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Investigation of Mechanical Properties of Fabrics Woven with Lyocell/ Cotton Blend Yarns

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ABSTRACT

This study aims to investigate mechanical properties of woven fabrics made from 100 % lyocell, combed cotton and lyocell-cotton blended yarns with different blend ratios. For this purpose, the tensile properties, tearing force, abrasion resistance, bending rigidity, drapability and wrinkle resistant properties of woven fabrics made from different ratios of lyocell and cotton yarns were tested. All the tests were carried out according to the standards, and the results obtained were assessed statistically. The analyses of variance were carried out at 5% (0.05) level of significance. The results of the study show that the effects of the proportion of the lyocell fibres in the lyocell/cotton blended yarns on the tensile properties, tearing force, abrasion resistance, bending rigidity and drape coefficient of woven fabrics are of statistical significance, and it was found that the tensile properties, tearing force and drapability properties were observed to be improve with the increase of lyocell fibre proportion in the blend.

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Tencel, lyocell, cotton, yarn, tensile, fibrillation, drapability

1. INTRODUCTION

Lyocell is the generic term for "regenerated cellulosic fibres" which are obtained using different organic solvent. The abbreviation CLY stands for lyocell and it is derived from the Latin word "lyein", meaning "dissolvable", and "cell", another Latin word meaning "cellulose". The production process of lyocell (Tencel) fibre was improved by using N-methyl-Morpholine-N-oxide (NMMO), and besides, Tencel fibres are manufactured as staple lyocell fibres (1.4 - 1.7 dtex) [1-8].

Lyocell fibre has several advantages over natural and manmade fibres. Since it is possible to recycle almost 99% of the organic solvent used in the obtaining of lyocell fibre and water is the only substance used in the coagulation bath without needing any acid or alkali, lyocell fibre can be considered harmless from toxicological and dermatologic aspects [6, 9-15]. Since the molecular orientation in the direction of fibre axis is quite high during the manufacturing process of the fibre, the crystallization degree is over 90%; therefore, the tenacity value of lyocell is quite high when compared with those of other regenerated cellulose fibres [1-4, 6, 8, 9, 12-14, 16-28].

The crystallization degree of lyocell fibre is 16% and 43% higher than those of modal fibre and viscose fibre respectively [28-30]. In addition, the dry tenacity value of lyocell fibre is much higher than those of other cellulosic fibres and it comes close to that of polyester fibre [6]. Therefore, lyocell can be considered to be one of fibres which can be used blended with other fibres in order to manufacture strong yarns and fabrics [9, 31].

The most important characteristic property of lyocell fibre is its fibrillation behaviour, which arises from the increased fibre fragility due to the fact that the fibre has a crystallization degree around 90% [1, 2, 5, 8, 19, 20, 32]. Although the first manufactured fibres showed a high degree of fibrillation, the improvement and development studies carried out later on eliminated or minimized this fibrillation property to a great extent; besides, depending on the intended use, alternative products with different fibrillation properties such as lyocell (Tencel) Standard, lyocell (Tencel) A100 and lyocell (Tencel) LF (low fibrillation) were manufactured [8, 10, 19, 26, 33, 34].

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A review of the literature about the studies related to lyocell revealed that different studies were performed in order to investigate the lyocell fibre structure [17, 23, 35], fibrillation properties of lyocell fiber [20, 21, 27, 28, 32, 36], lyocell yarn properties, lyocell yarn production methods [2, 7, 37, 47], dyeing/printing behaviors of lyocell fabrics [10, 26], sewing properties of lyocell fabrics [1, 5, 8], and comfort and mechanical properties of lyocell blended woven or knitted fabrics [38-45]. Other lyocell related studies with different topics are available in the literature [12, 22, 46].

From the above-mentioned studies, it can be seen that blending lyocell with different fibers has become increasingly common in recent years. The most important reason for this is presumably that the advantages of lyocell fiber were realized in terms of tenacity and comfort properties. The review of the studies described herein showed that the inclusion of lyocell into the blend led to improvements in tenacity and comfort properties of fabrics [38-45]. In a different study, all the physical properties of the lyocell/cotton blend yarns were measured, and it was seen that with the increase of lyocell percentages of blend yarns, breaking load, breaking elongation and work of rupture values increased while values of yarn evenness, thin and thick places decreased [7,47]. Cotton/lyocell blended yarns were specifically produced for our study using different blending ratios under the operating conditions of the plant, and the tensile properties of the fabrics manufactured from these yarns were measured. Also, this study was different from other studies in that the effects of the lyocell proportions in the cotton/lyocell blended yarns on the abrasion resistance, bending rigidity, wrinkle resistance and drapability of woven fabric were examined in detail.

2. MATERIAL AND METHOD

In the study, 100% lyocell, 100% combed cotton and lyocell-cotton blended yarns with different blend ratios were used as weft yarns and all yarns were produced at the same production line. The type of lyocell fibre used in this study is lyocell (Tencel) standard and the length and count of the fibre are 38 mm and 1.3 dtex respectively. HVI (High Volume Instrument) values of the cotton fibre used were given in Table 1. All the yarns were produced at a spindle speed of 11.000 rpm with C 2HRMT-1 travellers. In this study, all the woven fabrics were especially produced under the same conditions and they have same production parameters (linear density, turns/per meter, finishing process, weft density, warp density). All the yarns involved in this study were used as weft yarns in woven fabrics.

The properties of yarns used as weft yarns were given in Table 2. Combed compact cotton yarns with the linear density of Ne 20/1 were used as warp yarns in this study.

Five different fabrics with twill 2/2 weave, warp density 34 threads/cm and weft density 22 threads/cm were produced on the same warp, using the weft yarns properties of which were given above. The raw fabrics obtained were subjected to the processes given in the Table 3 respectively, and then finished fabrics were obtained.

The tensile properties, the tear and abrasion resistance, bending rigidity, drapability and wrinkle resistant properties of finished fabrics were tested according to the standards. The tensile properties of fabrics were tested on Instron device according to TS EN ISO 13934-1 [48] standard. Five different tests in the direction of weft were carried out for each fabric. The tearing forces of fabrics were tested on Digital Elmendorf tear tester according to TS EN ISO 13937-1 [49] standard. Five different tests in the direction of weft were carried out for each fabric. The abrasion resistance tests by the Martindale method were carried out according to TS EN ISO 12947-3 [50] standard and the average of three different measurements from each fabric sample was taken for the experiment. 9 kPa was chosen as the top weight for the abrasion tests, and the weights of fabrics were measured after 20.000 cycles.

Table 1. Properties of cotton fibres (HVI values) [47]

Properties	Value
Spinning Consistency Index	138
Upper Half Mean Length	29.08
Uniformity Index	83.3
Short Fibre Index	7.9
Fibre Strength in g/Tex	31.6 g/tex
Elongation	6.7
Colour Grade	31-41
Reflectance Rd	76
Yellowness +b	8.1
Trash Count	37
Trash % Area	0.4%
Trash Count	190

Table 2. Weft yarn properties [47]

Yarn linear density	Blending ratio	Twist value (Turns per meter)
Ne 20/1	100% cotton	600
Ne 20/1	75% cotton, 25% lyocell	600
Ne 20/1	50% cotton, 50% lyocell	600
Ne 20/1	25% cotton, 75% lyocell	600
Ne 20/1	100% lyocell	600

The bending rigidity of fabrics was tested using the Shirley Stiffness Tester according to TS 1409 standard [51]. Four different tests were carried out in the direction of weft for each fabric. Totally twenty tests were carried out for five fabrics. The drapability of fabrics was tested on Cusick drape tester according to TS 9693 [52]. Totally six tests were carried out for each fabric. Three of these tests were performed on the front surface, whereas the other three tests on the rear surface of each fabric. Totally thirty measurements were taken for five fabrics. Wrinkle resistances of fabrics were tested on crease recovery tester (brand name James H. Heal & Co. Ltd) according to TS 390-EN 22313: 1992 [53]. Ten different tests were carried out in the direction of weft for each fabric. 10 N was chosen as the weight for the wrinkle resistance.

Table 3. Process applied on raw fabric [47]

Processes	Specifications
Singeing	The length of flame: 12mm Fabric speed: 80m/min Two way
Bleaching and desizing	Caustic: 60ml/l Peroxide: 60ml/l Contavan TIS 8ml/l (stabilizer) Felusan BTM 5ml/l (wetting agent) Sodium persulphatet 10ml/l (auxiliary agent for desizing) Cold bleaching has been made (24 hour)
Washing	1. cabin 95 °C 2. cabin 95 °C caustic (ph 11), 1,5ml/l wetting agent 3. cabin 95 °C 4. cabin 80 °C 5. cabin 70 °C 6. cabin 50 °C neutralisation
Drying	150 °C 40 m/min

All the tests included in this study were carried out according to TS EN ISO 139 [54] under standard atmospheric conditions (20±2 °C and 65±4% relative humidity). The effects of the lyocell proportion in the cotton/lyocell blended yarn on the mechanical properties of woven fabrics were evaluated by means of a SPSS statistical program, performing analyses of variance and the SNK (Student Newman Keuls Test) tests at 5% (0.05) level of significance [47].

3. RESULT AND DISCUSSION

In this study, the effects of lyocell proportions in the cotton/lyocell blended yarns on the mechanical properties of woven fabrics were evaluated by means of the SNK test results and graphs. The values 1-5 in tables denote the effect of lyocell proportion in the Cotton/lyocell blended yarn on the maximum force values, elongation at maximum force (%), weft tearing force, abrasion resistance, bending rigidity and drape coefficient properties of woven fabrics (5 denotes the highest rank and 1 the lowest rank).

3.1 Tensile Properties of Woven Fabrics

The SNK test results given in Tables 4, 5 and Figures 1, 2 suggest that the effects of the lyocell proportion in the cotton/lyocell blended yarns on the maximum force (kN) and elongation at maximum force (%) of fabrics are statically significant. While the lowest force values were obtained in the fabrics made from 100% cotton yarn, the highest force values were obtained in the fabrics made from 100% lyocell yarns. Besides, it is noted that the maximum force and elongation at maximum force (%) values of the fabrics increase as lyocell proportion in the cotton/lyocell blended yarns increases.

Since lyocell fibre has more crystalline regions and higher orientation degrees than natural and other regenerated cellulosic fibres, their tenacity values are higher than those of cotton fibres [55]. Similarly, the results of this study confirmed that the maximum force values of the fabrics made of cotton/lyocell blended yarns increased as the lyocell proportions in the cotton/lyocell blended yarns increased. In addition, elongation values of woven fabrics at maximum force (%) increased with the increase of the lyocell percentages in the blend. We think that the reason for this was that elongation values of lyocell fibers and yarns were higher than those of cotton fibers and yarns (1, 5, 8, 9, 15, 20, 26). Also, a study performed by Bilir and Şardağ confirmed that elongation values of lyocell yarns at maximum force (10.8%) were higher than those of cotton yarns (6.6%) [7, 47].

Table 4. SNK test results of maximum force (kN) of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarn

Weft yarn content	Maximum force (kN) of woven fabrics
100% Cotton (Combed)	0.42 (1)
25% Lyocell - 75% Cotton	0.49 (2)
50% Lyocell - 50% Cotton	0.55 (3)
75% Lyocell - 25% Cotton	0.59 (4)
100% Lyocell	0.70 (5)

Table 5. SNK test results of elongation at maximum force (%) of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarn

Weft yarn content	Elongation at maximum force (%) of woven fabrics
100% Cotton (Combed)	13.23 (1)
25% Lyocell - 75% Cotton	14.60 (1)
50% Lyocell - 50% Cotton	16.45 (2)
75% Lyocell - 25% Cotton	17.85 (2)
100% Lyocell	18.27 (2)

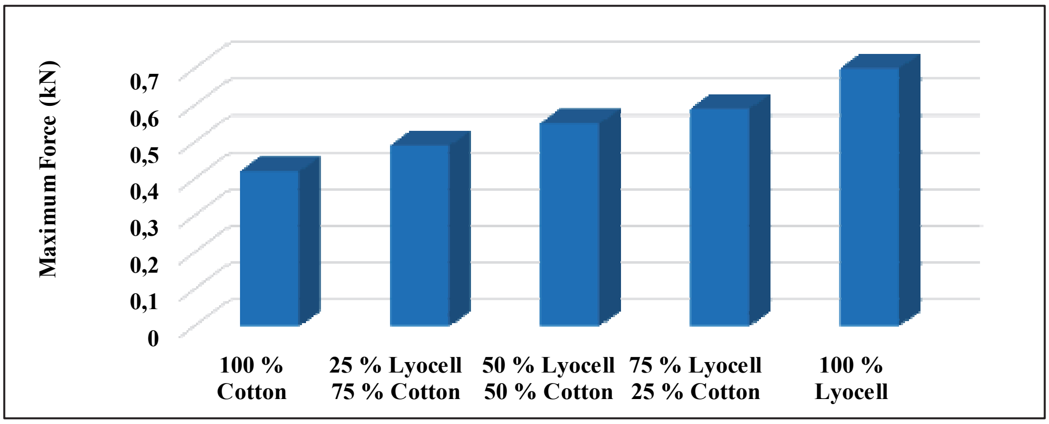

Figure 1. The results of maximum force (kN) of woven fabrics (in the direction of weft)

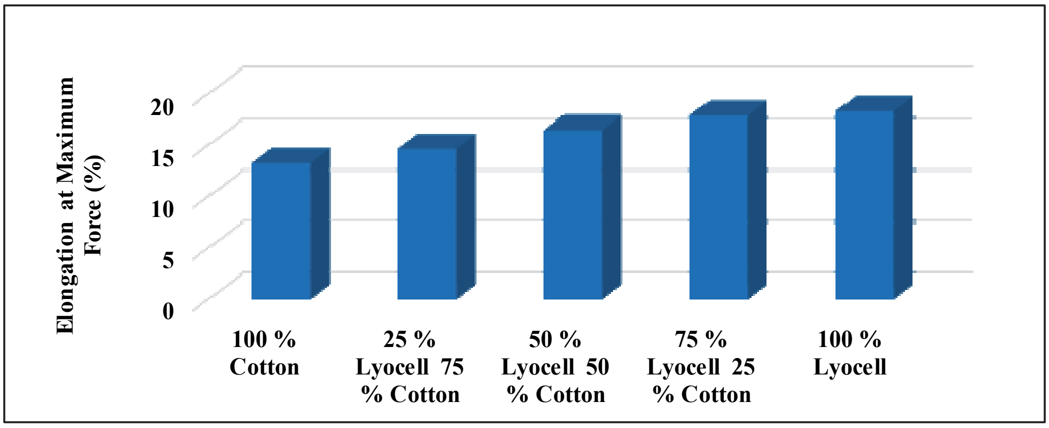

Figure 2. The results of elongation at maximum force (%) of woven fabrics in the direction of weft

3.2 Tearing Force of Woven Fabrics

The SNK test results given in the Table 6 suggest that the effects of the lyocell proportion in the cotton/lyocell blended yarns on the weft tearing force of the fabrics are statistically significant.

Table 6. SNK test results of weft tearing force of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarns

Weft Yarn Content	Weft Tearing Force (N)
100% Cotton (Combed)	51.88 (1)
25% Lyocell - 75% Cotton	49.21 (1)
50% Lyocell - 50% Cotton	49.55 (1)
75% Lyocell - 25% Cotton	53.54 (1)
100% Lyocell	61.19 (2)

Table 6 and Figure 3 show that the highest weft tearing force value was obtained from the fabrics made of 100% lyocell weft yarns, and it was noted that increasing the lyocell ratio in the blend caused no statistically significant difference.

As is the case with the effect of blending ratio on the breaking force of yarns [7] and tensile properties of fabrics, the tearing force value increases as the ratio of lyocell in the blend increases because the tenacity value of lyocell fibre is higher than that of the cotton fibre [55]; however, when maximum force values of fabrics were compared with tearing force values of fabrics, it was observed that the increases in these two values did not take place at the same rate. Besides, the studies available in the literature about tearing forces of fabrics confirm that there exists a weak relation between tearing force and breaking force values of fabrics [1].

In the case of tearing strength, all the yarns in the direction of loading share the load; in tear loading only one, two or at most a few yarns share the load. The movement of the yarns will be restricted in tight constructions and results in a low tearing force. Loose and open constructions allow yarns to move and group together, thus resulting in a high tearing force. The tearing force is affected by changes in yarn properties (linear density, turns/per meter), fabric properties (weft density, warp density, weave), finishing process, relaxation of the fibres and their frictional characteristics; however, the yarns with high tenacity values must be used in order to produce the fabrics with high tearing force [56].

In this study, all the parameters except lyocell blend ratios were kept constant and the highest tearing force was obtained in the fabrics woven from 100% lyocell yarns.

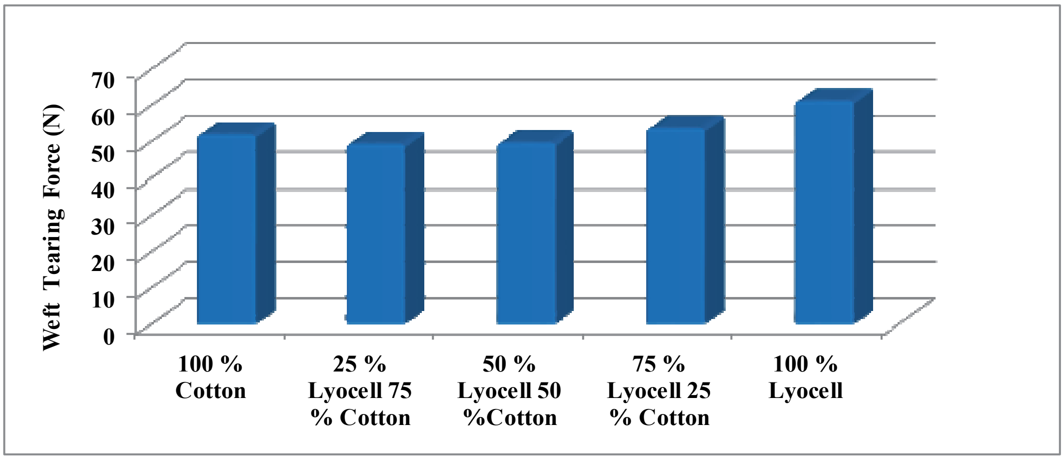

Figure 3. The results of weft tearing force (N) of woven fabric

3.3 Abrasion Resistance of Woven Fabrics

Table 7. SNK Test results of abrasion resistance of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarns

Weft yarn content	Abrasion resistance – The loss of mass (%)
100% Cotton (Combed)	7.50 (1)
25% Lyocell - 75% Cotton	7.80 (2)
50% Lyocell - 50% Cotton	12.10 (3)
75% Lyocell - 25% Cotton	11.90 (3)
100% Lyocell	12.00 (3)

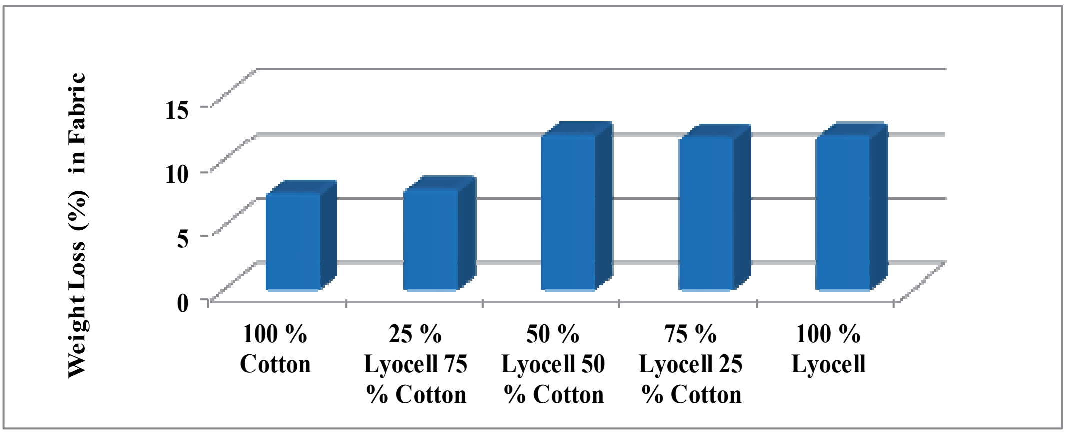

Figure 4. The results of abrasion resistance of woven fabrics

In this study, abrasion resistances of fabrics were examined in terms of mass loss. An examination of Table 7 reveals that a statistically significant increase takes place in the mass loss of the fabric as the ratio of lyocell in the blend increases. The highest mass loss was shown by the fabrics woven from 50% cotton 50% lyocell yarns.

An examination of Figure 4, which gives the mass losses in the fabrics after abrasion tests, reveals that rising the lyocell rate in the blend above 50% does not create a statistically meaningful difference. We think that the reason for this is that the surface hairiness decreases as a result of the defibrillation process (singeing) applied to the finished fabrics.

In principle, every cellulose-based fibre has a fibrillation tendency to a certain extent, and while the fibrillation tendency of cotton fibre is expressed by "2", this value for lyocell staple fibre changes between "4 and 6" [8]. Therefore, the number of fibres that protrude above the surfaces of the yarns or fabrics made from staple lyocell fibres with high fibrillation rate increases, which is an indication of high fibrillation tendency [3, 5, 8].

The abrasion resistance of a fabric is highly affected by the fibre properties, yarn properties, fabric properties and applied finishing processes [57, 58]. The fibrillation tendency of lyocell fibre is higher than that of cotton fibres, for this reason the fabrics show an increased mass loss after abrasion test as the rate of lyocell in the blend increases, which is a finding that is confirmed by our study.

3.4 Bending Rigidity of Woven Fabrics

Bending rigidity of a fabric depends on bending resistance, friction properties and linear density of yarns, fabric pattern and finishing condition. Fabric bending rigidity is proportional to fibre bending rigidity if all other construction factors of fabric structure are kept constant [59], and in this study, all the fabric construction parameters (yarn linear density, turns per meter of yarn, weave, warp and weft densities, finishing and defibrillation processes) were especially kept constant and defibrillation processes were performed on the fabrics.

The SNK test results given in Table 8 suggest that the lyocell proportions in the cotton/lyocell blended yarns do not have any statistically significant effects on the bending rigidity properties of fabrics. However, Figure 5 shows that the lowest bending rigidity was obtained from the fabrics made from 100% lyocell weft yarns. We think that the lyocell proportions in the cotton/lyocell blended yarns do not have any statistically significant effect on the bending rigidity properties of fabrics due to the singeing defibrillation processes applied. Defibrillation process removes fibres that protrude above the surfaces of the fabrics and eliminate surface unevenness such as pilling due to fibrillation; however, we think that the singeing defibrillation process applied is likely to have some effects on the bending properties of the fabrics.

3.5 Drapability Properties of Woven Fabrics

As can be seen from SNK test results given in Table 9 and Figure 6, the effect of lyocell ratio in the blend on drapability coefficients of fabrics is statistically significant and the best drape coefficient values are obtained from the fabrics which contain 50% cotton-50% lyocell yarns.

Table 8. SNK test results of bending rigidity of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarns

Weft yarn content	Bending rigidity of woven fabrics (mg.cm) (in the direction of weft)
100% Cotton (Combed)	0.66 (1)
25% Lyocell - 75% Cotton	0.66 (1)
50% Lyocell - 50% Cotton	0.71 (1)
75% Lyocell - 25% Cotton	0.77 (1)
100% Lyocell	0.57 (1)

Table 9. SNK test results of drape coefficient of woven fabrics made of different lyocell proportion in the cotton/lyocell blended yarns

Weft yarn content	Drape coefficient (%)
100% Cotton (Combed)	61.21 (2)
25% Lyocell - 75% Cotton	60.31 (2)
50% Lyocell - 50% Cotton	58.53 (1-2)
75% Lyocell - 25% Cotton	56.50 (1)
100% Lyocell	57.00 (1)

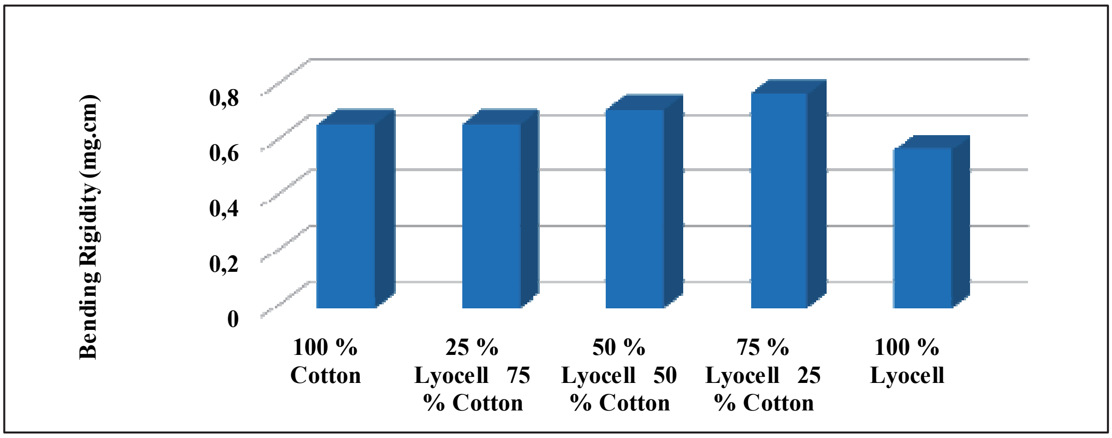

Figure 5. The results of bending rigidity of woven fabrics in the direction of weft (mg.cm)

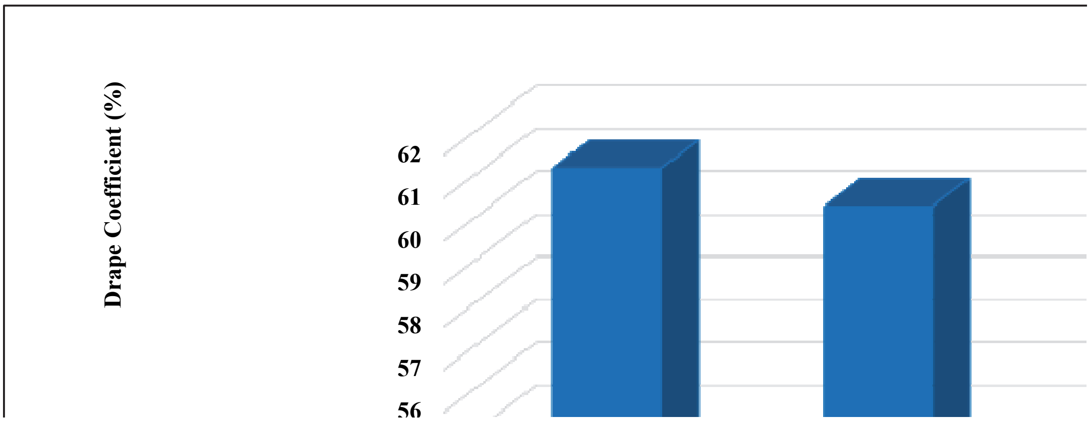

Figure 6. The results of drapability properties of woven fabrics

Increasing of the lyocell rate in the blend above 50% does not create a statistically meaningful difference.

Drapability is the deformation of the fabric under its own weight, and it decreases as its coefficient increases. Drapability of a fabric is affected by many factors such as fabric weight, raw material type and finishing processes applied. In this study, all other production parameters are especially kept stable in order to investigate the effect of lyocell ratio in the blend; therefore, it is thought that changes in drapability arise from the softness of lyocell fibres. Lyocell fabric tends to be softer and more drapable than cotton fabrics and this softness is because lyocell fibre has a very smoot surface.

3.6. Wrinkle Resistant Properties of Woven Fabrics

Wrinkle properties of a fabric depends on fibre properties, yarn properties, test direction, float length and weave pattern, so it is very difficult to know the effects of all factors on wrinkle properties of a fabric. A review of current literature on wrinkle properties of fabrics has shown that twist level, weave pattern and test direction are more effective than other factors on wrinkle properties of fabrics [60]. In this study, while amounts of twists in yarns, yarn numbers, and weaving pattern applied were kept constant, lyocell blending ratios in the blend yarns were changed, and as can be seen in Figure 7, the lyocell proportion in the cotton/lyocell blended yarns does not have a significant effect on the wrinkle resistant properties.

4. CONCLUSIONS

This study aimed to investigate maximum and tearing force, bending, drapability and wrinkle properties of woven fabrics made from lyocell/cotton blended yarns using different blend ratios.

The results of the study showed that the maximum force and elongation values of fabrics at maximum force increased as the proportions of lyocell in the cotton/Lyocel blended yarns increased. However, it was observed that lyocell percentages in the blend should be increased over 50% or 75% so that statistically significant differences could be obtained in tearing force, abrasion resistance and drapability properties of the woven fabrics.

No statistically significant differences were obtained in the bending and wrinkle properties of the fabrics. This was thought to be because of the defibrilattion process. All the parameters such as fiber properties, yarn production line, weave structure, density, etc. were kept and all the fabrics were subjected to the same finishing process in this study. However, we think that chemicals and heat used during the finishing and singeing defibrillation processes hindered the attainment of the expected results in bending and wrinkle properties of fabrics including lyocell.

The results of the study suggest that

- At least 50/50 ratio should be used in order to obtain optimum mechanical properties from lyocell/cotton blended fabrics
- Further studies seem to be necessary with a view to investigating the effects of different defibrillation processes on the mechanical and comfort properties of lyocell blend fabrics.

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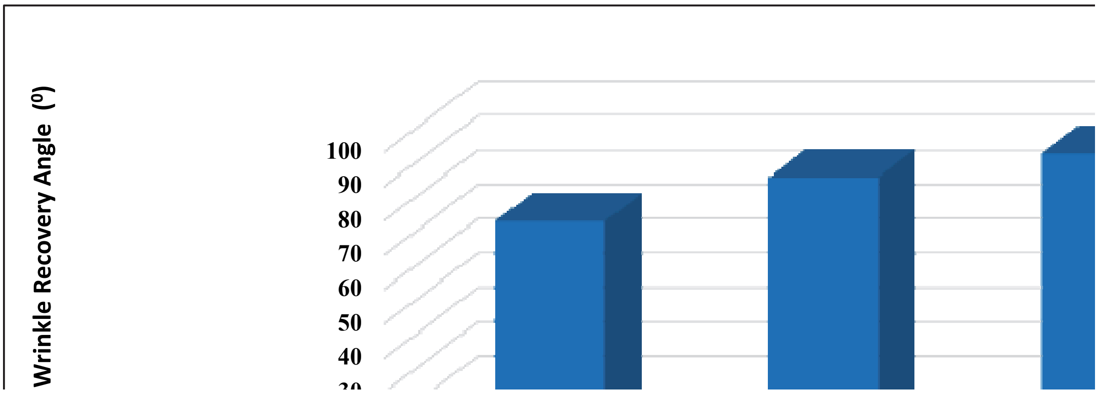

Figure 7. The results of wrinkle resistant properties of woven fabrics

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