

Research Article

Investigation on the Fastness and Dimensional Stability of the Knitted Fabrics Made of the New Generation Regenerated Cellulose Fibers

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Abstract

The purpose of this research is to examine fastness and dimensional stability of the knitted fabrics made of three types of new generation regenerated cellulose fibres such as Naia™ Renew, Tencel™ Lyocell and Ecocell™. The perspiration, washing, water and rubbing fastness tests and also dimensional stability determination were performed. The data was compared with the ones of the cotton fabric. The goal of this study is comparing whether recently developed new generation regenerated cellulose fibers compared to cotton, presents better performance considering customer perceptions. Accordingly, the acidic and basic perspiration (TS EN ISO 105–E04), washing (TS EN ISO 105–C06), water (TS EN ISO 105–E01) and rubbing fastness (TS EN ISO 105–X12) tests and also dimensional stability (TS EN ISO 3759) determination was performed in this concept.

Keywords: Sustainability, Innovative Raw Material, New Generation Regenerated Cellulose Fibers

1. Introduction

Sustainable and renewable materials such as cellulose and protein have attracted attention because of their abundance, ecologically friendly manner and biodegradability. Cellulose is the most abundant polymer in the world. Although it has many drawbacks such as high amount of hydrogen bond and also difficulty to solve, it has been used in many end-uses such as polymeric composites, biomedical applications, petroleum drilling industry, paper-packaging industry, electronics industry and also regenerated cellulose fiber spinning (Sharma et al., 2019; Liu et al., 2021).

Regenerated cellulose fibers can be defined as the fibers which are produced from natural source with human interference (Ramamoorthy et al., 2014). Cellulose has been converted by large scale industrial processing into cellulose regenerated materials. Chemical processing of cellulose is hard due to its non-meltable structure and difficulty in solving (Fink et al., 2001). However, many trials with different solvents were experimented to perform solving of cellulose. Accordingly, many regenerated cellulose fibers have been developed and commercialized in textile industry such as viscose, acetate, rayon, modal and lyocell. Different solutions were utilized to solve cellulose and many types of chemicals to prepare the cellulose pulp to be spinnable into textile filament. Some of these solutions particularly high concentrated sodium hydroxide and carbon disulphide can be hazardous to environment. In order to reduce environmental burdens of the manufacturing processes, new generation regenerated cellulose fibers were developed. The fibers prepared from the direct solution present better mechanical performance in comparison with conventional regenerated cellulose fibers (Jiang et al., 2012). Lyocell and Tencel fibers are produced from the direct solution of wood pulp in N-methylmorpholine-N-oxide (NMMO) (Ramamoorthy et al., 2014). There are also many studies which have been performed to investigate solubility of cellulose in different mediums such as ionic liquids, LiCl/N,N-dimethylacetamide, Tetra butyl ammonium fluoride/dimethyl sulfoxide and metal complex solutions (Wang et al., 2016) and spinning of textile fibers.

In this study, we focused on three different new generation regenerated fiber raw materials such as Naia™ Renew, Tencel™ Lyocell and Ecocell™. The general features of the new generation regenerated cellulose fibers which have more sustainable based production processes than regenerated cellulose fibers, are as follows. These fibers are naturally soft touching and provide long-lived comfort. These fibers exhibit a smooth surface area, when viewed under an electron microscope. Furthermore, these fibers thanks to thousands of microscopic channels on its surface, absorbs the sweat in our body first, that is, it has a very high absorbency feature. By making use of this feature, perfect

swelling of the fiber is achieved during wet finishing processes. Thus, a soft and flexible touch is obtained in the finished fabric.

Utilizing a special closed loop system that recovers and recycles the solvents used in the extraction process, Tencel™ Lyocell fibers are made from sustainably wood, limiting the production's negative environmental effects. With a recovery rate of more than 99%, this solvent-spinning procedure recycles process water and repurposes the solvent. Tencel™ Lyocell fibers have been certified by the U.S. Department of Agriculture as biobased fibres. Furthermore, the wood and pulp used by the Lenzing Group produced from sustainable management of forests. On request, these fibers are available with FSC® (FSC-C041246) or PEFC™ (PEFC/ 06-33-92) certification (Tencel™ Lyocell, 2022). Ecocell™ raw material is developed by KaraFiber, the first Turkish lyocell manufacturing plant. Ecocell™ is a lyocell fiber that is manufactured from sustainable crops and forests and is natural and biodegradable. Ecocell™ has a closed-loop manufacturing method using environmentally friendly processes. Unless significant conservation strategies and FSC® certification are in place, KaraFiber promotes the manufacturing of cellulosic fibers and fabrics made from wood fiber that is not taken from old and endangered forests, such the tropical forest of Indonesia and the Boreal Forest of Canada. Additionally, KaraFiber sources its wood fiber from plantations that are FSC and PEFC certified. The most recent closed-loop manufacturing technology is used to create Ecocell™, which uses an organic solvent that is safe and non-toxic and can be recycled and recovered to 99.5% of the composition. Tencel™ Lyocell stands out from other cellulosic fibers in this regard. In order to provide better properties in textile products, Ecocell™ fibers are designed to produce 40,000 tons per year at the factory (Ecocell™, 2022). With the development of circularity at scale, Naia™ Renew offers an inventive response to the major problems facing the fashion industry. Naia™ Renew is made from 40% certified recycled waste plastics and 60% wood pulp from sustainably managed forests, adding value to materials that would otherwise end up in landfills. External reviewed and verification have confirmed that Eastman's LCA for Naia™ Renew cellulosic yarn complies with ISO 14044. Naia™ Renew recycled content is obtained by distributing recycled plastics in a mass balance process certified by ISCC. The Naia™ Renew closed-loop method stresses the safe and environmentally responsible use of chemicals, ensuring that the items you produce are as fashionable and environmentally friendly as they are sustainable. The production of Naia™ Renew also permits a substantially reduced carbon footprint over the course of the fiber's life cycle, and because it is certified biodegradable and compostable, garments may be securely recycled back into nature when their useful lives are through (Naia™ Renew, 2022).

The purpose of the current research is to compare whether recently developed new generation regenerated cellulose fibers compared to cotton, presents better performance considering customer perceptions. Accordingly, the acidic and basic perspiration (TS EN

ISO 105–E04), washing (TS EN ISO 105–C06), water (TS EN ISO 105–E01) and rubbing fastness (TS EN ISO 105–X12) tests and also dimensional stability (TS EN ISO 3759) determination was performed in this concept.

2. Materials and Methods

2.1. Materials

In this concept of this study, for different fiber types were selected such as cotton, Naia acetat, Tencel™ Lyocell and Ecocell™ fibers. Via using these yarns, the fabrics were knitted in two different structures such as single jersey and also rib with elastic yarn. The knitted fabrics were pretreated to prepare the fabrics for dyeing process. The cotton, Tencel™ Lyocell and Ecocell™ fabrics were dyed with reactive dye whereas Naia™ Renew fabrics was dyed with disperse dyestuff. For fastness tests, ECE non-phosphate standard detergent was supplied from SDC Enterprises Ltd. Company used in washing fastness tests. $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$, $\text{Na}_2\text{HPO}_4 \cdot 2\text{H}_2\text{O}$, $\text{C}_6\text{H}_9\text{O}_2\text{N}_3 \cdot \text{HCl} \cdot \text{H}_2\text{O}$ and NaCl were provided from Sigma and Merck Corp.

2.2. Methods

2.2.1. Determination of fabric structural parameters

The mass per unit area was determined in accordance with TS 251. For the thickness test, each fabric was cut into a square shape (8x8 cm²). Thickness of the fabrics were measured using James Heal RxB Cloth Thickness Tester under pressure 50 g/cm².

2.2.2. Fabric fastness tests

Fastness to water, fastness to washing, fastness to perspiration, and fastness to rubbing of fabrics were tested according to TS EN ISO 105-E01, TS EN ISO 105-C06, TS EN ISO 105–E04, and TS EN ISO 105–X12, respectively. The fastness tests were practiced using the following instruments: SDL Atlas M231/PR1 Perspirometer for fastness to water and perspiration, SDL Atlas Linitest for washing fastness and SDL Atlas rubbing fastness. After testing, staining and change in color were evaluated to the standard gray scale rating (where 1 is poor and 5 is excellent).

2.2.3. Determination of fabric dimensional stability

Determination of dimensional change in fabrics was conducted according to TS EN ISO 3759. The fabrics were conditioned under standard atmospheric conditions before washing and drying. Dimensional stability tests of knitted fabrics were carried out at TYH Tekstil laboratories-inhouse. Test sample fabrics were adjusted according to standard conditions before test and analyzes (21 ± 1 °C, $65 \pm 2\%$ relative humidity). The dimensional change of fabrics after washing and drying was measured according to TS EN ISO 3759. The dimensional changes of fabrics were calculated using the following formulas:

$$\text{percentage change in length} = \frac{\text{last length} - \text{first length}}{\text{first length}} \times 100$$

$$\text{percentage change in width} = \frac{\text{last width} - \text{first width}}{\text{first width}} \times 100$$

The fabric structural parameters are listed in Table 1 and Table 2.

Table 1. The structural parameters of the rib knitted fabrics.

Parameter	Data			
	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
Fiber type	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
Mass per unit area (gr/m2)	324	256	268	388
Thickness (mm)	0.97	0.75	0.71	0.88
Width (cm)	180	165	155	175
Yarn count	30/1	30/1	30/1	30/1
Knitting structure	Rib	Rib	Rib	Rib
Colour	Dark navy	Dark navy	Dark navy	Dark navy
Image				

Table 2. The structural parameters of the single jersey knitted fabrics.

Parameter	Data			
Fiber type	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
Mass per unit area (gr/m ²)	182	155	154	197
Thickness (mm)	0.39	0.41	0.34	0.41
Width (cm)	160	175	170	175
Yarn count	30/1	30/1	30/1	30/1
Knitting structure	Single jersey	Single jersey	Single jersey	Single jersey
Colour	Dark navy	Dark navy	Dark navy	Dark navy
Image				

3. Results

Fastness to washing and water, acidic and basic perspiration and also rubbing are tabulated in Table 3, Table 4 and Table 5, respectively. In this study, the fabrics were manufactured in two different structures such as single jersey and rib and made of four different fibers such as cotton, Tencel™ Lyocell, Ecocell™ and Naia™ Renew. Knitted structures do not have major influence on color fastness to washing, color fastness to rubbing and color fastness to light of the knitted fabric if processing parameters remains same (Asif et al., 2015). The type of fiber determines the dyestuff applicable on textile fabric. The chemistry of dyestuff, dyeing parameters, chemical and physical bonding between fabric and dyestuff affect fastness properties of the colored textile material. In this study, the cotton, Tencel™ Lyocell and Ecocell™ fabrics were dyed with reactive dyestuff whereas Naia™ Renew fabrics was dyed with disperse dyestuff. Fastness properties of the reactive dyed fabrics are very good due to the covalent bonding of the reactive group of the dye to the fibre (Akalin et al., 2004). Dispersion dyes, hydrophobic and insoluble in water are dyestuffs. Dyestuffs with low sublimation fastness but good dyeing properties in aqueous media are used for dyeing cellulose acetate, triacetate and polyamide fibers (Icoglu, 2006). It can be determined from the Table 4 that there is no prominent difference between fastness to perspiration results for all the fabrics. In case of washing fastness, Naia™ Renew rib knitted fabrics present a decrease of half or one

grade in comparison with those of the other fabrics. Considering rubbing fastness results, Naia™ Renew rib knitted fabric present lower results as compared with the other fabric.

Table 3. Fastness to washing and water results

		Rib knitted fabrics				Single jersey knitted fabrics			
		100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
Washing	Color change	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	CA	5	4-5	5	4	5	5	5	4-5
	CO	5	4-5	4-5	4	4-5	4-5	5	5
	PET	5	4-5	4-5	3-4	4-5	4-5	5	4
	PA	5	4-5	4-5	3-4	4-5	4-5	5	4
	PAC	5	4-5	4-5	3-4	4-5	4-5	5	4-5
	Wo	5	4-5	4-5	3-4	4-5	4-5	5	4-5
Water	Color change	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	CA	5	4-5	5	4-5	5	5	5	4-5
	CO	5	4-5	5	4-5	5	5	5	4-5
	PET	5	4	5	4	5	5	5	4
	PA	5	4	5	4	5	5	5	4
	PAC	5	4	5	4	5	5	5	4
	Wo	5	4-5	5	4	5	5	5	4

Table 4. Fastness to perspiration results of fabrics

		Rib knitted fabrics				Single jersey knitted fabrics			
		100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
Washing	Color change	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	CA	5	5	5	4-5	5	5	5	4-5
	CO	5	5	5	4-5	5	5	5	4-5
	PET	5	5	5	4	5	5	5	4-5
	PA	5	5	5	4	5	4-5	5	4-5
	PAC	5	4-5	5	4	5	5	5	4-5
	Wo	5	5	5	4	5	5	5	4-5
Water	Color change	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	CA	5	4-5	5	5	5	5	5	4-5
	CO	5	4-5	5	5	5	5	5	5
	PET	5	4-5	5	5	5	5	5	4-5
	PA	5	4-5	5	4-5	5	5	5	4-5
	PAC	5	4	5	4-5	5	5	4-5	4-5
	Wo	5	4-5	5	4-5	5	5	5	4-5

Table 5. Fastness to rubbing results

		<i>Rib knitted fabrics</i>				<i>Single jersey knitted fabrics</i>			
		100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew	100% Cotton	100% Tencel™ Lyocell	100% Ecocell™	100% Naia™ Renew
<i>Wale</i>	<i>Dry</i>	4-5	4-5	5	3	5	4-5	4-5	5
	<i>Wet</i>	4	3-4	4-5	3	4	3-4	3-4	4-5
<i>Course</i>	<i>Dry</i>	4-5	4-5	5	3-4	4-5	4	4-5	5
	<i>Wet</i>	4	3	4	4	3-4	3-4	3-4	4-5

Dimensional stability is so important to maintain the aesthetics of knitted products in the user ends. Yarns can be exposed to different tensions during knitting process and the relaxation process which change the dimension of the knitted fabric (Asif et al., 2015). Table 6 lists the dimensional stability results of the fabrics. As it is determined from the data, the fiber type dimensional stability affects the dimensional stability. As examined in detail, the single jersey fabrics from regenerated fibers have comparable dimensional stability values whereas the cotton fabric has the lowest. In addition, it has been observed that fabrics produced from new generation regenerated cellulose fibers show a soft touch. These fibers exhibit a sleek surface area, enabling fabrics to glide lightly over skin. Fabric slips due to soft handling may also have affected the shrinkage values.

The fabrics with rib structure present lower shrinkage values as compared with the fabrics having single jersey knitting structure particularly in fabric width. When we examined the dimensional stability results for rib fabrics, Ecocell™ rib fabrics gave the closest values to cotton. For Naia™ Renew rib knitted fabric, value of the dimensional stability-percentage change in width gave the best result. Shrinkage in opposite after washing of Naia™ Renew rib knitted fabric, was higher than other fibers. We can

interpret it as follows: Naia™ Renew fibers were supplied as filaments, while other fibers are supplied as staples.

Table 6. Dimensional stability results of fabrics

		<i>Dyed</i>	
		<i>Percentage change in length</i>	<i>Percentage change in width</i>
<i>Single jersey structure</i>	<i>Raw material</i>		
	<i>100% Cotton</i>	-1.4	-2
	<i>100% Tencel™ Lyocell</i>	-6.3	-6
	<i>100% Ecocell™</i>	-7	-8
<i>Rib structure</i>	<i>100% Naia™ Renew</i>	-5.7	-2
	<i>100% Cotton</i>	-2	-4
	<i>100% Tencel™ Lyocell</i>	-6.3	-5
	<i>100% Ecocell™</i>	-1.4	-5
	<i>100% Naia™ Renew</i>	-7	0

4. Discussion and Conclusion

Regenerated fibers have attracted world-wide attention particularly at recent years. This is highly because of that the natural fibers cannot meet the increasing fiber demand and the demand for regenerated cellulose fibers increases. Furthermore, regenerated cellulosic fibers are more comfortable and healthy fibers compared to synthetics. The goal of this study is to examine fastness and dimensional stability of the knitted fabrics made of three types of new generation regenerated cellulose fibers such as Naia™ Renew, Tencel™ Lyocell and Ecocell™. The data is compared with that of the cotton knitted fabric. In the literature review, studies on the properties of textile fibers are promising. Performance: it differs depending on the physical and chemical properties

of fibers, yarns, fabric structure, the applied finishing and dyeing, the processes, and types of printing processes. A change in one or more of these components directly affects performance. Another factor affecting performance is the general fiber properties. Moreover, it depends on many properties such as origin, quality, length, diameter, density, crimp, surface properties, brightness, strength, elongation, elasticity, springiness, moisture absorption, conductivity, resistance to chemicals. The structural units form the chemical structure of the fiber and are also decisive in the formation of its physical properties. The regions that make up the structure in the fiber are the crystalline region and the amorphous region. The oriented regions of the macromolecules of the textile fibers, which are arranged in an ordered and regular manner, are called the crystalline region. Water, moisture, cannot penetrate the fibers where this region is excessive. Between the crystalline regions of textile fibers, macromolecules are randomly located, and it is called the easily permeable region that does not have a regular geometric shape. Since it is easy to penetrate the amorphous region, it absorbs water quickly, which affects its dyeability. In general, the surface structure is an important feature that manifests itself until the processing of the fiber, yarn, fabric and product formation.

In our study, we examined the fastness and dimensional stability properties of knitted fabrics produced from promising new generation regenerated cellulose fibers. When we compared these fibers with cotton, we observed that they could be an alternative to cotton. New generation regenerated cellulose fibers are increasingly used in clothing due to their comfort properties (naturally soft to the touch) and the inability of natural fibers to meet the increasing fiber demand. For this reason, it is important to know the properties of these fibers and to determine and eliminate the structural problems in knitted fabrics to be developed in this context. It can be seen as an alternative to cotton fibers and its properties can be improved according to its usage areas. Sustainability production in textiles is an important issue and new generation regenerated cellulose fibers make an important contribution to sustainability. It is seen that more research is needed on the successful and correct use of new generation regenerated cellulose fibers in textiles.

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