Araştırma Makalesi / Research Article

INVESTIGATION OF STIFFNESS OF ORGANIC COTTON AND CONVENTIONAL COTTON WOVEN FABRICS USED FOR GARMENTS

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***ABSTRACT*:** Organic clothing production is rapidly increasing in the textile and clothing industry, where sustainability and environmentally friendly production are gaining importance. Therefore, it is necessary to determine the differences and advantages of organic garments compared to conventional garments. Good tailorability is a required property for clothing manufacturers. Fabrics will be able to pass through the clothing manufacturing process easily without any problems for good appearance and wear performance. Improving fabric drape and stiffness is very important for the good appearance of the garments. Fabric stiffness may not be too high for a good drape in garment fabrics. This study aims to investigate the stiffness of reactive and naturally dyed organic cotton and conventional cotton woven fabrics used for garments. The fabric’s stiffness is determined by its flexural rigidity. Fabrics with very high flexural rigidity may cause sewing and handling problems as they are too stiff to be controlled. Lightweight fabrics often have low bending rigidity, making them difficult to handle during cutting and prone to seam puckering. In this study, five fabric groups of 100% cotton plain weaves, produced in different weight were used. Each group includes three samples: conventional cotton dyed with reactive dyes, organic cotton dyed with reactive dyes, and organic cotton dyed with natural dyes. Thus, 15 fabric samples with different properties were obtained. Warp and weft bending length, warp and weft flexural rigidity and overall flexural rigidity tests were applied to determine the fabric stiffness according to the cantilever test of ASTM D1388-64 standard of these fabric samples. SPSS 29.0 statistical program was used to evaluate the test results. SNK test results indicated that organic cotton fabric with natural dyes had higher overall flexural rigidity than organic and conventional cotton fabrics with reactive dyes.

Keywords: Organic cotton fabric, Conventional cotton fabric, Flexural rigidity, Stiffness

GİYSİ ÜRETİMİNDE KULLANILAN ORGANİK PAMUKLU VE KONVANSİYONEL PAMUKLU DOKUMA KUMAŞLARIN RİJİTLİĞİNİN İNCELENMESİ

***ÖZ*:** Organik giysi üretimi, sürdürülebilirlik ve çevre dostu üretimin önem kazandığı tekstil ve giyim sektöründe hızla artmaktadır. Bu nedenle, organik giysilerin konvansiyonel giysilere kıyasla farklılıklarını ve avantajlarını belirlemek gereklidir. İyi dikilebilirlik özelliği, giyim üreticileri için gerekli bir özelliktir. Kumaşlar, iyi bir görünüm ve giyim performansı için giysi üretim sürecinden sorunsuz bir şekilde geçebilmelidir. Kumaşın dökümlülüğünü ve sertliğini iyileştirmek, giysilerin iyi bir görünüm kazanması için çok önemlidir. Giysilik kumaşlarda iyi bir dökümlülük için kumaş sertliği çok yüksek olmamalıdır. Bu çalışma, giysilerde kullanılan reaktif ve doğal boyalı organik pamuk ve konvansiyonel pamuklu dokuma kumaşların sertliğini araştırmayı amaçlamaktadır. Kumaşın sertliği eğilme rijitliği ile belirlenmektedir. Çok yüksek eğilme rijitliği değerlerine sahip kumaşların kontrol edilmesi çok zor olduğu için dikiş ve tutum sorunlarına yol açabilir. Düşük gramajlı kumaşlar genellikle düşük eğilme rijitliğine sahiptir, bu da kesim işlemlerini zorlaştırır ve dikiş büzülmesine neden olur. Bu çalışmada, farklı gramajlarda üretilmiş %100 pamuklu bezayağı dokuma kumaştan oluşan beş grup kullanılmıştır. Her grup, reaktif boyalarla boyanmış konvansiyonel pamuklu kumaş, reaktif boyalarla boyanmış organik pamuklu kumaş ve doğal boyalarla boyanmış organik pamuklu kumaş olmak üzere üç numune içermektedir. Böylece, farklı özelliklere sahip 15 kumaş numunesi elde edilmiştir. Bu kumaş numunelerinin sertliğini belirlemek için çözgü ve atkı eğilme uzunluğu, çözgü ve atkı eğilme rijitliği ve genel eğilme rijitliği testleri, ASTM D1388-64 standardının cantilever testine göre uygulanmıştır. Test sonuçlarını değerlendirmek için SPSS 29.0 istatistik programı kullanılmıştır. SNK test sonuçları, doğal boya ile boyanmış organik pamuklu kumaşın, reaktif boya ile boyanmış organik ve konvansiyonel pamuklu kumaşlara göre daha yüksek eğilme rijitliği değerleri gösterdiğini ortaya koymuştur.

Anahtar Kelimeler: Organik pamuklu kumaş, Konvansiyonel pamuklu kumaş, Eğilme rijitliği, Sertlik

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1. INTRODUCTION

Organic clothing production is rapidly increasing in the textile and clothing industry, where sustainability and environmentally friendly production are gaining importance. For organic garment production to become widespread, the performance characteristics of these garments and their fabrics must be thoroughly analysed and compared with those of conventionally produced garments.

Since organic clothing manufacturing is a relatively new field, unlike conventional products, performance tests must be conducted to generate new information for the textile and clothing sector. Organic cotton is grown using 71 % less water and 62 % less energy than conventional cotton [1].

Buying organic cotton clothes helps protect water, air, soil, and the health of farmers and their employees. Organic cotton is made of 100 % natural cellulose fibers, making it biodegradable and compostable. Many chemicals are used in the production of clothes, and they are released back into the environment as waste. Since there is no use of GMO (genetically modified organisms) raw materials, chemicals, pesticides, or radiation in the production of organic products, no factors that could negatively affect human health or the environment are used afterwards [2, 3].

The OCS standard examines whether the product is organic in production stages, such as fiber and chemicals, throughout the supply chain. The OCS standard includes OCS 100 and OCS Blended labels. The OCS 100 label is used for products containing 95% or more organic materials. The OCS Blended label is used for products containing 5-94% organic materials [4].

While conventional fabrics receive little attention during weaving, organic cotton fabrics are given greater attention. If sizing of the warp is necessary in the weaving process of organic cotton fabrics, starch, starch derivatives, carboxymethylcellulose, and other natural substances can be used as sizing agents. If polyvinyl alcohol is required, the remaining sizing agent should be natural and should not exceed 25% of the total sizing. The woven fabric production process involves various mechanical operations, and lubricants are used on the machines. However, the lubricants used should not contain heavy metals due to the risk of contamination of the fabric [5].

Good tailorability is a required property for clothing manufacturers. Fabrics will be able to pass through the clothing manufacturing process easily without any problems for good appearance and wear performance. Improving fabric drape and stiffness is very important for the good appearance of garments. Fabric stiffness may not be too high for a good drape in garment fabrics.

A bending test measures the severity of the flexing action of a material. The bending behaviour of fabrics is presented by bending rigidity. The bending rigidity, which relates to perceived stiffness, is calculated from the bending length and mass per unit area. Fabrics with low bending rigidity may exhibit seam pucker and be prone to cutting problems. Fabric stiffness may not be too high for a good drape in apparel fabrics [6].

Bending and drapability properties of fabrics are very important for a garment's aesthetic appearance and also play an important role in garment comfort and determining the fit of clothing around the human figure [7].

The garment is desired to be soft and flowing on the body. The bending length is a characteristic property of a woven fabric and is dependent upon the energy required to produce a given bending deformation under its own weight. The bending or flexural rigidity, which is derived from the bending length, and the weight of the fabric form the bending properties of the fabrics that influence the mechanism of fabric deformation [8].

Some researchers actually propose that garment fit and drape are aesthetic concepts that depend on people's preferences; hence, they should be evaluated by people [9]. The drape coefficient has been developed to describe the degree and shape of drape. A lower drape coefficient indicates that the fabric is softer and drapes more easily. In other words, the higher the drape coefficient, the stiffer the fabric is [10]. There is a high correlation between drapability and the bending properties of fabrics. Drape property of a fabric is the combined effect of several factors, such as flexural rigidity, Young's modulus, weight, thickness, etc. Flexural rigidity is one of the most crucial factors in determining a fabric's draping quality of a fabric. For example, soft fabric drapes closer to the body, forming ripples, whereas stiff fabric drapes away from the body. The stiffness of fabric itself depends upon geometrical parameters of the fabric [11].

Resistance to bending or flexural rigidity is referred to as stiffness in textile test methods. The longer the bending length, the stiffer the fabric. Lightweight fabrics typically have low bending rigidity, which makes them difficult to handle during cutting due to their flexibility and causes seam puckering. It is recommended that lightweight fabrics have a minimum bending rigidity of 5 μNm in the warp and weft directions [12].

High amounts of water, energy, chemicals and other related sources are consumed at the stage of processing cotton fibers into textile products. Especially, the textile dyeing process may lead to environmental pollution due to chemical dyestuffs. As a remarkable approach to sustainable textiles, the usage of naturally coloured organic cotton fiber and converting it into textile materials is one of the promising methods which provide a reduction of the environmental hazard [13].

Dyeing of organic cotton is very important in textile production. Primarily, direct, reactive or vat dyes are used. In recent years, natural dyes have proven to be more sustainable than synthetic dyes in the textile industry. The literature generally accepts that natural dyes have a lower environmental impact. However, when natural dyes are used in industry, certain problems arise. For example, the mordants used to improve the dyeing process may release hazardous heavy metals [14, 15]. The sustainable use of natural dyes in the textile industry is achieved by integrating economic, social, and environmental considerations through increased technological innovation, enhanced capacity and productivity, and ensuring supply chain sustainability [16].

Environmentally friendly natural dyes are offered as alternatives to synthetic dyes due to their non-allergenic and non-toxic properties. The use of natural dyes is a viable "Green Chemistry" instead of harmful synthetic dyes due to increasing environmental and health problems [17]. Natural dyes produce a range of colours and shades. Compared to conventional cotton, organic cotton dyed with natural dyes is a safer and more eco-friendly option. [18].

A comparison of the biodegradation properties of conventional cotton and organic cotton samples shows that the organic cotton sample is much better than the conventional cotton sample [19].

This study aims to investigate the stiffness of reactive and naturally dyed organic cotton and conventional cotton woven fabrics used for garments. For this purpose, five fabric groups of 100% cotton plain weaves, produced in different weights, were used. Each group includes three samples: conventional cotton dyed with reactive dyes, organic cotton dyed with reactive dyes, and organic cotton dyed with natural dyes. Thus, 15 fabric samples with different properties were obtained. Warp and weft bending length, warp and weft flexural rigidity and overall flexural rigidity tests were applied to determine the fabric stiffness according to the cantilever test of ASTM D1388-64 standard of these fabric samples. SPSS 29.0 statistical program was used to evaluate the test results.

2. MATERIALS AND METHODS

Five groups of 100% cotton plain fabrics with different yarn counts were produced to examine the stiffness of organic cotton and conventional cotton woven fabrics used for garments. Each group includes three samples: conventional cotton dyed with reactive dyes, organic cotton dyed with reactive dyes, and organic cotton dyed with thuja oak natural dye.

Reactive dyeing was conducted at 60°C for 60 minutes in a bath containing salt and soda after pre-treatment, and a fabric softener was applied during the finishing process. In natural dyeing, pre-mordanting was first done in a hot bath. Then the dyeing was done with thuja oak natural dye in a hot bath at 60 °C for 60 minutes. Warm and cold washing was done, and no fabric softener was applied; the fabrics were air-dried.

The thickness, warp and weft densities, and yarn counts of the fabrics in each group were kept constant. Thus, 15 fabric samples with different properties were obtained. Table 1 shows the structural properties of the fabric samples.

Table 1. Structural properties of fabric samples

Fabric Code	Cotton Fabric/Dye Type	Average Weight (g/m^2)	Thickness (mm)	Yarn Density (thread /cm)		Yarn Count (Ne)		Composition (%)
				Warp	Weft	Warp	Weft	
1a	Conventional-Reactive	137	0.29	53	29	40/1	40/1	%100 CO
1b	Organic-Reactive		0.31	53	29			
1c	Organic -Natural		0.33	55	29			
2a	Conventional-Reactive	94	0.18	61	53	80/1	80/1	%100 CO
2b	Organic-Reactive		0.18	63	53			
2c	Organic -Natural		0.19	64	54			
3a	Conventional-Reactive	133	0.53	23	17	20/1	20/1	%100 CO
3b	Organic-Reactive		0.53	22	17			
3c	Organic -Natural		0.56	23	17			
4a	Conventional-Reactive	155	0.30	53	37	62/1	40/1	%100 CO
4b	Organic-Reactive		0.29	54	37			
4c	Organic -Natural		0.32	54	39			
5a	Conventional-Reactive	191	0.37	50	33	80/2	80/2	%100 CO
5b	Organic-Reactive		0.32	50	31			
5c	Organic -Natural		0.37	50	33			

The "Stiffness of fabric" was carried out according to option A-cantilever test of ASTM D1388-64. Equations (1), (2), and (3) were used to calculate the stiffness of fabrics for each sewn fabric strip [20].

$$c = O / 2 \quad (2)$$

where, c = Bending length,
O = The length of overhang, cm

$$G = W (O / 2)^3 = W x c^3 \quad (3)$$

where, G = Flexural rigidity, mg cm
W = Weight per unit area, mg/ cm^2

$$Go = (G w G f)1/2 \quad (4)$$

Where, Go = Overall flexural rigidity
Gw = Warp flexural rigidity
Gf = Weft flexural rigidity

The SDL Atlas (Model no M003B) fabric stiffness tester used in the tests is shown in Figure 1.

Prior to the tests, all fabric samples were conditioned for 24 hours under standard atmospheric conditions (20 ± 2°C and 65 ± 2 % relative humidity). Experiments were performed in three replicates and averaged.

SPSS 29.0 statistical program was used to evaluate the test results. A randomised two-factor analysis of variance (two-way ANOVA) was also performed to determine the statistical significance of fabric weight and fabric cotton fabric/dye type on bending length, flexural rigidity and overall flexural rigidity of the fabric samples. In the statistical analysis, bending length, flexural rigidity and the overall flexural rigidity were selected as dependent variables, while weight and cotton fabric/dye type were selected as independent variables. The means were compared using SNK tests. The value of the significance level (α) selected for all statistical tests in the study was 0.05. The treatment levels were marked according to the mean values, and levels marked with different letters (a, b, c, d, e) indicate significant differences.

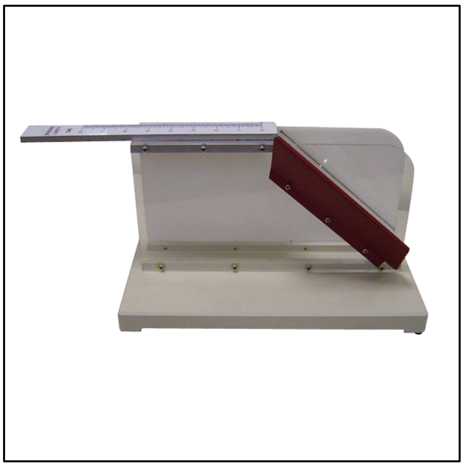

Figure 1. Fabric stiffness tester [21]

3. RESULTS

3.1. Stiffness Test Results

The stiffness test results of the fabric samples are given in Table 2. The weft direction bending length of a 1a fabric sample on the fabric stiffness tester is shown in Figure 2.

3.2. Bending length test results of fabric samples

The bending length test results of the samples in the weft and warp directions are given in the graph in Figure 3. When these results are examined, it is seen that the bending length values of the organic fabric + reactive dyed (1b, 2b, 3b, 4b, 5b, 6b) and organic fabric + natural dyed fabric samples (1c, 2c, 3c, 4c, 5c, 6c) are higher.

At the same time, the warp direction bending lengths of all fabric samples were higher than the weft direction bending lengths. This is due to the warp densities being higher than the weft densities of the fabric samples [22]. As shown in the structural properties of the fabric samples in Table 1, all samples have higher warp densities than weft densities.

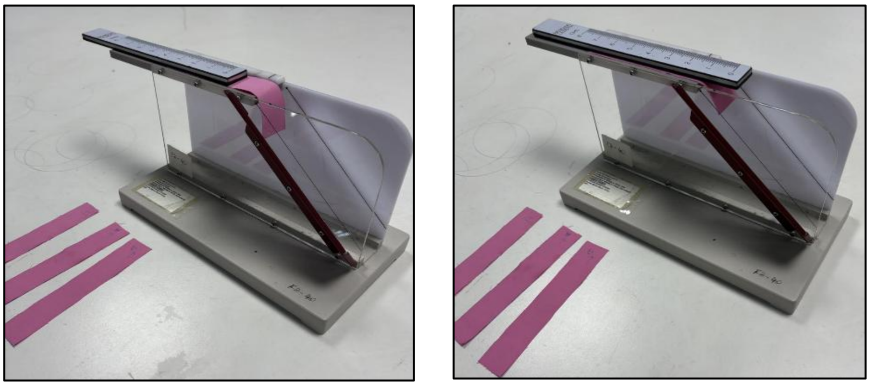

Figure 2. Measurement of the weft direction bending length of 1a fabric sample on the fabric stiffness tester

Table 2. Stiffness test results of fabric samples

Fabric type	Bending Length (cm)		Flexural Rigidity (mg cm)		Overall Flexural Rigidity (mg cm)
	Weft	Warp	Weft	Warp	
1a	1.95	2.18	100.79	137.09	115.75
1b	2.14	2.37	127.40	173.85	148.81
1c	2.15	2.44	146.77	214.64	176.33
2a	2.03	2.08	76.15	82.29	79.14
2b	2.02	2.03	79.21	80.50	79.84
2c	2.05	2.08	82.78	87.04	84.86
3a	2.03	2.05	113.67	116.72	114.86
3b	2.10	2.28	117.61	151.23	133.35
3c	1.95	2.30	101.71	166.15	129.95
4a	2.24	2.15	175.02	154.05	164.20
4b	2.35	2.27	194.65	175.34	184.72
4c	2.45	2.48	238.42	245.68	241.77
5a	2.33	2.20	252.14	209.44	229.46
5b	2.48	2.48	270.71	269.77	269.41
5c	2.88	2.83	473.84	451.35	462.40

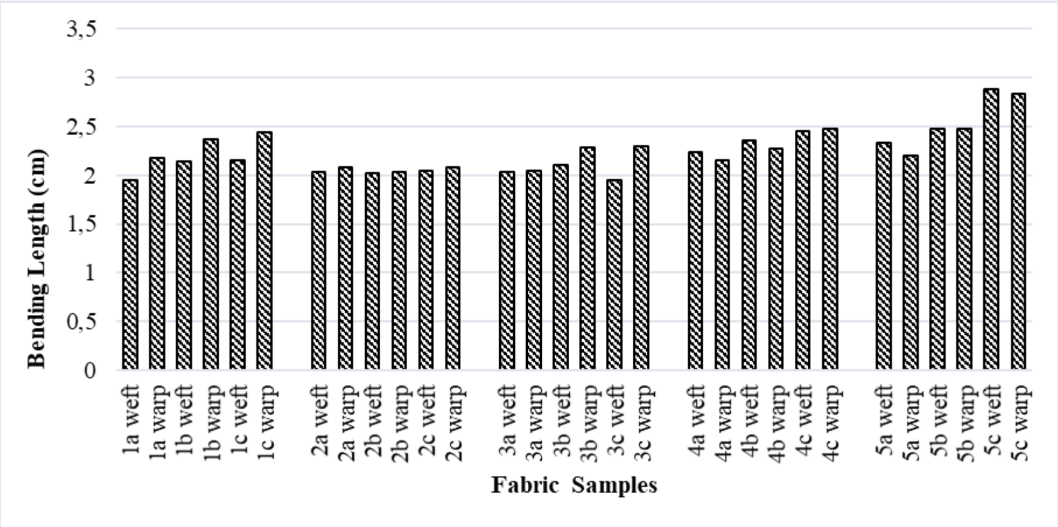

Figure 3. Bending length test results of the samples in the weft and warp direction test results of the fabric samples

The SNK test results in Table 3 revealed that the weight and cotton fabric/dye type of the fabric samples are statistically significant on the weft and warp bending length. Fabric groups with high weight (4th and 5th groups) have higher weft and warp bending lengths than fabric groups with low weight. Fabric samples with organic /reactive dyes and organic/natural dyes have higher weft and warp bending lengths than conventional/reactive dye fabric samples.

The bending length is dependent on the fabric weight. The structural properties of the fabric, such as density, weight and weave structure, are the main factors affecting the stiffness of the fabric. A greater number of warp and weft threads and a higher linear density of threads result in a higher mass per square meter, leading to higher stiffness.

3.3. Flexural rigidity test results of fabric samples

The flexural rigidity test results of the samples in the weft and warp directions are given in the graph in Figure 4. When these results are examined, it is seen that the flexural rigidity values of the organic fabric + reactive dyed (1b, 2b, 3b, 4b, 5b, 6b) and organic fabric + natural dyed fabric samples (1c, 2c, 3c, 4c, 5c, 6c) are higher.

At the same time, the warp direction flexural rigidity of all fabric samples was higher than the weft direction flexural rigidity. This is due to the warp densities being higher than the weft densities of the fabric samples.

The SNK test results in Table 4 revealed that the weight and cotton fabric/dye type of the fabric samples are statistically significant on the warp and weft flexural rigidity. Fabric groups with high weight (4th and 5th groups) exhibit higher weft and warp flexural rigidity than those with low weight. Fabric samples with organic /reactive dyes and organic/natural dyes have higher weft and warp flexural rigidity than conventional/reactive dye fabric samples.

Table 3. Statistical analysis (ANOVA and SNK test) results for bending length

		Bending Length			
		Weft		Warp	
		P/Sig.	SNK Ranges	P/Sig.	SNK Ranges
Weight (g/m^2)	1st group		2.08 b		2.33 b
	2nd group		2.03 b		2.06 a
	3rd group	.001*	1.89 a	.001*	2.31 b
	4th group		2.35 c		2.30 b
	5th group		2.56 d		2.50 c
Cotton fabric/ dye type	Conventional-Reactive		2.07 a		2.14 a
	Organic-Reactive	.001*	2.21 b	.000*	2.27 b
	Organic-Natural		2.26 b		2.48 c

*: statistically significant (P <0.05), (a), (b), (c), and (d) represent statistically difference ranges according to the SNK test

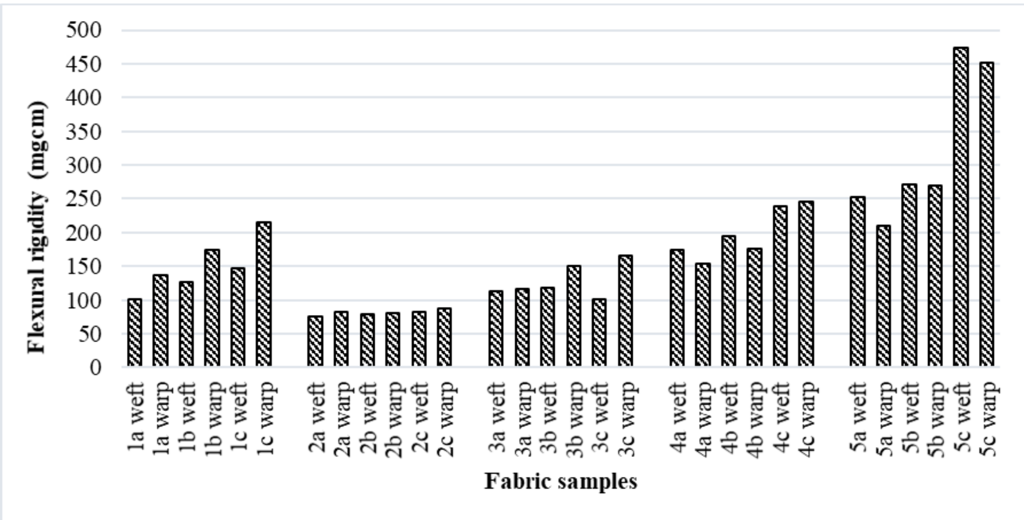

Figure 4. Flexural rigidity test results of the samples in the weft and warp direction test results of the fabric samples

3.4. Overall flexural rigidity test results of fabric samples

The overall flexural rigidity of the fabric was calculated by determining the bending lengths and flexural rigidities of the fabric samples in the warp and weft directions; the results are shown in Figure 5.

When these results are examined, it is seen that the overall flexural rigidity values of the organic fabric + reactive dyed (1b, 2b, 3b, 4b, 5b, 6b) and organic fabric + natural dyed fabric samples (1c, 2c, 3c, 4c, 5c, 6c) are higher.

Under the same weights, a fabric made with thick yarn and low warp and weft densities will be thicker; a fabric made with fine yarn and high warp and weft densities will be thinner but have a tighter structure. Although the weights of the first and third groups are similar in Table 1, the samples in the third group are thicker than those in the first group. This is because the warp and weft densities of the fabric samples in the third group are lower, resulting in softer fabrics and lower overall flexural rigidity.

The SNK test results in Table 4 revealed that weight and cotton fabric/dye type of the fabric samples are statistically significant for overall flexural rigidity. Fabric groups with high weight (4th and 5th groups) exhibit higher overall flexural rigidity than those with low weight. In fabric samples a, b, and c within each group, with an organic/reactive dye and an organic /natural dye, have higher rigidity than conventional/reactive dye fabric samples.

In all tests, organic and natural dyed fabric samples are harder because they are not treated with chemicals such as fabric softener. Natural dyeing can affect the stiffness properties of fabrics [23].

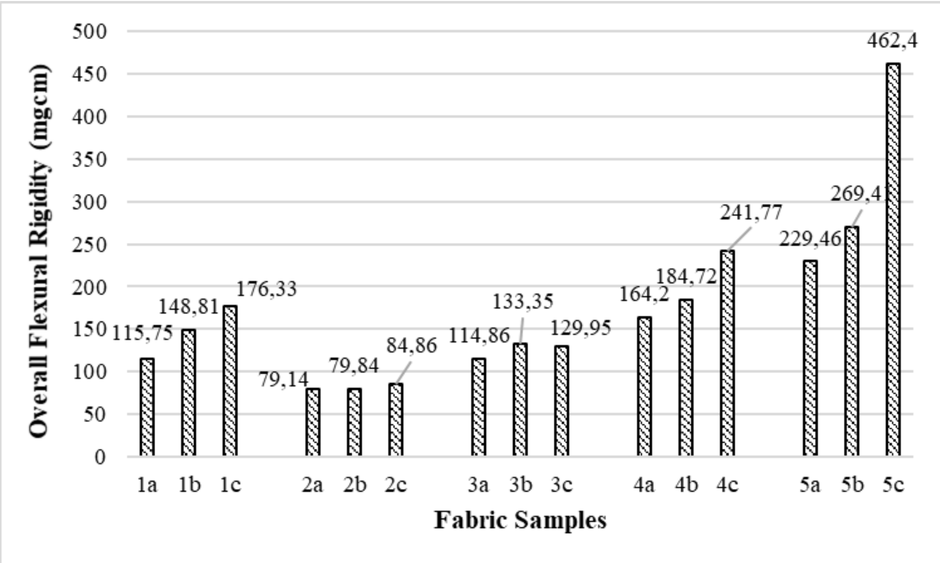

Figure 5. Overall flexural rigidity results of the fabric samples

Table 7. Tensile strength and elongation values of the fabrics with their %CV values

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="4">Flexural Rigidity</td><td colspan="2" rowspan="2">Overall Flexural Rigidity</td></tr>
<tr><td colspan="2">Weft</td><td colspan="2">Warp</td></tr>
<tr><td>P/Sig.</td><td>SNK Ranges</td><td>P/Sig.</td><td>SNK Ranges</td><td>P/Sig.</td><td>SNK</td></tr>
<tr><td rowspan="5">Weight (g/m^2)</td><td>1st group</td><td rowspan="5">.001*</td><td>124.99 b</td><td rowspan="5">.001*</td><td>175.19 c</td><td rowspan="5">.001*</td><td>146.96 c</td></tr>
<tr><td>2nd group</td><td>79.38 a</td><td>83.27 a</td><td>81.28 a</td></tr>
<tr><td>3rd group</td><td>73.64 a</td><td>138.71 b</td><td>99.39 b</td></tr>
<tr><td>4th group</td><td>202.69 c</td><td>191.69 d</td><td>197.89 d</td></tr>
<tr><td>5th group</td><td>332.22 d</td><td>310.18 e</td><td>320.42 e</td></tr>
<tr><td rowspan="3">Cotton fabric/ dye type</td><td>Conventional-Reactive</td><td rowspan="3">.001*</td><td>133.63 a</td><td rowspan="3">.000*</td><td>137.57 a</td><td rowspan="3">.000*</td><td>134.11 a</td></tr>
<tr><td>Organic-Reactive</td><td>151.37 b</td><td>161.12 b</td><td>152.52 b</td></tr>
<tr><td>Organic-Natural</td><td>202.75 c</td><td>240.73 c</td><td>217.33 c</td></tr>
</table>

4. CONCLUSION

This study aims to investigate the stiffness of reactive and naturally dyed organic cotton and conventional cotton woven fabrics used for garments. Organic cotton cultivation has been a new solution for sustainable textile and clothing production. Since organic clothing manufacturing is a new field, unlike conventional products, performance tests are essential to generate new data for the textile and clothing sector.

Good tailorability is a required property for clothing manufacturers. Fabrics will be able to pass through the clothing manufacturing process easily without any problems for good appearance and wear performance. Improving fabric drape and stiffness is very important for the good appearance of the garments. Fabric stiffness may not be too high for a good drape in garment fabrics.

In this study, five fabric groups of 100% cotton plain weave, produced in different weight were used. Each group includes three samples: conventional cotton dyed with reactive dyes, organic cotton dyed with reactive dyes, and organic cotton dyed with natural dyes. Thus, 15 fabric samples with different properties were obtained. Warp and weft bending length, warp and weft flexural rigidity and overall flexural rigidity tests were applied to determine the fabric stiffness according to the cantilever test of ASTM D1388-64 standard of these fabric samples.

As seen from the results of this study, fabric weight and cotton fabric/dye type were significant factors in weft and warp bending length, weft and warp flexural rigidity and overall flexural rigidity of cotton woven samples at the 0.05 significance level. SNK test results indicated that organic cotton woven fabric samples had higher overall flexural rigidity than conventional cotton woven fabric samples. SNK test results also indicated that organic cotton fabric dyed with natural dyes had higher overall flexural rigidity than dyed with reactive dyes. In all tests, organic and natural dyed fabric samples are harder because they are not treated with chemicals such as fabric softener.

The structural properties of the fabric, such as warp and weft densities, weight, weave structure and dyeing processes, are the main factors affecting its stiffness.

Although organic cotton woven fabric is more stiffer than conventional cotton, it offers a unique blend of sustainability, comfort and style, making it an excellent choice for both environmentally conscious consumers and fashionistas. Finally, it can be concluded that, in terms of sustainability, quality and biodegradability, organic fabric with natural dyed samples for garments is easily acceptable as an alternative to conventional fabric with reactive dyed samples.

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