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RESEARCH ARTICLE

A novel approach to produce neppy yarn in vortex spinning technology

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ABSTRACT
A novel, cost-effective method for producing neppy yarn using the vortex spinning process was presented in this research. The vortex and ring spinning processes were utilized to produce 26/1 Ne neppy yarn from viscose rayon as a host fiber and polyester as a neppy fiber in three different ratios (98/2, 97/3, and 96/4). It was explored that neppy yarn produced by the vortex spinning system is aesthetically more appealing as it has very low hairiness, fewer coefficient of variation (CV%), and minimal thick and thin places compared to ring-spun neppy yarn. However, the count strength product (CSP) of the vortex-spun neppy yarn is comparatively lower than that of the ring-spun neppy yarn. The close engagement of the neppy fibers to the mother yarn in a vortex spinning system increased the neppy yarn's aesthetic beauty and strengthened its endurance was a significant discovery of this study. The hairiness value of neppy yarns was measured numerically and evaluated statistically with one-way analysis of variance (ANOVA) and found significant differences between the two-spinning system. The adoption of the vortex spinning technique presents novel approaches for manufacturing neppy yarn, with potential advantages for the textile industry such as enhanced yarn quality, greater productivity, fewer machinery requirements, and ultimate cost-effectiveness.

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KEYWORDS
Neppy yarn; vortex spinning; viscose rayon; cost calculation; ANOVA

Introduction

Fancy or novelty yarns still hold strong market potential as they are more visually appealing than traditional yarn (Halepoto, Gong, & Kaleem, 2019). Fancy yarns are unique products created through various techniques that intentionally introduce irregularities in diameter, unevenness, and color, as well as the inclusion of periodic or non-periodic effects such as knops, loops, dots, spots, neps, curls, slubs, or other similar effects, to create a visually distinctive product (Alshukur, 2013; Petrulyt & Petrulis, 2004). Neppy yarn is a fancy yarn containing visible small clusters or lumps of fibers introduced prior to the carding stage to create a unique textured appearance. These neps can be of varying sizes and colors, made from the same or different fibers (Alshukur, 2013; Gong, 2017), and the fabric may or may not necessarily undergo a dying process, which can significantly reduce the processing time and manufacturing cost. This approach can meet the demands of modern consumers for personalized, diverse, fashionable, and environmentally friendly products without the need for additional dyeing procedures (Zou, 2014). The ring-spinning process is often used to produce neppy yarn. Since the quality of neppy yarn is all about its tenacity, the ring spinning process for neppy yarn production may not be effective, which can increase the cost and complexity of the production process. This has led to an interest in alternative spinning processes.

Vortex spinning is a modern spinning technique that is regarded as one of the most potential technologies that offer a very high production rate and produces yarns with a distinct layered structure made up of untwisted fibers in the center and helically wrapped fibers in the outer layer (Behera, 2020; Erdumlu, Ozipek, Oztuna, & Cetinkaya, 2009; Erdumlu & Saricam, 2013; Li, Yu, & Shang, 2014; Ortlek & Ulku, 2005; Pei et al., 2021; Shamey & Shim, 2019). In the vortex spinning system, fibers are drafted and fed into a spindle orifice using an air vortex. As the fibers enter and pass through the orifice, they are twisted by the swirling airflow (Li et al., 2014; Ortlek, 2006; Ortlek & Ulku, 2005) and the yarn is created through a process that involves a bundle of fibers arranged mainly in a parallel manner, known as the core. This core is then wrapped with a twisted fiber ribbon, forming the wrapping part of the yarn (Erdumlu et al., 2009; Moučková, Mertová, Jirásková, Krupincová, & Křemenáková, 2015; Ortlek & Ulku, 2005; Pei et al., 2021; Uyanık & Duru Baykal, 2018). The textile industry has been increasingly interested in the air vortex spinning system owing to its distinctive properties and faster production rates (Behera, 2020). In the vortex spinning system, viscose rayon has shown more favorable outcomes in terms of yarn evenness, and tensile properties, especially in coarser yarn counts (Ortlek & Ulku, 2005; Uyanık & Duru Baykal, 2018). Compared to ring and compact yarns, vortex yarns have a larger diameter due to their porous nature, yet

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they have significantly less hairiness than ring yarns (Behera, 2020).

The vortex spinning technique is a relatively new and innovative method for producing yarns (Basal & Oxenham, 2006; Kim & Kim, 2018; Thilagavathi et al., 2017). Despite its potential advantages, there is a limited amount of research available on the production of fancy yarns using this technique. As far as our knowledge extends, it appears that no prior research has concentrated on the production of neppy yarns using vortex spinning technology. Considering the existing knowledge gap in this area, the present research aims to become the pioneering work for the manufacturing of neppy yarns through vortex spinning technology.

In this study, neppy yarn with a count of 26/1 Ne was produced using combinations of viscose rayon and polyester neppy fibers in three different ratios (98/2, 97/3, and 96/4) *via* both vortex and ring spinning methods and evaluated based on their manufacturing cost, yarn strength as well as their visual characteristics. By investigating the feasibility and potential advantages of producing neppy yarns using vortex spinning technology, this research work seeks to contribute to the development of innovative techniques for yarn production. Additionally, the findings of this study may be useful for textile manufacturers and researchers interested in exploring new methods for producing high-quality and unique yarns.

Materials and methods

In this study, viscose rayon was used as a host fiber from Birla Jingwei Fibre Co Ltd, China, and 100% virgin polyester was utilized as a neppy fiber from PT. Indorama Polychem, Indonesia. The fiber properties are given in Table 1, where linear density indicates fiber fineness, cut length represents staple length, tenacity indicates the breaking strength of fiber, and whiteness refers luster of the fiber. The same fineness and staple length have been used for both fibers to ensure proper blending between them. Figure 1 represents viscose rayon and polyester nappy fiber which was used in this study.

Table 1. Properties of fiber.

		Host fiber (viscose rayon)		Neppy fiber (polyester)	
Parameters	Unit	Nominal value	Tolerance	Nominal value	Tolerance
Linear Density	denier	1.2	± 0.1	1.2	± 0.04
Cut Length	mm	38	± 1	38	± 1
Tenacity	gram/den	Min 2.75		6.3	± 0.5
Elongation	%	Min 18		22	± 5
Whiteness	%	Min 80		85.5	± 1.5
Oil Pick Up	%	Min 0.24		0.14	± 0.03

The fiber blend used in the study consisted of three different ratios of viscose rayon and polyester neppy fibers, with a total of 15 kg of fiber used for each ratio. For the 2% neppy yarn, the composition was 14.7 kg of viscose rayon and 0.30 kg of polyester neppy fiber. Similarly, for the 3% neppy yarn, the blend comprised 14.55 kg of viscose rayon and 0.45 kg of polyester neppy fiber, while the 4% neppy yarn consisted of 14.4 kg of viscose rayon and 0.60 kg of polyester neppy fiber. The neppy fiber composition consisted of 50% black and 50% parrot polyester neppy fiber in each specified ratio, as shown in Table 2, to get different texture effects in the yarn. To ensure a uniform distribution of fibers, the viscose rayon and neppy fibers were thoroughly mixed in a clean environment before feeding them into a manual bale opener. The manual bale opener was used to further blend the fibers and prepare them for the carding machine. Figure 2 represents the blending process of viscose rayon and polyester nappy fiber.

Preparation of neppy fiber

The neppy fiber production process involved several steps in this study. Firstly, 100% virgin-colored polyester fiber was fed through a conveyor belt and feed roller to create a web on the cylinder which was coming out between perforated drum and guide roller onto the conveyor belt. Then, water was applied to the web to intentionally cause a jam in the subsequent process. The wetted web was then fed to the licker-in and passed through between the first guided roller and the first perforated drum. Finally, the web was passed through a second licker-in, where the second guided roller

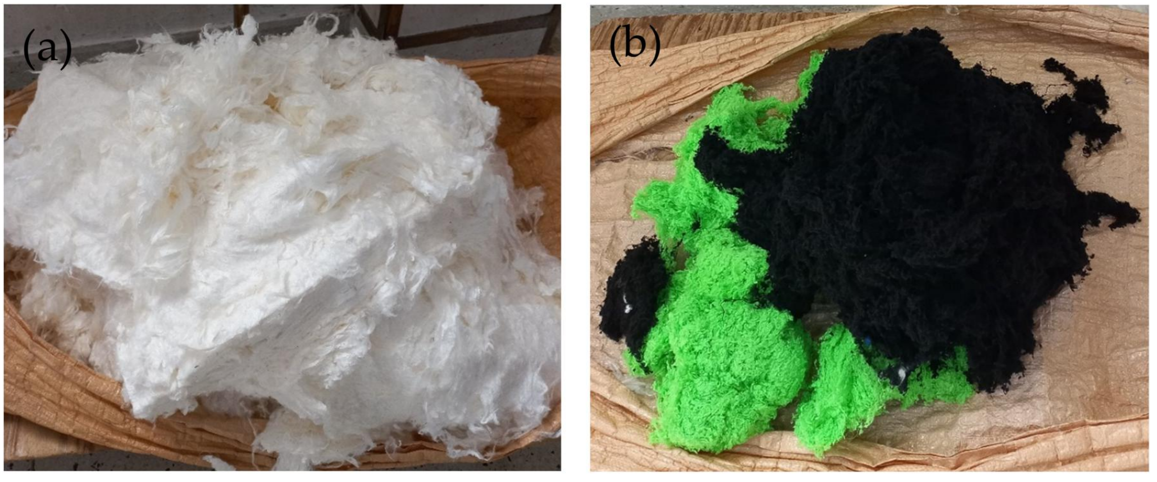

Figure 1. (a) Viscose rayon as a host fiber and (b) polyester as a neppy fiber.

Table 2. Blow-room mixing plan.

Blend ratio (viscose/polyester)	Host fiber viscose rayon	Neppy fiber (polyester) Black	Parrot	Total	Total mixing	Neps percentage
98 / 2	14.7 Kg	0.15 Kg	0.15 Kg	0.30 Kg	15 Kg	2%
97 / 3	14.55 Kg	0.225 Kg	0.225 Kg	0.45 Kg	15 Kg	3%
96 / 4	14.4 Kg	0.30 Kg	0.30 Kg	0.60 Kg	15 Kg	4%

Figure 2. Processes for blending neppy fiber with host viscose rayon fiber: (a) hand mixing and (b) manual bale opener.

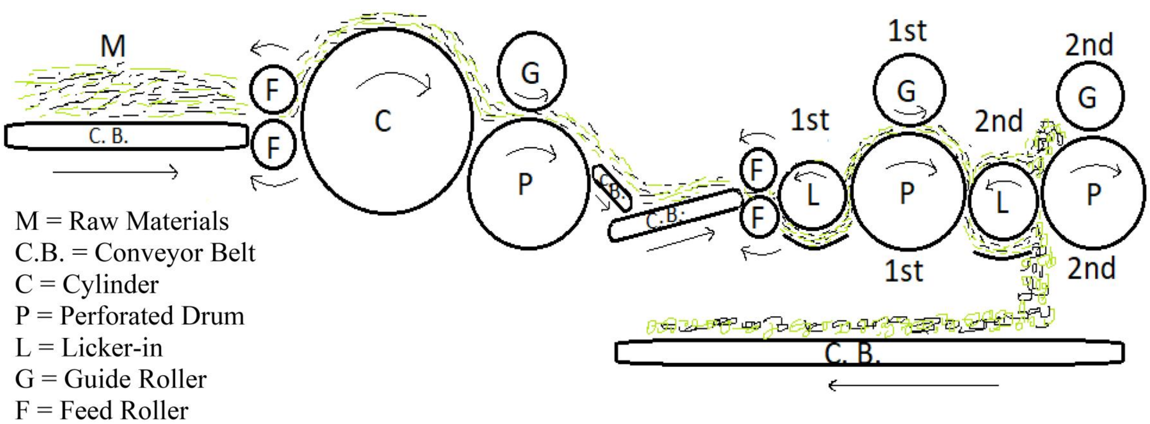

Figure 3. Production process of neppy fiber.

of the second perforated drum remained off. As the second guided roller was off, the material could not pass out, and instead, it dropped out between the second licker-in and the perforated drum. This caused the fiber to roll up in this region, then the roll-up fiber was again fed to the first licker-in through the conveyor belt. This process was repeated 5 times to obtain the desired level of neppiness. It is worth noting that during this process, the licker-in and perforated drum rotated in opposite directions. The schematic diagram of the neppy fiber production process is illustrated in Figure 3.

Production of neppy yarn

The production process of neppy yarn in this study involved several key steps. Initially, a blend of host fiber and neppy fiber was prepared in three different ratios (98/2, 97/3, and 96/4). This blend was then processed through a carding machine to produce card sliver. Following carding, the breaker draw frame process was repeated twice to improve the sliver regularity. The sliver then underwent the finisher draw frame, enhancing its thickness and uniformity. The finished drawn sliver was divided into two equal portions. One portion was directed to a simplex machine to produce roving, which was further processed on a ring frame machine to produce conventional neppy yarn. The final step involved passing the neppy yarn through a winding machine to form cones of neppy yarn. Simultaneously, the other portion of the sliver was directly fed into a vortex spinning machine to produce vortex-spun neppy yarn. Figure 4 represents the process flow chart of neppy yarn production in both vortex and ring spinning process.

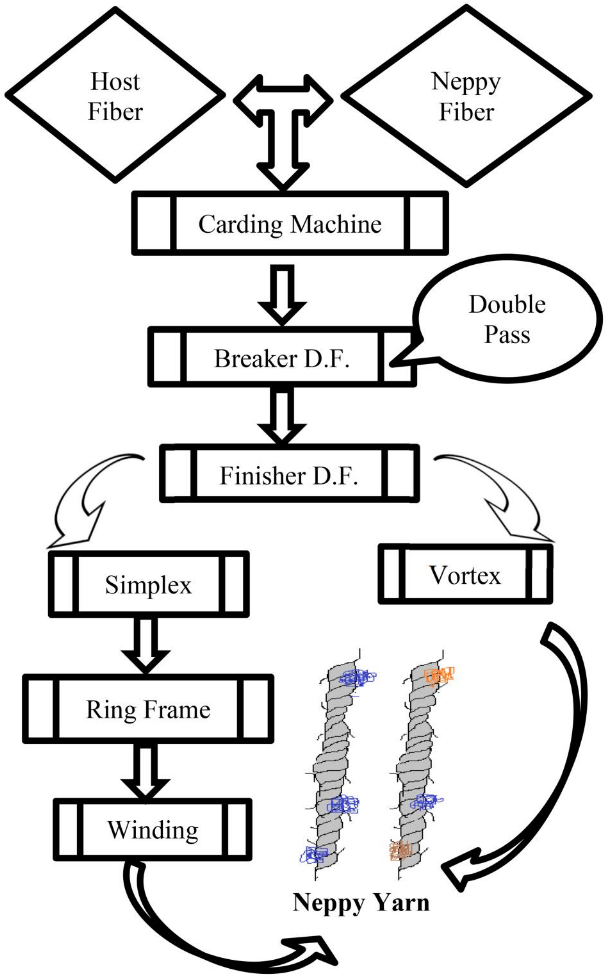

Figure 4. The diagram of the neppy yarn production process.

Table 3. Carding machine parameters.

Machine parameters	Gauge	Parameters	Gauge
Revolving flat to cylinder	24 thou	Cylinder speed	560 m/min
Post-stationary flat to cylinder	20 thou	Flat speed	180 m/min
Pre-stationary flat to cylinder	22 thou	Licker-in speed	1200 m/min
Licker-in to cylinder	12 thou	Sliver grain	80 Grain/yd.
Doffer to cylinder	10 thou	Production speed	50 Kg/h

Adjustment of card settings

The carding machine settings used for the production of card slivers during neppy yarn manufacturing were crucial in this study. The machine used in this research was Trützschler TC 11 originated from Germany and set in such a way that all gauges were kept open to prevent the neps from opening out. This meant that the carding machine played a reverse role in the production of neppy yarn, compared to its traditional role in producing smooth and even yarn. The gauges (Table 3) of the carding machine helped to retain the neppy fibers within the sliver and allowed for the formation of neppy clusters. By adjusting the machine settings in this manner, the study was able to produce card slivers that were suitable for subsequent spinning processes to create neppy yarn.

Table 4. Draw frame machine parameters.

Machine	Roller gauge	Doubling	Sliver grain	Machine speed
Breaker draw frame	44 × 48 mm	6	80 Grain/yd.	700 m/min
Finisher draw frame	44 × 48 mm	5	60 Grain/yd.	550 m/min

Preparation of drawn sliver

In this study, the production of uniform drawn slivers was a critical step in the manufacturing of neppy yarn. The Breaker Draw Frame (SB D 15) and Finisher Draw Frame (RSB D 45) used in this research were Rieter originated from Switzerland. After carding, the breaker draw frame process was repeated twice to ensure that the sliver was adequately prepared for subsequent spinning processes by removing irregularities in the fiber blend. The sliver was then passed through the finisher draw frame, which further refined the thickness of the sliver and made it more uniform and regular. This study was able to create a uniform and consistent fiber blend that was suitable for subsequent spinning processes to create neppy yarn. The resulting drawn slivers were of high quality and met the necessary standards required for the production of neppy yarn. Table 4 represents the machine parameters of the draw frame machine.

Manufacturing of neppy yarn in the ring spinning process

The production of neppy yarn through the ring spinning process required careful attention to several steps. Firstly, the finisher-drawn sliver was fed into a simplex machine to produce roving. Once the roving was made, it was further processed on a ring frame machine to produce neppy yarn, but this yarn was in cops form that's why these cops were undergone to the winding machine to form yarn in cone form that was suitable for subsequent next processes. Table 5 represents the process parameters of simplex, ring frame, and winding machine.

Manufacturing of neppy yarn in the vortex spinning process

The production of neppy yarn using the vortex spinning process was a key focus of the present research. The vortex machine used in this research was Muratec Vortex 870 originated from Japan. Multiple trials were undertaken to optimize the manufacturing process by adjusting various parameters, including nozzle air pressure, spindle type, total draft ratio, feed ratio, take-up ratio, drum speed, and classmate setting. The nozzle pressure was set slightly lower than usual to ensure proper attachment of neps to the mother yarn. A coarser spindle type was employed to facilitate the easy release of neps from the spindle needle. The total draft ratio and feed ratio were kept slightly higher, while the drum speed and take-up ratio were lower than usual. In terms of classmate setting neps and short thick (S) were kept wider to prevent the cutting of any neps, while other classmate settings remained unchanged. Through careful adjustments, this research was ultimately successful in

Table 5. Process parameters for the simplex, ring frame, and winding machine.

Machine gauge	Simplex	Ring frame	Winding machine	
Brand name	Toyota	Marzoli	Muratec	
Country of origin	Japan	Italy	Japan	
Model	FL 200	MP 1 N	Process Coner II QPRO	
Roller gauge	39.5 × 52.5 × 58.5 mm	40 × 45 mm	Winding speed	1350 m/min
Count	Roving; 0.80 Ne	Yarn; 26 Ne	Classmate Settings	
TPI	0.82	17.50	Nep %	400 %
Spacer	Green	Orange	S %	200%
Traveler	–	3/0	S cm	2.5 cm
Speed	1150 m/min	12500 m/min	L %	50 %
			L cm	50 cm
			T %	50 %
			T cm	50 cm

Table 6. Parameters of vortex machine.

Machine parameter	Settings	Classmate Settings	
Sliver input	60 Grain/yd.	Parameter	Gauge
Yarn count	26 Ne	Nep %	400 %
Winding speed	400 m/min	S %	200%
T.D.R.	191	S cm	2.5 cm
Feed ratio	0.990	L %	50 %
Take up ratio	1.000	L cm	50 cm
Spindle type	Coarse(C)	T %	50 %
Nozzle pressure	0.52 MPa	T cm	50 cm

Table 7. Process ambient temperature of different spinning sections.

Ambient condition	Blow-room	Carding	Drawing	Simplex	Ring frame	Winding	Vortex
Temperature °C	34	34	34	34	32	30	30
RH%	50	50	50	50	52	65	54

producing neppy yarn using the vortex spinning process. This work represents a pioneering achievement in the field of neppy yarn manufacturing. Table 6 represents the process parameters were used for producing neppy yarn in vortex spinning machine.

Quality assessment of neppy vortex and ring yarn

Consistent ambient temperature is crucial in yarn production as it directly impacts the final product's quality. In this research, temperature and relative humidity (RH%) were strictly maintained at all stages to ensure optimal yarn formation, as outlined in Table 7 and a yarn conditioning chamber (Condibox Welker 1 Vapomat 600ht) was used to condition the neppy yarn produced by both vortex spinning and ring spinning processes. The chamber was maintained at a temperature of 45 °C and vacuumed in 90%, for 45 min.

An optical microscope, Micros, MCX 100 originated from Austria, was used to observe the surface morphology of the yarns. For the microscopic analysis 50 images were taken and the most common images obtained from the microscope were used to analyze the neppy yarn surface structure for both vortex and ring-spun neppy yarn.

In accordance with the ASTM D1425/1425M14(2020) standard, Uster® Tester 6, Uster Technologies, Switzerland was utilized to determine the coefficient of mass variation (CVm%), thick place, thin place, and hairiness of the neppy yarns at a testing speed of 400 m/min. For data analysis, the sensitivity thresholds of thick place (+50%) and thin place (−50%) per 1000 m of yarn were considered as these thresholds limits are most commonly used during calculation of Imperfection Index (IPI). The hairiness of the neppy yarns (H) was measured based on optical principle using the hairiness sensor of the evenness tester. U% and CV% from the Uster® Evenness Tester both represent yarn mass variation. In this study, CV% is chosen as the primary parameter for analyzing yarn mass variation due to its widespread use in such analyses. TENSOLAB-4, MesdanLab Strength Tester, Italy was used to measure the tensile properties of the neppy yarn produced by both vortex and ring-spun yarn. The testing was performed with a constant rate of extension principle according to EN ISO 2062:2009 with a 50 N load cell, sample length of 500 mm, and clamp speed of 500 mm/min. The samples were conditioned before testing in accordance with ISO 139, and all the tests were conducted in the laboratory under standard testing conditions of 65 ± 2% relative humidity and 25 ± 2 °C temperature.

Knitting process of fabric

Single jersey knit fabric samples were constructed by both vortex-spun neppy yarn and ring-spun neppy yarn using Mayer & Cie MV 4-3.2 II, Germany, with a cylinder diameter 610 mm, cylinder speed 20 rpm, number of needles 1800 (Gauge 24), and number of feeders 78.

Result and discussion

Analysis of tensile properties

In this study, it was observed that the elongation percentage and count strength product (CSP) of the vortex neppy yarn were lower than that of the ring-spun neppy yarn (as shown in Figure 5). This is due to the differences in the spinning process, as the vortex spinning process, airflow is employed to form a vortex that envelops the fibers around a core resulting in the alignment of the fibers in a parallel manner with respect to the yarn axis (Erdumlu et al., 2009; Ortlek & Ulku, 2005). The parallel alignment of fibers in the vortex spinning process is responsible for a lower elongation percentage due to reduced fiber mobility and inter-fiber friction. This would lead to a yarn that is less elastic and more rigid compared to yarn produced through the ring spinning process. Additionally, with the increase of neps percentages,

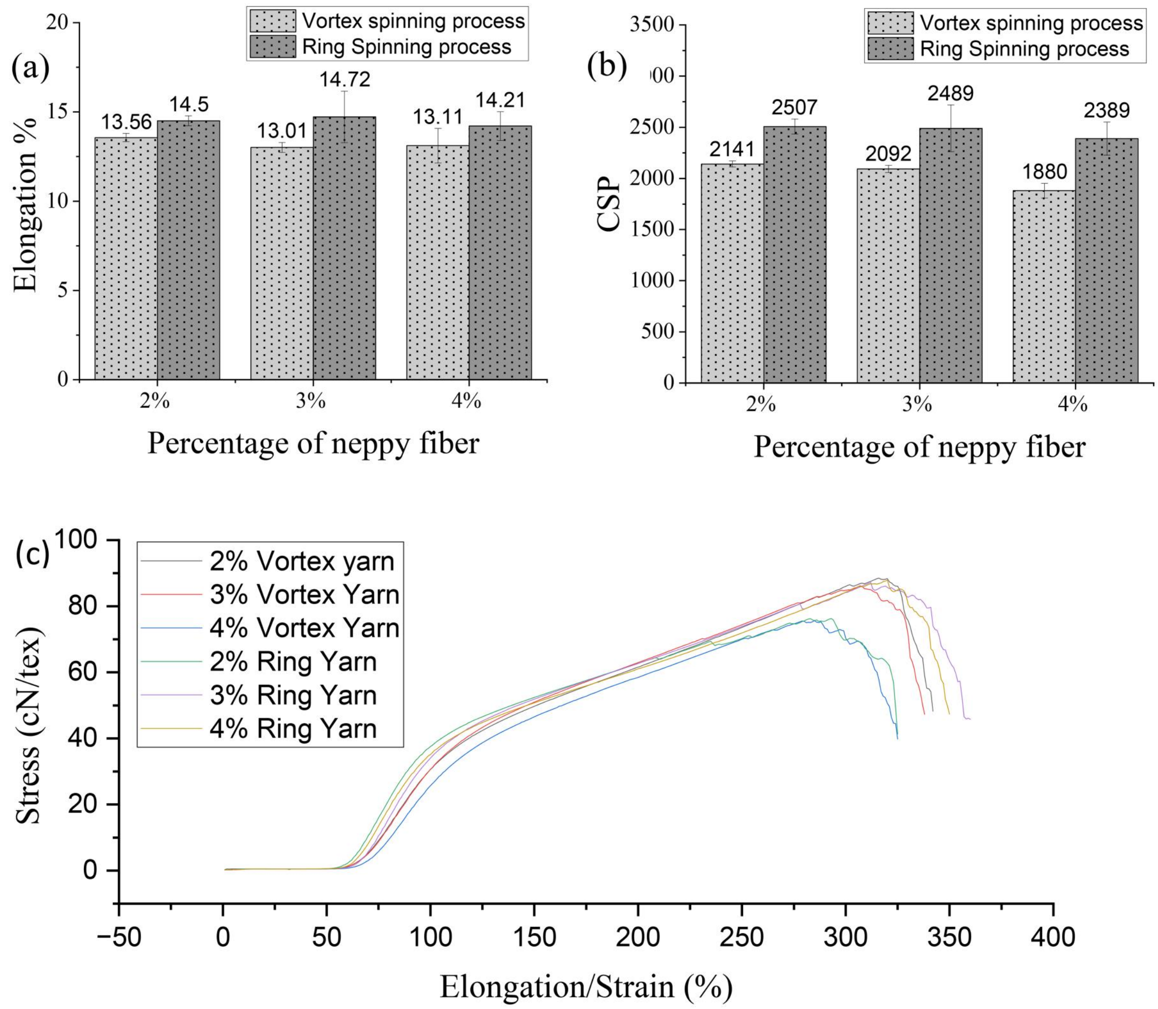

Figure 5. Neppy yarn produced by vortex and ring-spinning processes at different neps percentages: (a) elongation%, (b) count strength product (CSP), and (c) stress–strain curves.

the elongation percentage in the vortex neppy yarn was further decreased. This is because as the number of neps increases, the yarn becomes thicker and more compact, which may limit its ability to stretch. Furthermore, several reasons could account for the lower CSP of the neppy yarn produced through the vortex spinning process as compared to that of the ring-spun neppy yarn. In the vortex spinning process, the core fibers are oriented in a parallel manner concerning the yarn axis, resulting in minimal fiber migration (Basal & Oxenham, 2006). On the other hand, in ring spinning, fiber migration occurs at the highest degree (Behera, 2020; Kim & Kim, 2018), which leads to improved twist distribution in the resulting yarn. This difference in the spinning processes is responsible for dissimilarities in the strength of the resulting yarn. This finding holds significant implications for the textile industry as it suggests the need for further research and development to improve the strength of neppy yarn produced through the vortex spinning process. The error bars in the below figures indicates standard deviation.

Analysis of mass variation

This study observed that the coefficient of variation (CV%), thick place (+50%), and thin place (−50%) values of the vortex-spun neppy yarn was significantly lower than that of the ring-spun neppy yarn (as shown in Figure 6), which means that the vortex neppy yarn had a more uniform thickness or diameter compared to the ring-spun neppy yarn. The vortex spinning process involves the use of airflow to create a vortex that wraps fibers around a core (Moučková et al., 2015). The core fibers constitute a significant portion of the yarn body, aligning parallel to the yarn axis (Moučková et al., 2015). This results in a more uniform distribution of fibers, which in turn leads to a more consistent thickness or diameter of the yarn (Uyanık & Duru Baykal, 2018).

On the other hand, in ring spinning, there are several stages of drafting, including the drafting in the roving frame and the final drafting in the ring frame. The drafting process in ring spinning involves stretching and thinning the fiber bundle to create the desired yarn thickness, and any inconsistencies or irregularities in this process can result in variations in yarn thickness furthermore, each stage of drafting contributes to the formation of drafting waves. This results in variations in the amount of fiber in each section of the yarn, which can lead to an increase in mass variations, thick and thin places, or diameter of the yarn (Ben Hassen, Sakli, Sinoimeri, & Renner, 2003). Thus, the vortex

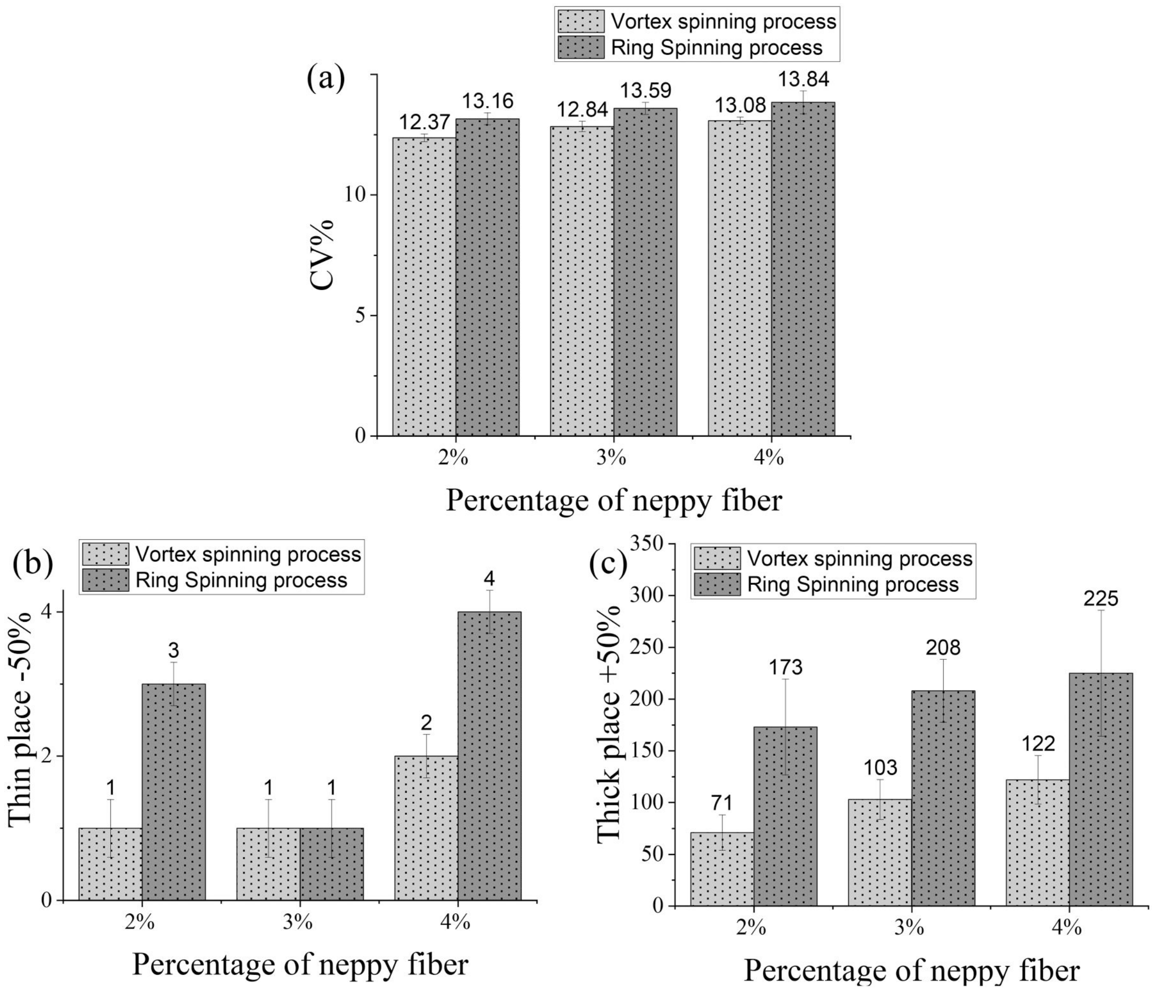

Figure 6. Neppy yarns produced by vortex and ring-spinning processes at different neps percentages: (a) coefficient of variation (CV%), (b) thin place (−50%), and (c) thick place (−50%).

spinning process may be more suitable for producing neppy yarn with a more uniform thickness or diameter. Additionally, the study found that with an increase in the percentage of neps, the CV%, thick place, and thin place values in both vortex neppy yarn and ring-spun neppy yarn also increased, which is due to the added irregularities in the yarn caused by the neps. The error bars were calculated in the Figure 6 from the standard deviation.

Hairiness analysis of neppy yarn

The hairiness value of a yarn refers to the number of fiber ends protruding from the surface of the yarn. Generally protruding fibers are present throughout the yarn, in cases of excessive hairiness the visibility of neps is significantly reduced for this reason it becomes a crucial parameter during neppy yarn production process. In this study, it was found that the hairiness value of neppy yarn produced by the vortex-spinning process was significantly lower than that of the ring-spinning process (Figure 7). This is because the fibers that make up the yarn core are a substantial portion of the yarn body and are arranged in a parallel manner with respect to the yarn axis (Moučková et al., 2015), resulting in

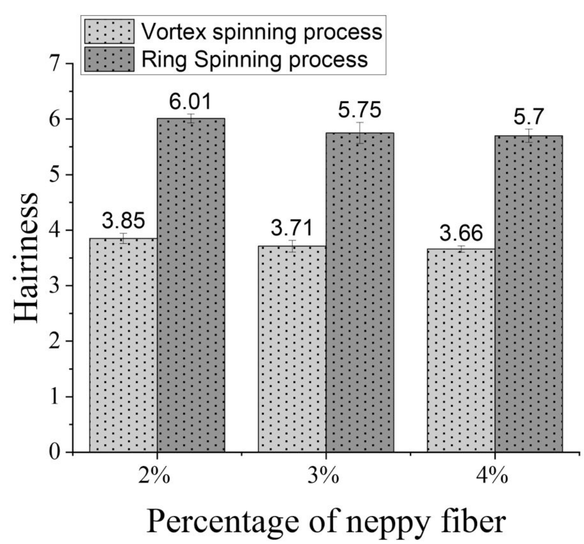

Figure 7. Hairiness value in neppy yarn for vortex and ring-spinning processes at different neps percentages.

fewer fiber ends protruding from the surface of the yarn body.

Additionally, the vortex spinning process allows for better control over the fiber positioning, which also contributes to the lower hairiness value. On the other hand, in the ring

Table 8. ANOVA test result of hairiness between vortex and ring-spun neppy yarn.

Polyester (%)	Source	Df (degree of freedom)	Sum of squares	Mean square	*F*	*p*-value
2	Factor /Spinning system	1	11.664	11.664	1575.152	0.000
	Error	8	0.059	.007		
3	Factor /Spinning system	1	10.445	10.445	443.141	0.000
	Error	8	.189	.024		
4	Factor /Spinning system	1	10.404	10.404	1191.753	0.000
	Error	8	.009	.070		

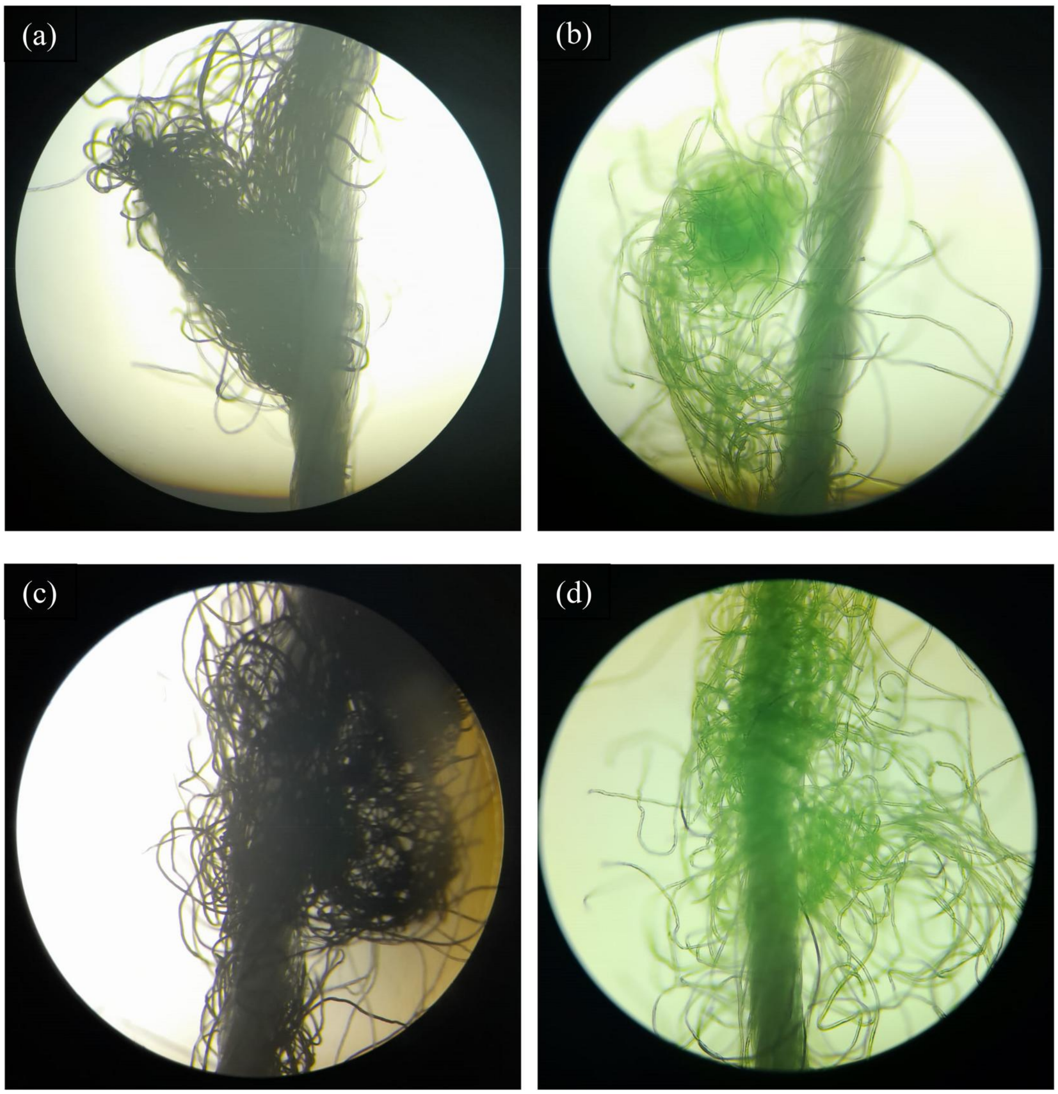

Figure 8. Optical microscopic views (40×) of yarns obtain from: (a, b) vortex spinning process and (c, d) ring spinning process.

spinning process, several factors such as the spinning triangle (Feng, Gang Xu, Tao, & Hua, 2010) and spinning geometry (Wang & Chang, 2003) contribute to higher hairiness values. Table 8 demonstrates the statistical analysis (ANOVA) of neppy yarn's hairiness for regular ring spinning and novel vortex technology. Here, F is a ratio of explained variance (Factor/spinning system) to unexplained variance (Error) while the p-value indicates the level of significance. Results show a significant difference in hairiness among two neppy yarns as the p-value (0.000) is less than the significance level (0.01) indicating that the observed difference was highly statistically significant at 99% confidence interval. Generally, a significance level of 0.05 is commonly employed; however, this result demonstrated at 0.01 level that indicates hairiness values was highly significant difference.

Microscopic analysis of neppy yarn

In the case of vortex-spun neppy yarn, as depicted in Figure 8a, b it is evident that the neps portion is more visually prominent compared to ring-spun neppy yarn Figure 8c, d. This is because VSNY has very low hairiness, fewer coefficients of variation (CV%), and minimal thick and thin places. Furthermore, Figure 8a, b illustrate that VSNY exhibits a more uniform surface on the mother yarn. The vortex spinning process allows better control over the fiber positioning, which in turn leads to a more consistent thickness

Table 9. Raw material cost calculation.

	Ring spinning process				Vortex spinning process			
Particulars	Mixing (%)	Qty (Kg)	Rate/Kg (BDT)	Cost/ Kg (BDT)	Mixing (%)	Qty (Kg)	Rate/Kg (BDT)	Cost/Kg (BDT)
2% neppy yarn								
Raw Materials								
Viscose	98.00%	0.98	250.00	245.00	98.00%	0.98	250.00	245.00
Polyester	2.00%	0.02	100.00	2.00	2.00%	0.02	100.00	2.00
Initial Raw Materials	100.0%	1.00		247.00	100.0%	1.00		247.00
Process Loss								
Saleable wastage	11.50%	0.115	50.00	5.75	9.50%	0.095	50.00	4.75
Invisible wastage	0.85%	0.009	–	–	0.50%	0.005	–	–
Total Waste Recovery	12.35%	0.12		5.75	10.00%	0.10		4.75
Actual Raw Materials	87.65%	0.88		241.25	90.00%	0.90		242.25
Raw Materials Cost	100.0%	1.00		275.24	100.0%	1.00		269.17
3% neppy yarn								
Raw Materials								
Viscose	97.00%	0.97	250.00	242.50	97.00%	0.97	250.00	242.50
Polyester	3.00%	0.03	100.00	3.00	3.00%	0.03	100.00	3.00
Initial Raw Materials	100.0%	1.00		245.50	100.0%	1.00		245.50
Process Loss								
Saleable wastage	11.50%	0.115	50.00	5.75	9.50%	0.095	50.00	4.75
Invisible wastage	0.85%	0.009	–	–	0.50%	0.005	–	–
Total Waste Recovery	12.35%	0.12		5.75	10.00%	0.10		4.75
Actual Raw Materials	87.65%	0.88		239.75	90.00%	0.90		240.75
Raw Materials Cost	100.0%	1.00		273.53	100.0%	1.00		267.50
4% neppy yarn								
Raw Materials								
Viscose	96.00%	0.96	250.00	240.00	96.00%	0.96	250.00	240.00
Polyester	4.00%	0.04	100.00	4.00	4.00%	0.04	100.00	4.00
Initial Raw Materials	100.0%	1.00		244.00	100.0%	1.00		244.00
Process Loss								
Saleable wastage	11.50%	0.115	50.00	5.75	9.50%	0.095	50.00	4.75
Invisible wastage	0.85%	0.009	–	–	0.50%	0.005	–	–
Total Waste Recovery	12.35%	0.12		5.75	10.00%	0.10		4.75
Actual Raw Materials	87.65%	0.88		238.25	90.00%	0.90		239.25
Raw Materials Cost	100.0%	1.00		271.82	100.0%	1.00		265.83

Table 10. Cost calculation/Kg (Bangladesh currency, BDT).

	Ring spinning process			Vortex spinning process		
Particulars	2% neppy yarn	3% neppy yarn	4% neppy yarn	2% neppy yarn	3% neppy yarn	4% neppy yarn
Raw materials cost (BDT)	275.24	273.53	271.82	269.17	267.50	265.83
Packing materials cost (BDT)		3.30			3.30	
Factory overhead cost/conversion cost						
Salary & wages (BDT) (Akter & Bhuyan, 2018)		24.00			19.00	
Depreciation (BDT)		30.00			25.00	
Power Expenses (BDT) (Kaplan & Koç, 2010; Koç & Kaplan, 2007)		45.00			38.00	
Other Mfg. Expenses (BDT)		12.00			9.00	
Final manufacturing cost (BDT)	389.54	387.83	386.12	363.47	361.80	360.13

of the yarn compared to ring-spun neppy yarn Figure 8c, d. Notably, Figure 8a, b also highlight that some sections of the neppy fibers of VSNY remain within the yarn core while others participate in wrapping around it, resulting the neps being firmly attached and closer to the body of the mother yarn. In contrast, in ring-spun neppy yarn (as depicted in Figure 8c, d the neps have loosely resided on the surface of the mother yarn body.

Cost analysis of neppy yarn

This study comprehensively analyzed a renowned selected spinning mill to compare the production costs of vortex and ring-spun neppy yarn using Equation (1)–(3), here all kinds of machine wastage were considered as a saleable wastage. Details breakdown of the raw materials cost calculation are presented on Table 9.

$$\text{Actual raw material} = \text{Initial raw materials} - \text{Total waste recovery} \tag{1}$$

$$\text{Raw materials cost} = \left(\frac{\text{Actual raw materials cost}}{\text{Actual raw materials mixing}} \times 100\%\right) \tag{2}$$

$$\text{Final manufacturing cost} = \text{Raw materials cost} + \text{Packing materials cost} + \text{Factory overhead cost/Conversion cost} \tag{3}$$

The results demonstrated a significant cost reduction in the vortex spinning process compared to the traditional ring

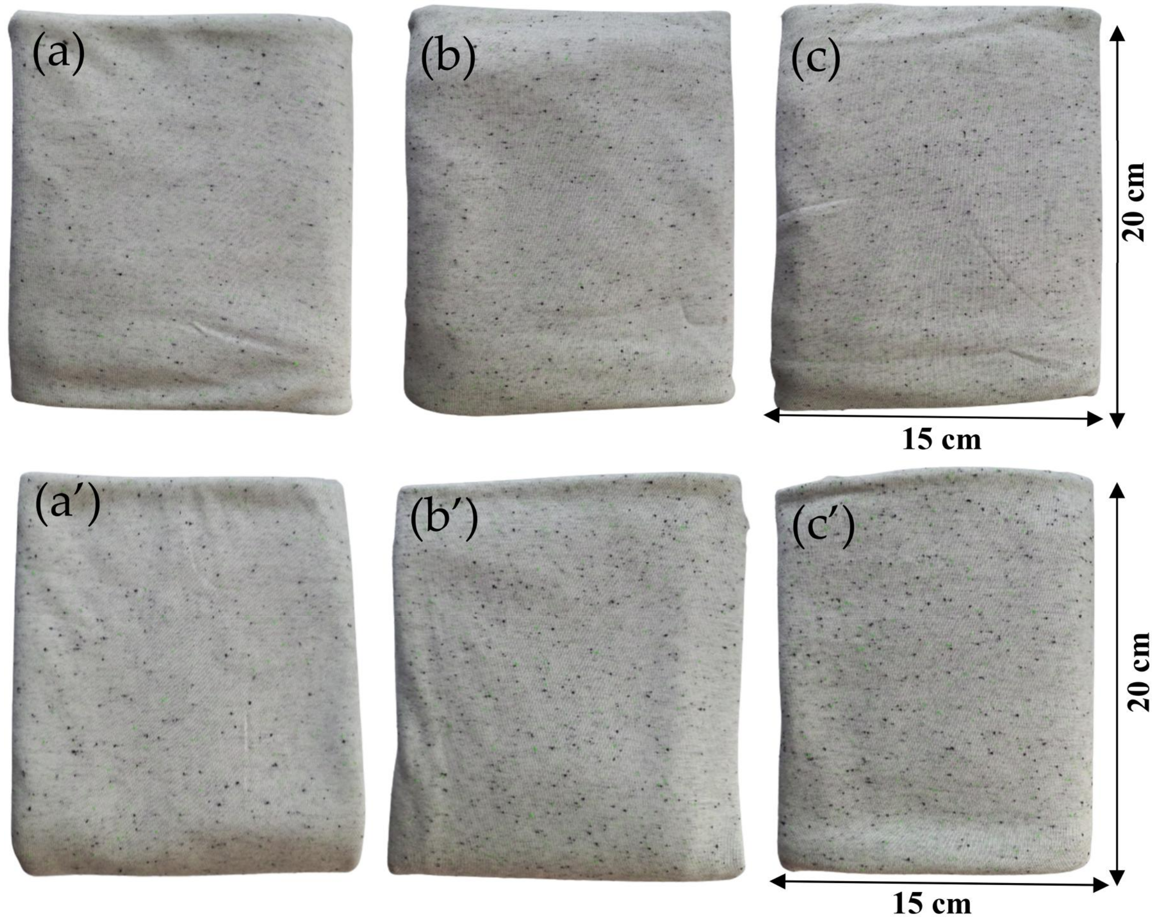

Figure 9. Single jersey knitted fabric produced from: vortex-spun neppy yarn (a–2%, b–3%, and c–4%) and ring-spun neppy yarn (a′–2%, b′–3%, and c′–4%).

spinning process. The cost savings were particularly notable for different percentages of neppy yarn, as indicated in Table 10. Specifically, the vortex spinning process resulted in a substantial manufacturing cost reduction of 6.69% for 2% neppy yarn, 6.71% for 3% neppy yarn, and 6.73% for 4% neppy yarn, and that is because of less machinery, energy, and man-power are required in vortex spinning process. These findings emphasize the cost-effectiveness and potential economic advantages associated with the implementation of the vortex spinning process in neppy yarn production.

Neppy yarn was produced for the first time using the vortex spinning process. Consequently, a single jersey knit fabric was manufactured to observe its appearance. Fabric produced from vortex-spun neppy yarn found more aesthetical appeal (Figure 9) due to its lower hairiness, coefficient of variation (CV%), and reduced thick and thin places when compared to ring-spun neppy yarn. It is acknowledged that future investigations regarding fabric performance properties produced from neppy yarn would further enrich our understanding.

Conclusion

This study aimed to explore new and cost-effective methods to produce neppy yarn, a type of yarn that is increasingly popular in the textile industry due to its unique aesthetic properties. The novelty of this work lies in the fact that neppy yarn was produced for the first time using the vortex spinning process, which had not been previously explored for this purpose. The results of the study showed that the neppy yarn produced through the vortex spinning method has a better visual appearance compared to ring-spun yarn due to its low hairiness, low coefficient of variation (CV%), and minimal thick and thin places. However, the count strength product (CSP) of the neppy yarn produced by vortex spinning was found to be lower in comparison to that of the neppy yarn produced by the ring spinning process. Furthermore, the use of the vortex spinning process for neppy yarn production offers several advantages for the textile industry. This process is cost-effective, requires less machinery and energy, and allows for better control over the fiber positioning, resulting in improved yarn quality.

In conclusion, this study demonstrates the potential of the vortex spinning process as a new and effective method for producing neppy yarn with high quality and aesthetic appeal. The findings of this study can be beneficial to the textile industry, particularly in terms of improving the production process and reducing costs.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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