

Tencel Process Optimization in Conventional Cotton Processing Machineries and a Quality Comparison with Similar Cotton Yarn Count

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Abstract

Tencel a regenerated fiber manufactured from cellulose derivatives, is getting popularity nowadays due to its biodegradability and environment amenity depending on the less land and water consumption relative to organic and conventional cotton. Spinning process optimization of tencel is performed and reviewed in this article in comparison with conventional cotton process. Wider setting with low production speed is observed for tencel processing with superior yarn quality. Quality parameter of different yarn count evaluated and compared. Mass uniformity and its cv is significantly higher in tencel yarn; breaking strength is 50% greater in tencel along with breaking elongation; tencel yarn possess more twist (>15%) while twist cv is slightly lower; yarn cuts in autoconer machine is lower in tencel yarn.

Keywords: Tencel; Organic cotton; Unevenness; Co-efficient of variation (CV); Yarn; Spinning

Introduction

Lyocell is a manmade fiber derived from cellulose [1], better known in the United States under the brand name Tencel. Tencel fiber, though related to rayon, is a kind of regenerated cellulose fiber produced in a way called “solvent spinning method”, the production mainly uses coniferous wood pulp as raw materials. Tencel fiber has the advantages of both natural fiber and synthetic fiber. Such as cellulose fiber, tencel fiber has good hygroscopic, permeability and performance, its wearing comfort is much better than polyester, and its feel, gloss, drape are all good. The strength of tencel fiber is higher than that of cotton fiber and viscose fiber; it also has advantages such as warm and soft and comfortable; in addition, tencel has good performance and dimensional stability; it can be blended with other natural fiber and synthetic fiber [2]. The source ingredients of tencel fiber mainly come from green cellulose fiber in nature, chemical solvent used in production can be recycled, so it won't cause any damage to human and the environment. After using, tencel fiber can be decomposed completely in soil, which can greatly reduce the environmental destruction, therefore, tencel fiber is also known as “green fiber and eco-friendly fiber”. Tencel fiber, as a kind of biodegradable fiber, will become the mainstream in the future [3]. Because, throughout the world modern civilization's greater inclination and attention towards environmental protection, social development towards the direction of environmental protection and sustainability, processing and manufacturing green textiles. It is an extremely strong fabric with industrial uses such as in automotive filters, ropes, abrasive materials, bandages and protective suiting material. It is primarily found in the garment industry, particularly in women's clothing (Table 1).

Historical background and production

Whatever it's called, Tencel or Lyocell is a sustainable fibre, regenerated from wood cellulose. It is similar in hand to rayon and bamboo, both regenerated fibres. However, Tencel is one of the most environmentally friendly regenerated fibre for several reasons. Tencel fibres are grown sustainably. Tencel has earned Forest Stewardship Council (FSC) certification that the products come from environmentally responsible forests. Tencel eliminates the negative environmental impacts of traditional fibre processing, using new

sustainable technologies. As a new kind of cellulose fiber, tencel fiber has been published for many years. It's now popular in United States, Japan and other countries mainly for the production of high fashion. 1939 Patent appears describing the dissolution of cellulose in amine oxide. Kaoerzi Company had started researching cellulose fiber production with NM-MO solvent method since 1978. 1969-1979 American Enka/Akzona Inc. work on spinning fiber from a solution of cellulose in amine oxide but did not scale up. In 1981, the company used amine oxide as a new solvent to spin; the experiment showed that the spinning method is feasible. In 1983, the company set up experimental factory; in 1987, the continuity of large scale plant was established. In 1989, it's named tencel fiber after recognized by the International Bureau of Artificial and Synthetic Fiber Standards, then

	Organic Cotton	Tencel
Synthetic pesticides and fertilizers	Not allowed	None used
Water use	As low as about 10.6 gallons/lb for rain-fed from Brazil and as high as 782 gallons/lb for CA organic cotton	154.7 gallons/lb fiber
Land use	3.5 acres/ton	0.52 acres/ton
Heat-trapping gases	3.5 pounds/lb	Less than 1 lb/lb fiber
3 rd party certification	USDA organic, GOTS in some cases	Oeko Tex 100, FSC, PEFC-accredited certifiers

Table 1: Comparison of tencel vs. cotton in environmental perspective.

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American factories began commercial production of tencel and its production capacity had reached 55 million kilograms. Tencel has some distinct advantages over traditional fibres in terms of chemical processing, which can often be extensive and toxic. For example, Rayon manufacturing generates highly polluting air and water emissions, uses catalytic agents containing cobalt or manganese, and creates a strong unpleasant odor. Tencel products can be decomposed, solvent of which is non-toxic, the cellulose used for Tencel is treated in what is known as a closed loop process in which the solvents are recycled with a recovery rate of 99.55%. The tiny amount of remaining emissions is decomposed in biological purification plants. Because of the natures of the material, the processing never requires bleach. This method of manufacturing of fibre was awarded the “European Award for the Environment” by the European Union. So it is regarded as the third generation of regenerated cellulose fiber. Because of its unique properties, it had been applied into a variety of goods in many fields. The whole Asia has also appeared upsurge of tencel development [4]. Japan is currently the largest developers of tencel textiles, lots of men products in department stores were tencel goods. It can be said that tencel fiber goods in Japan entered a new stage. Textile software and hardware for tencel, especially the commercialization of tencel commodity, were also under development in Japan. This had helped Japan to maintain a leading position in the manufacturing of tencel fiber. In 2000, the British tencel fiber output reached 6,140,000 tons. Tencel fiber with its incomparable superiority is in rapid development in international and domestic market. Tencel is used in a variety of applications, including men's wear, sheets, and blankets. Since it's absorbent and dries quickly, it is also suitable for towels. Clothes made from this material are often recommended for traveling because they are light and keep their shape well. Tencel® is also available as fabric for sewing, as yarn for knitting or crocheting, and as fiber for spinning. Besides its use as a cloth, it is also used in making bandages, baby wipes, oil filters and carpeting for cars, as well as conveyor belts and plastic parts. In powder or fiber form, this material is used in making specialized papers, as an additive for building materials, and in making foam mattresses [5].

The purpose of this study is to analyze the suitability of conventional cotton processing machineries in tencel processing and establish a successful benchmark and provide necessary guidelines for yarn manufacturers.

Tencel in comparison with organic and conventional cotton fibers

Bearing in mind that the figures below include wide room for variation that makes any strict head-to-head comparison impossible, we can distill the discussion down to some basics (Table 1).

Lyocell fiber spinning process

This section provides a description of the process steps required for making lyocell [6]. A diagram of the process is shown in Figure 1. The principles are simple. Firstly, the pulp is wetted out with dilute aqueous amine oxide to fully penetrate the pulp fibers. The subsequent removal of the excess water under heat and vacuum is a very effective way of making a homogenous solution with a minimum of undissolved pulp particles and air bubbles. The solution is highly viscous at its operating temperature (90 to 120°C) and must be processed in similar high pressure equipment to that used in melt polymer systems. The fibres are formed by spinning into an air gap and then coagulating in a water/amine oxide bath. They are then washed and dried and cut. The wash liquors are recovered, purified, concentrated then recycled. The process description below applies to the two commercial-scale operations of

Tencel® and Lenzing. Variations in detail have been cited in patent applications and the literature but these are at a much smaller scale of operation (Figure 1).

Methodology

Fiber selection

Before start of the production following fiber characteristics were measured and bale laydown was done according to the quality parameters (Table 2).

Yarn Spinning Process

Spinning is the twisting together of drawn out strands of fibers to form yarn, and is a major part of the textile industry (Figure 2).

Testing of machine gauge and yarn characteristics

Following tests were carried out on the Square Texcom Ltd. Situated at kathali, valuka, Mymensingh (Table 3).

Results and Discussion

Process optimization and benchmarking for Tencel and Cotton fiber:

Opening and cleaning

Fiber length uniformity is the main reason for closer setting in Mixing Bale Opener (MBO). In addition to the length uniformity tencel fiber is free from foreign matter. Which lead to narrower setting of grid bar angle as 2 to 3. Another important aspect of tencel processing is the bypass of two saw tooth beater and it is advised to use only one pin beater. More beater exploits fiber to pass through more beating action and which was highly responsible for curling of fibers and finally generation of fiber to fiber entanglement neps. Some of the fabrics are

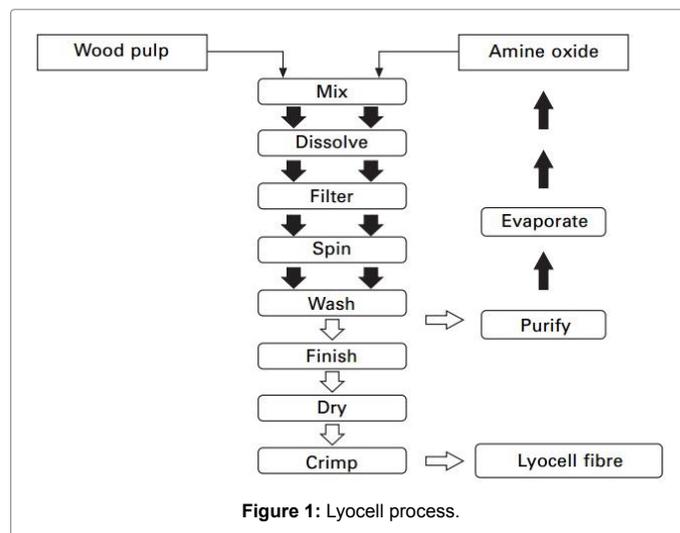
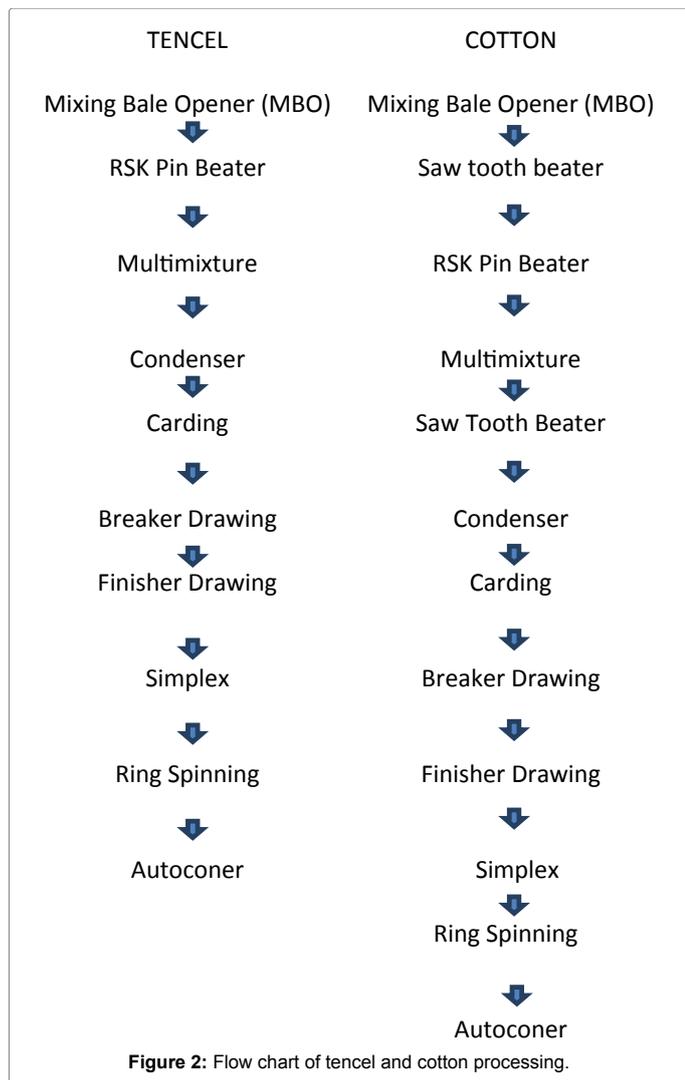


Figure 1: Lyocell process.

Fiber specifications	Tencel	Cotton (CO)
Country of origin	Austria	Australia, Brazil, Turkmenistan, USA, Uzbekistan
Color	Bright natural white	Natural yellow white
Fiber count	1.3 dtex	4.3 Mic.
Commercial staple	35 mm	28.75 mm
Tenacity	30 g/tex	29.4 g/tex
Elongation	7.90%	7.40%

Table 2: Properties of both Tencel and cotton fiber.



observed to be white specks on the surface. It is advised to set larger beater grid angle and more beating sections for cotton than that of tencel processing due to less length uniformity and large number of foreign matter (Table 4).

Carding

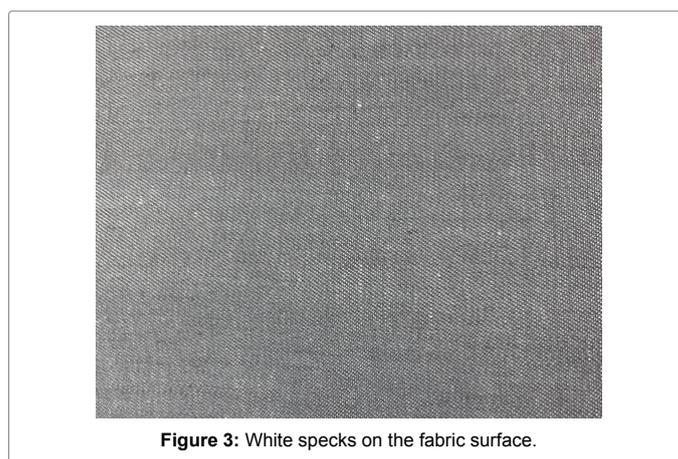
As tencel fiber processing was performed in the carding, usually designed for cotton processing, with higher point density more than 960 points per square inch does not allow higher speed of production. Higher jamming of cylinder-flat region and cylinder-doffer region was highly noticeable and less nep generation was observed in carding machine. Ultimately numerous complaints of nappy yarn and white specks (Figure 3) on fabric surface were done by the buyers of the yarn. Finally, in optimization of carding setting at a speed of 45-50 kg per hour at a delivery speed of 250 m/min was maintained successfully in comparison to cotton processing speed, which was significantly higher 65-70 kg per hour in the same machine. In order to improve web quality; licker-in speed, cylinder and flat speed was reduced as well as gauge of those elements were amplified. On the other hand for cotton setting optimized narrower with higher processing speed. Tencel fiber is with larger fiber volume quality is smooth and fluffy, its moisture regain rate is higher but its cohesion is not good, so the carding should

Test name	Test method (ASTM standard)	Testing instrument
Different machine gauge		Supplied by machine manufacturers
Yarn count	D1059-97	Wrap reel, balance
Tensile strength, breaking elongation	D2256-02	USTER Tensorapid
Twist/unit length, twist CV	D1422-99	Single yarn twist tester
Hairiness	D5647-01	USTER Tester 5 (UT5)
Yarn fault classifying system		USTER CLASSIMAT QUANTUM
Yarn evenness	D1425-96	USTER Tester 5 (UT5)
Thin/km, thick/km, or Nep/km	D1425-96	USTER Tester 5 (UT5)

Table 3: Test method and testing instrument.

Machine name	Process parameter	100% Tencel	100% Cotton
MBO	MBO grid bar angle:	1	4
Pin Biter	Grid bar setting:	1	4
	Condenser-III:	1	3.5

Table 4: Setting of Mixing Bale Opener and other opening and cleaning machineries.



Machine name	Process parameter	100% Tencel	100% Cotton
Carding Machine	Sliver weight:	6.5 Ktex (91.7 gr/yd)	5.2 Ktex (73.4 gr/yd)
	Speed:	45-50 kg/hr	70kg/hr
	Flat to cylinder gauge:	0.30/0.30/0.25/0.25/0.25	0.225/0.20/0.20/0.175/0.17
	BSF to Cylinder:	0.45/0.40/0.45/0.40	0.40/0.40/0.40/0.40
	FSF to Cylinder:	0.40/0.35/0.40	0.35/0.35/0.35
	Licker in speed:	1200 rpm	1200 rpm
	Cylinder speed:	550 rpm	850 rpm
	Flat speed:	0.26 m/min	0.35 m/min
	Cylinder to Doffer	0.175	0.175

Table 5: Carding machine setting for both tencel and cotton processing.

choose with less number of card clothing 800-850 points per square inch clothing similar to polyester or polyester blend in order to reduce yarn neps and improve cotton web quality [7,8] (Table 5).

Drawing (Breaker and finishing)

Higher staple length and length uniformity are the primary reason for wider setting in tencel processing compare to the cotton processing in drawing frame machine. Hygroscopicity, higher moisture regain rate, is highly responsible for generation of roller lapping and jamming

of the drawing frame machines. It is optimized as 47/49 roller setting for front to back zone whereas in cotton 37/42. Higher top roller weighting 380-380-320 (front top roller to back roller) along with larger amount of break draft 1.6-1.9 was optimized for tencel and on the other hand for cotton those were 320-320-320 and 1.15, respectively [9]. Second drawing is mainly in order to make the fiber straight and to make the weight unevenness reduced to a certain extent. Draft configuration may be the most important aspect for tencel processing as well as lower production speed to improve straightening of back hook and enhancement of web quality (Table 6).

Simplex

Number of twist per unit length of tencel roving was carefully observed and was substantially lower than that of cotton; twist value was appropriately increased which allows lower appearance of spinning head. Beside this precise measurement of spinning tension and its optimization was done at 1.033 both for cotton and tencel. Optimization of the above mentioned due to less roller lapping and unevenness of yarn. may be slipping tendency due to lack of fiber cohesion and spin finish on the tencel fiber creates layer on the roller surface and roller slip occurred thus higher break draft was advised to intensify desired total draft [10,11] (Table 7).

Ring frame

Roller gauge both for tencel and cotton processing was

Machine name	Process parameter	100% Tencel	100% Cotton
Breaker Draw Frame	Sliver weight:	4.9 Ktex (69gr/yd)	4.9 Ktex (69gr/yd)
	Breaker draft:	1.4	1.3
	R/R setting	47/49	37/42
	Condenser size:	4.6	4.2
	Funnel no:	8	10
	Doubling	6	6
	Speed:	450 m/min	650 m/min

Table 6: Drawing frame machine setting for cotton and tencel fiber.

Machine name	Process parameter	100% Tencel	100% Cotton
Simplex	Breaker draft:	1.206	1.1206
	Tension:	1.033	1.033
	TPI:	0.78	1.05
	Roving hank:	0.9	0.75
	Spacer color:	Blue	Green
	Flyer speed:	1050	1200
	Roller gauge:	40/49.5/60	40/49.5/60

Table 7: Simplex machine setting and quality parameters to be maintained for tencel and cotton.

Machine name	Process parameter	100% Tencel			100% Cotton			
		Knitted yarn			Knitted yarn			
		20	30	40	20	30	40	
Ring Frame	TPI:	15.12	18.21	21.7	16.52	20.55	23.92	
	TM:	3.25	3.325	3.45	3.34	3.46	3.54	
	Spacer:	Yellow (2.9 mm)	White (2.8 mm)	White (2.56 mm)	Yellow (3.0 mm)	White (3.0 mm)	White (2.8 mm)	
	Traveller size:	1/0	3/0	4/0	1/0	3/0	4/0	
			Weaving			Weaving		
	TPI:	16.9	20.55	24.51	20.28	25.07	29.41	
	TM:	3.55	3.6	3.7	3.78	3.75	3.74	
	Spacer:	Yellow (3.25 mm)	White (3.0 mm)	White (2.8 mm)	Yellow (3.25 mm)	White (3.0 mm)	White (2.8 mm)	
	Traveller size	1/0	3/0	4/0	1/0	3/0	4/0	

Table 8: Ring frame machine setting parameters for cotton and tencel of different count.

60/42.5 (back to front roller) maintained and yarn count variation was noticeable for tencel. Suitable drafting force in optimizes the yarn quality; exact roller pressure on pneumatic drafting with apron guidance and proper spacing with 70/42.5 (back to front roller) for tencel fiber. Higher break draft 1.72 facilitates achieving tencel yarn of less thick, thin places and minimum end breakage. Lighter traveller with flat cross-sectional shape optimizes the yarn quality profile for tencel yarn (Table 8).

Analysis of yarn quality parameters

Comparison of yarn properties of Tencel and Cotton yarn, greater cohesion between the fibers and length uniformity may be the significant contributor on higher tensile strength of tencel yarn. Fiber migration, the displacement of fibers along the yarn axis during spinning, is dependent on the amount of twist inserted on the yarn. Higher amount of twist per unit length higher the packing density thus cotton yarn is firm than compare to tencel yarn and exhibited lower elongation percentage than compare to that of tencel yarn (Tables 9 and 10).

By lubricating the fiber surfaces, the fibers move smoothly against each other and machine parts like the yarn guide, trumpets and aprons. This prevents friction and potential fiber breakage and protects the fibers from the static electricity charges that are generated due to inter-fiber friction, friction between the fibers and machines parts, and the low electrical conductivity of the fiber. A spin finish can also prevent fibers from splitting from each other, thus leading to less hairiness and less fiber lapping in the final yarn. By promoting greater adherence between fibers, a spin finish can improve the efficiency of bale opening. The spin finish increases cohesion between the fibers and the machine parts, reducing fly which otherwise introduces defects into the yarn [12].

Uniform draft distribution after several trial and errors allows much uniformity of tencel yarn along with less thick, thin and neps which finally exploits less yarn cut in autoconer machine than compare to that of the cotton yarn. This is because of less thick, thin, and abnormal neps in the tencel yarn (Tables 11-14).

Conclusion

Tencel yarn, comprise of high strength fibers, exhibits higher breaking strength over conventional 100% cotton yarn. Other yarn parameters like breaking elongation, mass uniformity, and hairiness of tencel yarn are significantly better in comparison with that of cotton yarn. Another important aspect of tencel yarn is Eco friendliness which overweighed lower production speed. Ultimate quality profile of tencel yarn facilitates its uprising popularity. Eco friendliness will enhance the use of tencel on basic garments manufacturing as well as

Yarn Count (Ne)	Woven yarn		Knitted yarn		Woven yarn		Knitted yarn	
	Uniformity (U%)	CVm	Uniformity (U%)	CVm	Uniformity (U%)	CVm	Uniformity (U%)	CVm
20	8.36	2.2	8.27	2	9.84	3	10.62	1.7
30	10.56	1.4	10.56	1.4	12.03	2.1	12.11	2.8
40	11.58	1.8	12.16	2.2	12.97	2.23	13.62	1.7

Table 9: Mass Uniformity of tencel and cotton yarn.

Yarn Count (Ne)	Tencel Yarn				Cotton Yarn			
	Woven yarn		Knitted yarn		Woven yarn		Knitted yarn	
	Breaking Strength (CSP)	Breaking Elongation	Breaking Strength (gm/tex)	Breaking Elongation	Breaking Strength (CSP)	Breaking Elongation	Breaking Strength (CSP)	Breaking Elongation
20	4777	12	3449	11	3197	10	2740	10
30	4339	11	3773	10	2712	9	2522	9
40	4080	10	3172	9	2521	8	2119	9

Table 10: Breaking strength and elongation of tencel and cotton yarn.

Yarn count (Ne)	Knitted (Tencel)				Knitted (Cotton)			
	20	30	40	50	20	30	40	50
Hairiness	6.06	5.59	5.2	4.9	6.51	6.46	5.96	5.65
Evenness	8.36	10.56	11.55	13.13	10.62	12.11	13.26	13.42
Thin (-50%)/km	0	2	17	76	6	4	71	73
Thick (+50%)/km	8	82	211	375	126	200	520	553
Nep (200%)/km	20	166	281	794	155	266	673	600
IPI	28	250	511	1245	387	469	1263	1226

Table 11: Imperfection Index, Hairiness of tencel/cotton yarn.

Yarn Count (Ne)	Tencel Yarn				Cotton Yarn			
	Woven yarn		Knitted yarn		Woven yarn		Knitted yarn	
	Twist	Twist CV	Twist	Twist CV	Twist	Twist CV	Twist	Twist CV
20	16.9	1.04	15.12	1.02	20.28	0.8	16.52	1.01
30	20.55	0.89	18.68	0.85	25.07	1.08	20.55	1
40	24.51	1.01	21.7	1.03	29.41	1.15	23.92	0.81

Table 12: Tencel and cotton yarn twist and twist cv% comparison.

	Tencel			Cotton		
	20 Ne	30 Ne	40 Ne	20 Ne	30 Ne	40 Ne
Nep cuts	10	8	10	10	8	13
Short cuts	60	75	85	70	65	88
Long cuts	10	15	10	15	25	12
Thin cuts	8	10	10	10	13	11
Short off count cuts	2	1	1	5	1	2
Off count cuts	1	1	3	1	1	4
Splice cuts	2	4	3	2	7	3
Total	93	114	122	113	120	133

Table 13: Autoconer cut of tencel and cotton yarn comparison for knitted yarn.

	Tencel			Cotton		
	20 Ne	30 Ne	40 Ne	20 Ne	30 Ne	40 Ne
Nep cuts	8	8	10	20	25	25
Short cuts	50	65	70	70	65	78
Long cuts	6	10	10	15	18	12
Thin cuts	7	8	10	15	13	18
Short off count cuts	2	1	1	5	5	2
Off count cuts	1	1	2	3	3	4
Splice cuts	2	2	2	3	7	3
Total	74	95	105	131	136	142

Table 14: Autoconer cut of tencel and cotton yarn comparison for Woven yarn.

intensify use of tencel as blend with cotton, jute etc. which will solve the problem of dependency on synthetic fiber to a large extent and sustain environment [13].

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