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Investigation of the Feasibility and Physico-Mechanical Properties of Jute/Polypropylene Blended Yarns

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Abstract

Worldwide demand of natural-based products is rapidly increasing due to the depletion of petroleum products and concerns about sustainability. This study presents jute (JU) based yarns by blending polypropylene (PP) to expand the diversified uses of jute products. A novel approach in the JU spinning system blended Bangla White D grade JU fiber and PP with a linear density of 6 denier at 100/0, 80/20, 70/30, and 60/40 % (JU/PP) ratios at the breaker card machine. With a constant 8 lbs/spyndle (275 tex) linear density for all yarns were produced from JU yarn production line, and yarn properties were determined at different blend ratios of jute and polypropylene. In comparison to 100% reference JU yarn, blended yarns became stronger, had a higher elongation percentage, lower-end breakage rate, and higher quality ratio. The study also revealed that coefficient of variance of yarn twist deteriorated with the higher percentages of polypropylene in the blended yarns. Test results were evaluated statistically with one-way analysis of variance (ANOVA) and found significant differences among different blend ratios of yarns.

Keywords: Jute, polypropylene, blending, quality ratio, ANOVA, biodegradable.

1. Introduction

Jute, often referred to as golden fiber, is a lignocellulosic bast fiber. It is a textile fiber with good spinnable character and low extensibility due to its 'composite-like' structure with highly oriented long-chain molecules. Jute fibers have a number of problems, including poor drapability, crease resistance, brittleness, fiber shedding, and sunshine yellowing. When compared to cotton or wool yarns, jute yarns, especially the finer ones, have a higher degree of irregularity [1,2]. There are large numbers of man-made fibers in the global textile market, and the traditional jute products face tough competition with synthetics. Jute industries are steadily losing productivity, and virtually little effort is being made to enhance it. To stay ahead of the competition, making various jute goods using blended jute yarns is vital to boost efficiency.

On the other hand, polypropylene is the least expensive synthetic fiber and has better abrasion resistance, color fastness, low static, thermally bondable, stain and soil resistance, high tenacity, UV resistance, comfort, and lightweight. These properties have been particularly helpful in the development of jute polypropylene blended blankets, upholstery, carpet and apparel fabrics [3]. Therefore, it is necessary to expand the creation of many diverse jute products (using jute alone or in combination with other fibers). Jute and polypropylene blended yarns are a step ahead of more diverse jute products.

The feasibility of jute-cotton blends was found in the literature more than four decades earlier. Fabrics produced from the 20/80% jute/cotton blends in the cotton spinning system showed suitability for curtain and furnishing materials [4]. Several studies have investigated the feasibility of blending of JU with other natural or man-made fibers and functional finishing on JU textiles to expand diversified uses of JU fibers in the world market [5–9]. In a study, JU/PP blended yarn was developed in the jute production line at different ratios where blending was performed in the jute finisher drawing frame, and fabric produced from that blended yarn (weft) with cotton yarn (warp) showed suitability for tablecloth and bed sheet [10]. Another study envisaged the blending process of jute and ramie fibers to develop fine quality blended yarns and fabrics. Jute/Ramie blended fabric exhibited improved

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physical as well as aesthetic properties [11]. Roy et al., investigated the feasibility of jute/Yak blend yarns and fabrics from underutilized black yak with treated and untreated. The study discovered that the blended yarn, which contained more than 50% untreated yak fiber, is not suitable for spin [12]. In a sought, it was observed that JU/PP needle punched nonwoven showed highest water absorbency (720%) with 60/40% (JU/PP) content and lower needling density and fabric weight [13]. Cai et al., revealed that the application of pre-metallised dyes on chemically modified jute and jute/cotton blends fabric significantly improved dyeability and fastness properties [14].

The present work was designed to investigate the feasibility of JU/PP blended yarns at four blend ratios 100/0, 80/20, 70/30, and 60/40% in the jute yarn spinning system. Emulsified jute fibers and tuft of polypropylene were blended at the feeding stage of the breaker carding machine. In all the cases, 275 tex (8 lbs/spyndle on the jute count system), at 3.65 turns per inch, Z-twist yarns were produced and investigated for their physico-mechanical properties. It may seem that the biodegradability uniqueness of jute is lost when Jute and Polypropylene are blended. However, the goal of this research was to expand the diversified uses of Jute products and lessen reliance on synthetic fibers and to enable the effective entry of jute based goods into the textiles sector. In addition, Jute and jute-based products are not only eco-friendly, but they also serve to protect the environment from ecological damage. Natural products are becoming more popular as the world becomes more aware of the need for a pollution-free environment.

2. Material and Method

In this study, 100% Bangla White D (BWD)(Pucca grade) fibers were procured from the local market of Bangladesh. The average length of reeds was 8 feet, and no red ends were visible in the jute fibers but bark and specks were visible. The polypropylene was purchased from Xinxiang Sunshining Textiles Co. Ltd, Xinxiang, China. Fiber properties of jute and polypropylene fibers are listed in Table 1, and Figure 1 exhibits the jute and polypropylene fibers used in this study.

Table 1. Properties of selected JU and PP fibers

	Length (mm)	Fineness	Strength	Elongation (%)
JU	-	20 dtex	31.28 g/tex	1.65
PP	64	6 Denier	>3.5 cN/dtex	40 ± 20

a) Morah of jute **(b) Tuft of polypropylene**

Figure 1. Raw materials used in this study

BWD grade jute fibers and polypropylene were taken by weight according to 60/40, 70/30, 80/20, and 100/0% blend ratios. The experimental works were conducted by using jute spinning system. A new approach has been applied to blend JU/PP in the feed lattice of JU breaker carding machine. Figure 2 represents the processing sequence of JU/PP blend yarns. The JU reed prior to blending was softened by application of emulsion (15% on weight of fiber) at softener machine and stored for 72 hours. The emulsion was prepared from 20% oil, 78.5% water and 1.5 % emulsifier. After that jute fiber strand (handful of reeds taken each time) prepared morah form by doing jute strand half twisted and folded at the middle. The PP fibers were separated and opened up manually, teasing and tufts of certain weights were made. Finally, the jute fibers were laid down and thoroughly mixed with polypropylene in the required ratio at the feed side of the breaker carding machine to convert JU/PP into sliver form. Four types of yarn 100/0, 80/20, 70/30, and 60/40 JU/PP were spun in the jute production line with a constant (275 tex) 8 lbs / spyndle linear density. Table 2 shows the preparation of morah and tuft for different blend ratios yarn and Table 3, 4 & 5 represents process parameters of carding, drawing, and spinning stage, respectively. JU production line was installed by James Mackie & Sons Ltd (England) machinery.

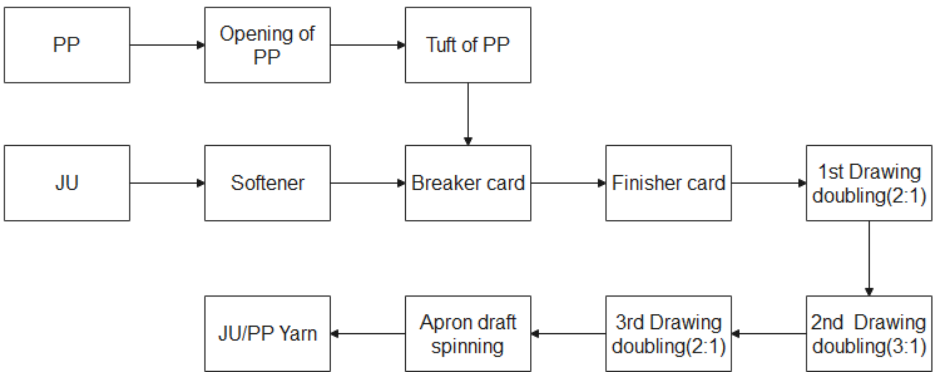


Figure 2. Spinning process of JU/PP blended yarn

Table 2. Preparation of JU fiber morah and PP tuft

Blend ratio of jute/PP (%)	Amount of fiber (Kg)	Number of morah	Weight of each morah (gm)	Number of tufts	Weight of each tuft (gm)
100 /0	jute: 30 PP : 0	15	500	×	×
80 /20	jute: 24 PP : 6	48	500	24	250
70 /30	jute : 17.50 PP : 7.50	36	486.11	18	416.66
60 /40	jute : 13.62 PP : 9.07	40	340.20	20	453.60

Table 3. Process parameters of breaker and finisher card machine

Parameter	Breaker Card	Finisher Card
Surface speed of cylinder	29642.18 inch / min	28539.46 inch / min
Surface speed of flutted roller	159.76 inch / min	157 inch / min
Surface speed of worker	816.71 inch / min	687.26 inch / min
Surface speed of stripper	5879.65 inch / min	4772.73 inch / min
Surface speed of Doffer	1629.47 inch / min	904.32 inch / min
Surface speed of Delivery roller	2059.84 inch / min	1347.845 inch / min
Draft	12	9

Table 4. Process parameters of drawing frame

Parameters	First drawing frame	Second drawing frame	Third drawing frame
Front retaining roller (Surface speed)	409.77 inch/min (rpm = 58 & dia = 2.25 inch)	226 inch/min (rpm = 36 & dia = 2 inch)	188.4 inch/min (rpm = 30 & dia = 2 inch)
Gill pins (Surface speed)	468 inch/min	235 inch/min	199 inch/min
Drawing roller (Surface speed)	1515 inch/min (rpm = 193 & dia = 2.5 inch)	1335 inch/min (rpm = 189 & dia = 2.25 inch)	1570 inch/min (rpm =250 & dia = 2 inch)
Delivery roller (Surface speed)	1550 inch/min (rpm = 141 & dia = 3.5 inch)	1362 inch/min (rpm = 124 & dia = 3.5 inch)	1674 inch/min (rpm = 130 & dia = 4.1 inch)
Pitch	0.5 inch	0.5 inch	0.375 inch
Doubling	2	3	2

Table 5. Spinning parameters of different blend ratios yarn

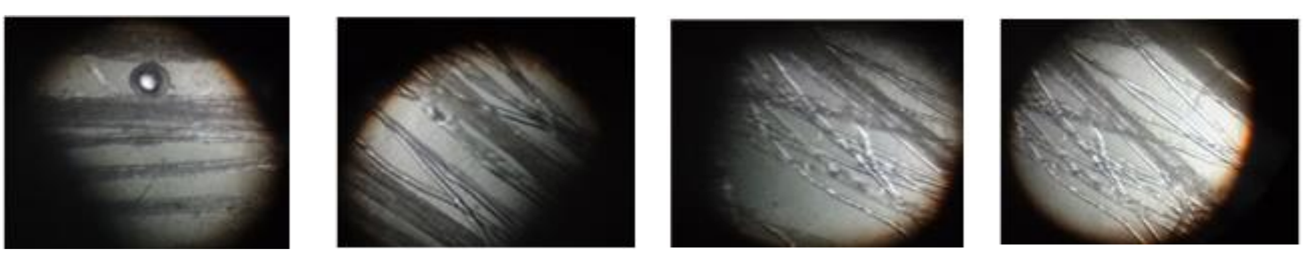
Blend Ratio Jute / PP (%)	3rd Draw Frame (lbs/100 yds)	Count (lbs/spyndle)	Draft	DCP	TCP	Twist Constant	TPM	Spindle Speed (rpm)
80/20	0.7215	8	12.72	59	41	5906	144.08	3200
70/30	0.862		15.20	50				
60/40	0.856		15.09	50				
Jute / PP 100 / 0	0.625		11.00	69				

Yarn counts were measured by wrap reel and balance according to ASTM D 1059-17 standard. ASTM D 2256 test method was used to determine single yarn strength, extension at the break, elongation % by tensile strength tester (James H. Heal & Co Ltd). ASTM D 1422-99 standard was used to determine twists per inch in the blended yarns. All tests were carried out in standard atmospheric conditions of 65 ± 2% relative humidity and 20 ± 2°C temperature. The yarns were conditioned in above atmospheric temperatures for 24 hours before testing. The average results of ten specimens of each type of test were reported. Optical microscopy was used to examine the longitudinal surface views of four distinct JU/PP yarns. SPSS v.20 software was used to analyze the performance test results of JU/PP blended yarns. The ANOVA technique was used to estimate the proportion of variability due to four JU/PP blended yarns to determine statistical significance. The statistical significance of the F values obtained from the ANOVA was assessed ($p > 0.05$) [15].

3. Results and Discussion

3.1. Analysis of microscopic appearance

Jute fibers appear as crosswise markings called nodes or joints under a microscope. Polypropylene, on the other hand, has a very regular, rod-like appearance. Figure 3 clearly shows that as the polypropylene ratio increases, crosswise markings reduce, and the rod-like appearance gradually increases.



100/0 (JU/PP) 80/20 (JU/PP) 70/30 (JU/PP) 60/40 (JU/PP)

Figure 3. Longitudinal views of different blend ratios yarns from optical microscope (100×)

3.2. Effect of blending on yarn count realization

Jute yarn count is expressed by lbs/spyndle. In the lbs/spyndle system, the yarn number or count is the weight in lbs of 14400 yards. The sample of length 100 yards is prepared using a wrap reel [16]. To compute the average yarn count, ten tests were conducted for each blend ratio. Table 6 shows the realization of yarn count against different blend ratios of jute and polypropylene. Except for the 60/40 percent blend ratio, the Count CVt percent increased as the PP ratio increased. According to the findings, the coefficient of variation of count (CVt%) percent of 100% jute reduced from roughly 5.02 to slightly over 6.21 in an 80/20% combination. However, about 7.15, it rose again in a 70/30 percent blend. So, blended yarns count (CV %) deteriorated with the increase of PP portion due to the huge possibility of uneven distribution of fibers.

Table 6. Yarn count realization on different blend ratios

Blend ratio of Jute/PP (%)	Average count (lbs/spyndle)	Standard deviation	Count (CVt %)
100/0	8.11	0.41	5.02
80/20	8.59	0.53	6.21
70/30	8.45	0.60	7.15
60/40	8.16	0.50	6.14

3.3. Effect of blending on yarn strength

JU/PP blended yarns offered significant improvement in strength as compared to control jute yarn. Table 7 clearly shows that the strength of blended yarns rose steadily when the polypropylene ratio was raised. One of the most essential characteristics in determining the quality of jute strands is its strength. All blended yarns showed more strength due to more fiber in the JU/PP blended yarn cross-section compared to 100% reference jute yarn. Polypropylene was finer than jute fiber, as a result of this, blended yarn consists of more number of fibers in the cross-section. The quality ratio (QR percent) is a crucial criterion for jute yarn quality. It is the percentage ratio of the breaking load to the linear density of the yarn. It is an expression of jute yarn strength [1] and expressed as;

$$\text{QR} = \frac{Average\ breaking\ load\ (lb)}{Grist\ (lbs/spy)} \times 100 \tag{1}$$

Table 7. Strength and elongation % of blend yarns

Blend ratio % (Jute / PP)	Average load at break (kg)	Strength CV%	Extension at break (average) (cm)	Average elongation (%) at break
100 / 0	2.75	10.32	1.69	3.38
80 / 20	2.99	10.27	1.81	3.62
70 / 30	3.13	8.52	2.16	4.32
60 / 40	3.18	6.07	2.19	4.34

Figure 4 depicts the quality ratio of four blended yarns. The error bars in the figure indicates standard deviations. As observed here, the lower the PP fiber, the lower the quality ratio of that blended yarn. Four different blend yarns were used in this investigation to compare strength. To perform this comparison, a one-way ANOVA test was used. According to ANOVA Table 8, the significance value (P- value):0.004 is less than the significance value ($\alpha = 0.05$) value, indicating that the null hypothesis for different blend ratios is rejected, indicating that there is a significant variation in the strength of different blend ratio yarns.

Table 8. ANOVA for breaking strength among different blend ratios yarns

Source	Sum of Squares	df	Mean Square	F	p-value
Factor / Breaking strength	1.113	3	0.371	5.234	0.004
Error	2.551	36	0.071		

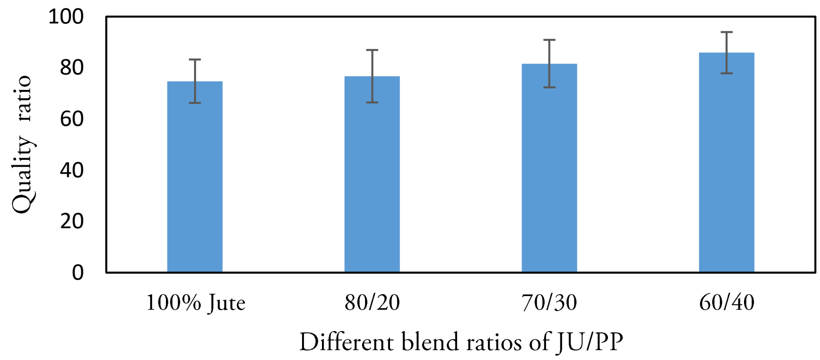


Figure 4. Quality ratio of different blend ratios of yarns

3.4. Effect of blending on yarn twist

Table 9 shows the results of twist testing against various JU/PP blend ratios. As can be seen, the twist CV % increases as the PP ratio rises. The twist CV% was found to be lower when using 100% jute compared to other blend ratios yarns, according to the findings. However, it increased slightly at a 70/30 percent blend of roughly 3.72. According to the test results, the twist CV percent climbed to roughly 4.88, with a 60/40 percent blend. Due to frictional properties of PP twist CV% were becoming more with the increase the ratio of PP. Table 10 demonstrates the statistical evaluation of twist test results among blended yarns with four different JU/PP ratios. One-way ANOVA test was used to compare the twist of blended yarns consisting of different JU/PP ratios. A significant difference was found among the blend ratios ($F(3,36) = 13.268$, $p < 0.05$).

Table 9. Analysis of twist for different blend ratios of yarns

Blend Ratio (Jute / PP)	Average twist per inch (TPI)	Standard Deviation (SD)	Twist CV%
100 / 0	3.58	0.078	2.20
80 / 20	3.52	0.010	2.93
70 / 30	3.85	0.143	3.72
60 / 40	3.76	0.183	4.88

Table 10. ANOVA for twist among different blend ratios yarns

Source	Sum of Squares	Df	Mean Square	F	p-value
Factor / Twist	.709	3	0.236	13.268	0.000
Error	.641	36	0.018		

3.5. Effect of blending on yarn end breakage

End breakage rate is calculated by the number of times the spindle end remains idle per unit time or per 100 spindle due to discontinuation of sliver flow from the back of the spinning machine to the spinning bobbin for a spinning machine. This is expressed in terms of number of end breakage per 100 spindle per hour revealed through a snap study. The end breaks on one spindle by running the apron draft spinning frame at 20 minutes were recorded. During this period, three breaks occurred for 100% JU yarn. In the case of production for 70/30 and 60/40% JU/PP blended yarns observed one break. 80/20% JU/PP showed no break for 20 minutes production time. The results indicate the productivity of blended yarns compared to 100% reference jute yarn.

4. Conclusion

The main goal of this research was to investigate the feasibility of producing JU/PP blended yarn at different ratios in jute spinning system. The results revealed that the tendency of blended yarn counts (CV %) was higher than 100% jute yarn. Twist variance (CV %) showed a significant difference due to the frictional properties of PP in the blended yarns. It was observed that breaking strength and elongation increased remarkably with the increase of PP ratio. JU/PP blended yarns improved the low extensibility of jute yarn. Blended yarns exhibited more quality ratio, which expresses the overall strength of the yarn. The produced blended yarns can be utilized in furnishing, decorative, shopping bags, and other applications. There is a prospective market of jute products globally due to their low cost, low density, bio-renewable nature, and eco-friendly behavior. Therefore, it is most essential to produce value added jute products with existing machines through an extensive study. Finally, by analyzing blended yarn properties, the effectiveness of blending at the feed lattice of a breaker card machine can be compared to blending at the draw frame stage in the jute yarn production line. This novel approach of blending could be implemented for the feasibility of Jute/Pineapple leaf fiber, Jute/Banana, Jute/Coconut, and blending jute with other natural fibers and determining yarn properties. The developed yarns could be the revival of the jute industry of south Asia by increasing diversified uses of jute products, directly impacting the jute industry, and yielding better quality yarns and fabrics by implementing the suggested method.

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