Coefficient*		
		Density	N	Subset			Density	N	*Subset*		
				1	2	3			1	2	*3*
Effect of Weft Density	Ne 50/1-αe=4-Plain Fabric	loose	16	6,2			loose	6	45,3		
		medium	16		7,7		medium	6	47,5		
		tight	16			8,9	tight	6		52,0	
		Sig.		1,000	1,000	1,000	**Sig.**		0,084	1,000	
	Ne 100/2-αe=4-Plain Fabric	tight	16	11,2			loose	6	47,8		
		medium	16	11,5			medium	6		52,2	
		loose	16	11,8			tight	6			*55,0*
		Sig.		0,648			**Sig.**		1,000	1,000	*1,000*
	Ne 50/1-α_e=4-Sateen Fabric	medium	16	7,6			loose	6	44,5		
		loose	16	7,8			medium	6	45,7		
		tight	16	8,7			tight	6	47,8		
		Sig.		0,056			**Sig.**		0,055		
	Ne 100/2 -αe=4-Sateen Fabric	loose	16	14,9			loose	6	54,2		
		medium	16	17,6			medium	6	54,6		
		tight	16		22,4		tight	6		60,6	
		Sig.		,057	1,000		**Sig.**		0,765	1,000	

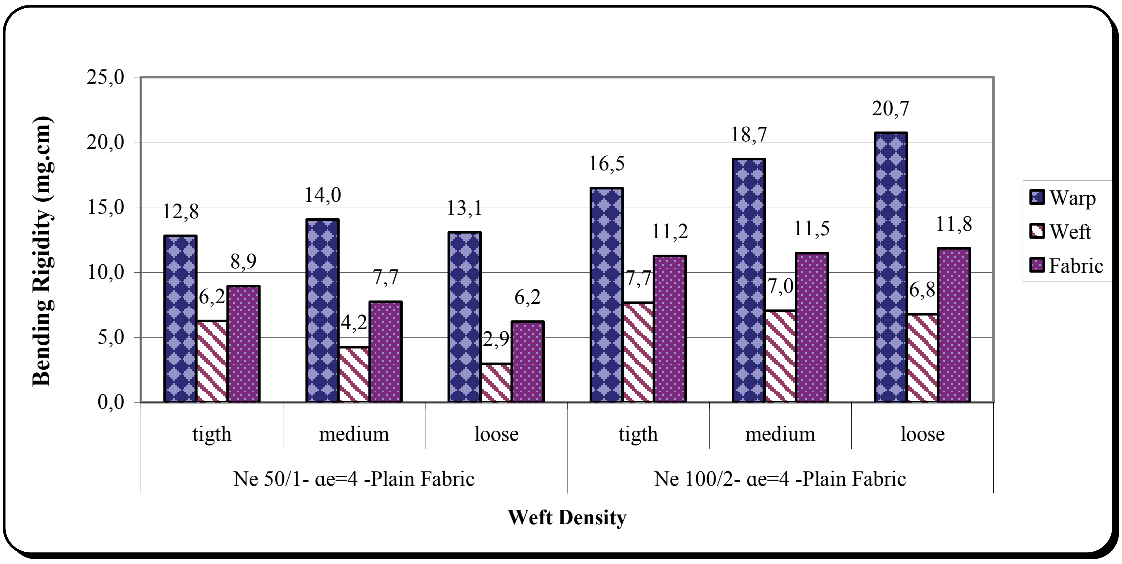

Figure 7. Bending rigidity results of Ne 50/1 (α_e=4) and Ne 100/2 (α_e=4) plain fabric in different weft density

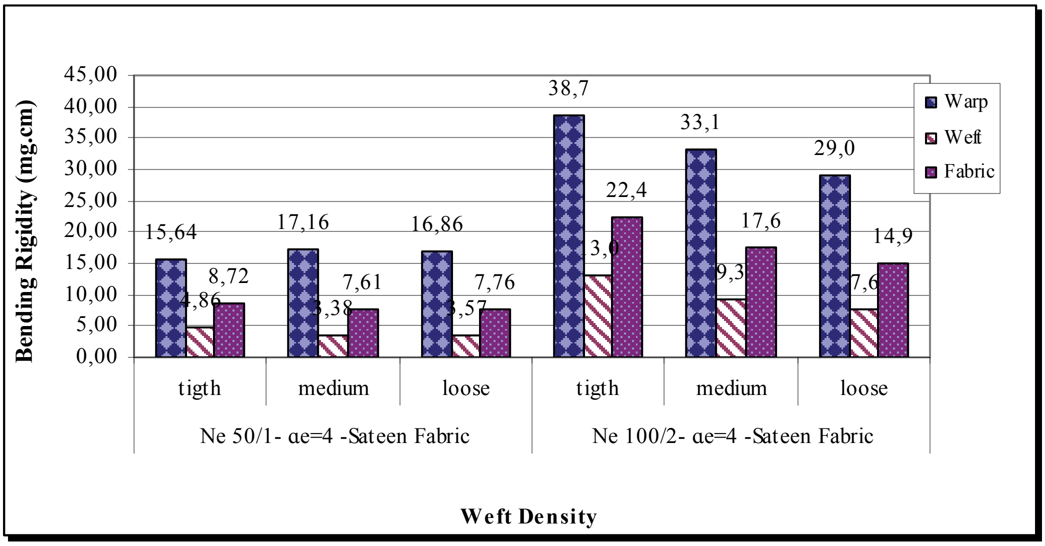

Figure 8. Bending rigidity bending results of Ne 50/1 (α_e=4) and Ne 100/2 (α_e=4) sateen fabric in different weft density

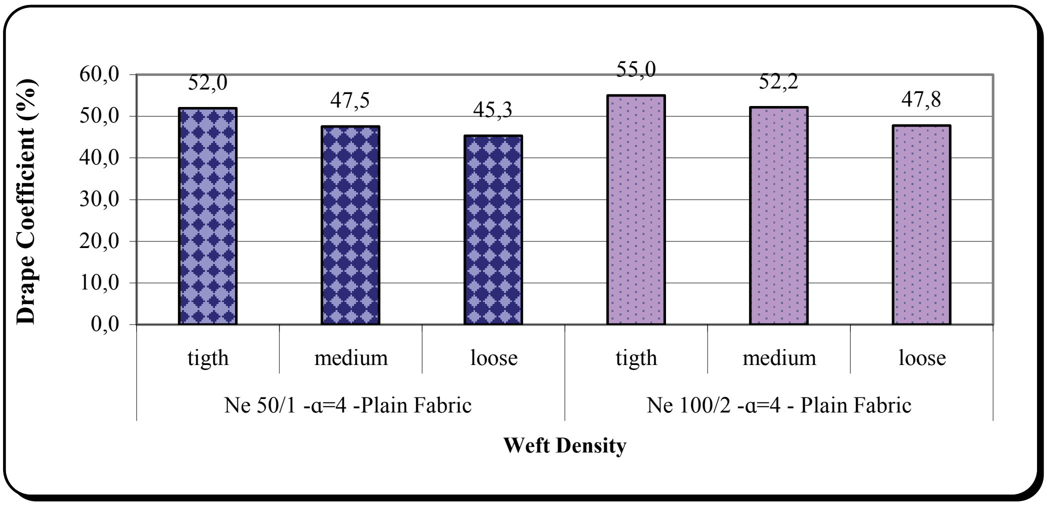

Figure 9. Drape coefficient results of Ne 50/1 (αe=4) and Ne 100/2 (αe=4) plain fabric in different weft density

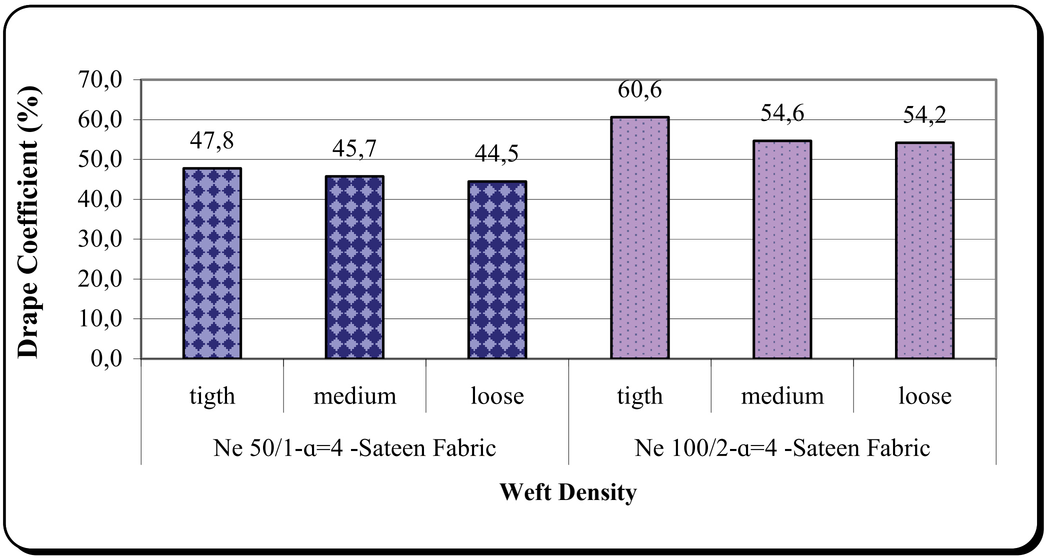

Figure 10. Drape coefficient results of Ne 50/1 (αe=4) and Ne 100/2 (αe=4) sateen fabric in different weft density

3.3. The Effect of Fabric Construction

The effect of fabric construction on bending rigidity values is given in Figure 11 and statistically evaluation of the given in Table 4. Due to the lower yarn interactions and longer yarn floats, warp direction bending rigidity values of the sateen fabrics are higher than the values of plain fabrics, whereas they are lower for weft direction. Although the bending rigidity results of sateen fabrics are higher than the results of plain fabrics, there is not a statistically significant difference between them.

Figure 12 represents the relationship between the fabric construction and drape coefficient values. According to results drapeability of the sateen fabrics are found better than the values of plain fabrics. The differences between the test results were found statistically significant (Table 4).

3.4. The Effect of Yarn Ply

As it can be seen from Figure 13 and Table 5, the fabrics produced from plied yarns have higher bending rigidity than the fabrics produced from single yarns for both plain and sateen fabrics. Plied yarns generate a stiffer fabric structure in both cases.

Table 4. Independent samples T-Test results (effect of construction)

PARAMETER	Fabrics	Fabric Construction (Compared Parameters)	Sig. (Bending Rigidity)	*Sig. (Drape Coefficient)*
Effect of Construction	Ne=50/1-αe=4-56*31	Plain Fabric	0,881	0,000*
		Sateen Fabric		
	Ne 100/2-αe=4-56*31	Plain Fabric	0,723	0,009*
		Sateen Fabric		

* Statistically significiant at the α=0.05 level

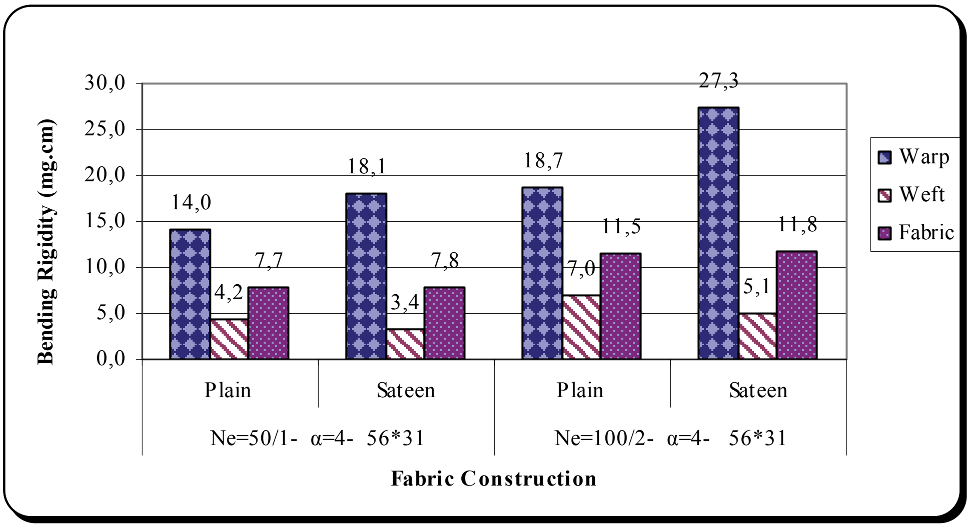

Figure 11. Bending rigidity results of Ne 50/1 (α_e=4) and Ne 100/2 (α_e=4) fabricss in different construction

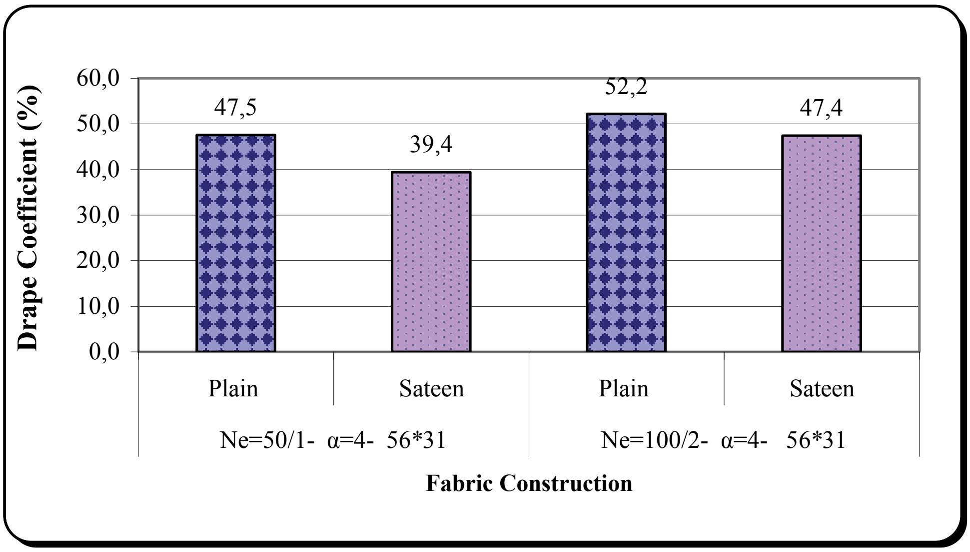

Figure 12. Drape coefficient results of Ne 50/1 (α_e=4) and Ne 100/2 (α_e=4) fabrics in different construction

Table 5. Independent samples T-Test results (effect of yarn ply)

PARAMETER	Fabrics	Yarn ply (Compared Parameters)	Sig. (Bending Rigidity)	Sig. (Drape Coefficient)
Effect of Yarn Ply	αe=4-56*31-Sateen Fabric	Ne=50/1	0,006*	0,000*
		Ne 100/2		
	αe=4-56*31-Plain Fabric	Ne=50/1	0,047*	0,001*
		Ne 100/2		

* Statistically significiant at the α=0.05 level

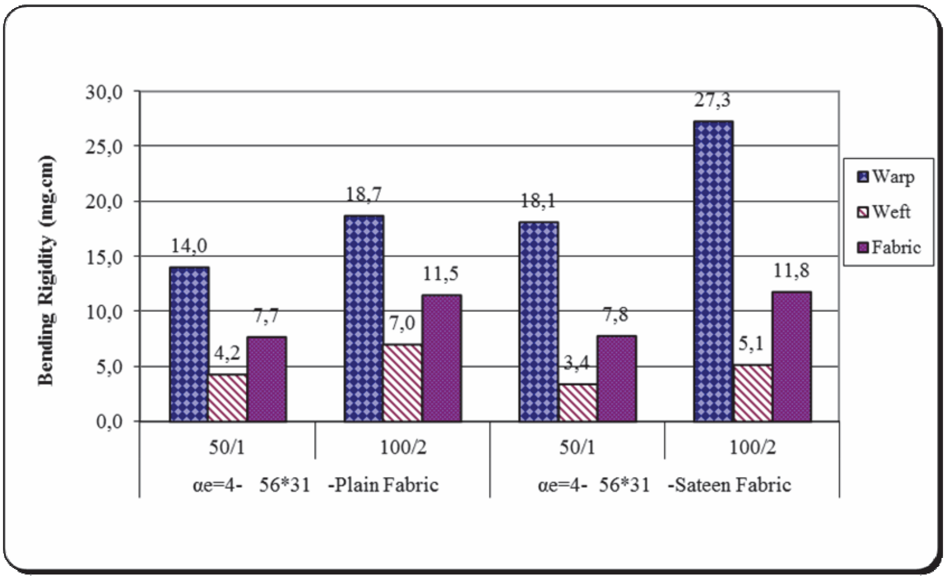

Figure 13. Bending rigidity results of the plain and sateen fabrics in different number of yarn ply

Figure 14 and the results in Table 5, indicate the effect of yarn ply on drape coefficient values of the fabrics. Due to the higher bending rigidity of the fabrics produced from plied yarns, they have higher drape coefficients than the fabrics produced from single yarns as expected.

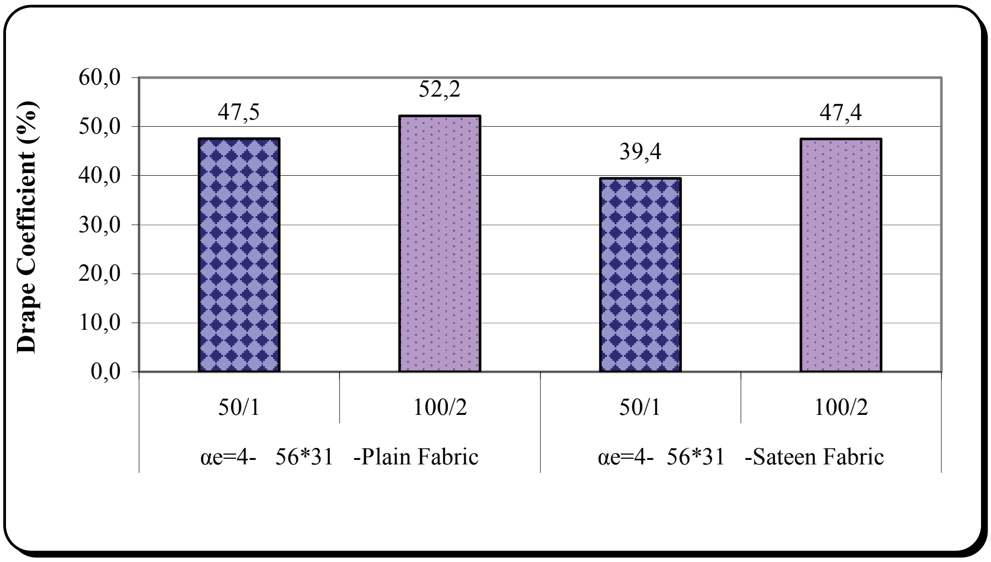

Figure 14. Drape coefficient results of the plain and sateen fabrics in different number of yarn ply

3.5. The Effect of Yarn Count

The effect of the yarn count on bending and drape properties of the fabrics is given in Figure 15 and Figure 16 respectively.

Similar to the previous studies, fabrics produced from finer yarns have better drapeability and lower bending rigidity both in warp and weft directions. The difference between the results were found statistically significant (Table 6).

Table 6. Independent samples T-Test results (effect of yarn count)

PARAMETER	Fabrics	Yarn count (Compared Parameters)	Sig. (Bending Rigidity)	Sig. (Drape Coefficient)
Effect of Yarn Count	αe=4-56*36-Plain Fabric	Ne=50/1 Ne=70/1	0,000*	0,000*

* Statistically significiant at the α=0.05 level

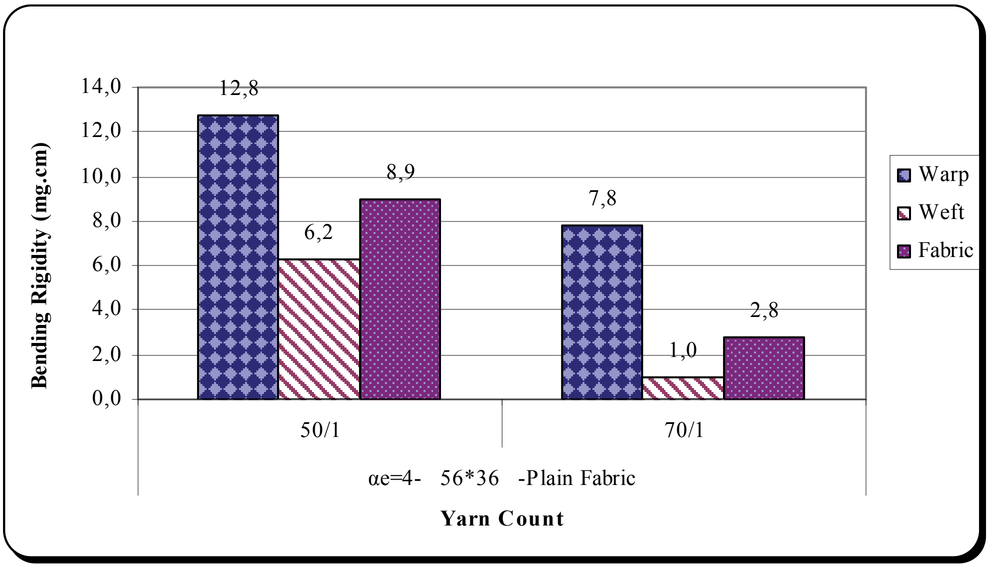

Figure 15. Bending rigidity results of the plain fabrics (αe=4) in different yarn count

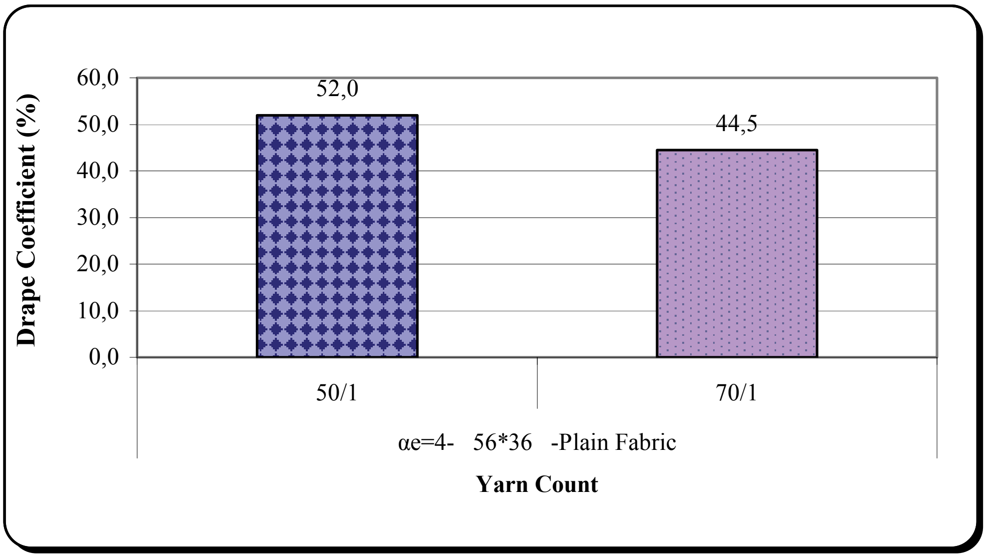

Figure 16. Drape coefficient results of the plain fabrics (α_e=4) in different yarn count

4. RESULTS AND DISCUSSION

This research was focused on the physical parameters such as yarn count, yarn twist, weft density and fabric construction of cotton fabrics, and the effect of these parameters on drape and bending behaviour, of the fabrics.

100% cotton woven fabrics were produced in three different yarn counts (Ne50/1, 70/1 and 100/2). For single yarns α_e= 3,3- 4,0- 4,8, for plied yarns α_e=3,3- 3,8- 4,0 twist coefficients were used.

According to the results, it was concluded that, as the twist level of the yarns increases, bending rigidity values of the plain fabrics decrease. For sateen fabrics the lowest bending rigidity values were obtained at optimum twist values.

Bending rigidity and drape coefficient values increase with the increasing weft density. Looser structures have better drapeability. Bending rigidity values of warp direction for sateen fabrics were found higher than the values of plain fabrics, whereas they were lower in case of weft direction. In addition to this, drape properties of the sateen fabrics were better than plain fabrics.

Using plied yarn instead of single yarn generates a stiffer structure. Thus, the fabrics produced from plied yarns have higher bending rigidity and lower drapeability than the fabrics produced from single yarns. Finer yarns results in lower bending rigidity and better drape property was another result related with the effect of yarn count.

ACKNOWLEDGEMENTS

The authors give their special thanks to “Cotton Incorporated” for their financial support in this study.

REFERENCES

1. Mäkinen, M., Meinander, H., Luible, C., Magnenat-Thalmann, N. 2005, “Influence of Physical Parameters on Fabric Hand”, Proceedings of the HAPTEX'05 Workshopon Haptic and Tactile Perception of Deformable Objects, Hanover, December
2. Behery, H.M., 2005, *“Effect of Mechanical and Physical Properties on Fabric Hand”*, The Textile Institute, CRC Pres, Boca Raton Boston New York Washington, DC, Woodhead Publıshıng Lımıted Cambridge England.
3. Owen, J.D. 1971, ‘Hand and Drape of Fabrics’, Shirley Link, 4, 18.
4. Saville, B.P., 1999, *Physical Testing of Textiles,* Woodhead Publishing Ltd, Cambridge England, ISBN 0849305683, 256-259.
5. AbouNassif, G.A., 2012, Effect of Weave Structure and Weft Density on the Physical and Mechanical Properties of Micro polyester Woven Fabrics, Life Sci J; 9(3):1326-1331). (ISSN: 1097-8135).
6. Postle, R., 1989, “Fabric objective measurement: 1. Historical background and development”. Textile Asia, 20, 64.
7. Schwartz, P. 2008, *Structure and Mechanics of Textile Fiber Assemblies,* Woodhead Textiles Series No. 80, ISBN-13: 978 1 84569 135 6
8. Kayseri, G.Ö., Özdil, N., Süpüren Mengüç, G., 2012, “Chapter 9: Sensorial Comfort of Textile Materials”, *Woven Fabrics* p:235-266, InTech, Croatia, ISBN 978-953-51-0607-4.
9. Ngoc, N.T.T., Anh, H.N., 2010, “Investigating on Fabric and Skirt Drape In Clothıng Construction”, 7th International Conference - TEXSCI 2010 September 6-8, Liberec, Czech Republic
10. Okur, A., Cihan, T., 2001, “Kumaş Mekanik Özelliklerinin Dökümlülük Üzerine Etkileri”, *Tekstil Maraton,* Temmuz Ağustos, 4 pp.18-27.
11. Alpay H. R. and Kavuşturan Y., 2000, “Pamuklu dokuma kumaşların eğilme dayanımını etkileyen faktörler”, *Tekstil Maraton* Eylül-Ekim 5.
12. Çelik N., Dilsiz D., Bebekli M., 2002, “Dokumada konstrüksiyon ve atkı sıklığının kumaş performans özelliklerine etkisi”, *Tekstil Maraton*, Temmuz- Ağustos 4.
13. Omeroglu, S., Karaca, E., Becerir, B., 2010, “Comparison of Bending, Drapability and Crease Recovery Behaviors of Woven Fabrics Produced from Polyester Fibers Having Different Cross-sectional Shapes”, *Textile Research Journal,* Vol 80(12): 1180–1190 .
14. Süle G., 2012, “Investigation of Bending and Drape Properties of Woven Fabrics and the Effects of Fabric Constructional Parameters and Warp Tension on These Properties”, *Textile Research Journal*, 82(8) 810–819.
15. Jevsnik, S., J. Gersak, 2004, “Modelling the Fused Panel for a Numerical Simulation of Drape”, *Fibres & Textiles in Eastern Europe*, 12, 47.
16. http://coel.ecgf.uakron.edu/~chase/Equipment/equipment%20Stiffness%20Tester.pdf (available on 28.02.2014)
17. BS 3356:1990-Method for Determination of bending length and flexural rigidity of fabrics.