Research Article
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Research on the performance properties of yarns produced by pineapple leaf fibers

Abstract

The importance of sustainability in textiles increases day by day. The reuse, recycle, and upcycle of materials are popular techniques of sustainability. Managing waste of production is as important as finding new raw material sources for production. Pineapple is a delicious and preferred fruit, and disposing the leaves of pineapple from the field is also a big problem for farmers. Transforming this waste into a value-added product is quite important but also difficult. This study is about the optimum yarn linear density and blend type for pineapple leaf as a fiber. During the study, pineapple leaf was added to viscose and cotton, and ring-spun yarns were produced with different counts. According to the quality parameters, the most convenient linear density for each blend is selected, and then knitted fabrics are produced by these yarns. The dyeing process is applied to detect the thermal performances of samples. Finally, the best yarn type and blend type are chosen in accordance with all dependent values.

Keywords: pineapple leaf fiber, PALF, sustainability, waste management

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Introduction

Research on new fiber development studies has increased because of the improvement in environmental awareness, bio-based economy, and sustainability activities. Pineapple leaf fiber is an herbaceous perennial plant. The leaves of fruit are generally left in the field after ginning, and the disposal of them seemed to be a problem. Obtaining fiber from pineapple leaves plays a role in transforming waste products into a value-added product. Surface structure of Pineapple fiber leaves (PALF) is covered with a waxy coating.[1] Extracting PALF can be done manually or mechanically. In manual technique, stripping of fibers is actualized by hand, then washed, dried, and knotted. This method requires high labor (3-4 % efficiency, 30 man/ton). The quality of fiber is high, but it is slow and troublesome. Types of rebuttals are: soaking in water (15-18 days, danger for the environment), bacterial (4-5 days, quality is high but not non-commercialized), raw rebuttal (3-6 weeks, quality is high but slow). In mechanical technique, the leaves are crushed by machines, washed, carded, and spun. This system is fast and efficient, but the fibers become coarser. If necessary, the quality is improved by wetting. Large-scale production is probable.[2,3] The leaves are covered by gum (pectin), and this gum has to be extracted for spinning. Extracting can be made by wetting or chemical/biochemical techniques. Thus, the fineness, moisture recovery, luster, whiteness, and other mechanical performances of the fiber develop. Chemical methods are harmful to the cellulosic structure of fiber and also to the environment. The quality of the fibers obtained by enzymatic methods is higher; however, this method is more expensive.[4]

PALF lacks a network structure, its color is white, and the luster of the fiber is similar to silk.[5] The fineness of the fiber is lower than that of jute; however, it is ten times coarser than cotton. Average staple length is 0,6-1 m.[6] Average density of fiber is 1,44 (g/cm^3), tensional strength is 413-1627 (MPa), breaking elongation is 1,6 (%), and young modulus is 34,5-82,5 (GPa). Chemical components of the fiber are cellulose, hemicellulose, and lignin. Lignin inside the fiber ensures water keeping capacity and protects against biological attacks. Cellulosic molecular chains are settled in the crystalline region of the fiber in parallel.[7] This cellulosic structure increases the tenacity of the fiber, as in jute and flax. Also, the antibacterial property of the fiber is available.[8–10] In this study, authors produced woven fabrics from PALF, bamboo and cotton fibers and compared the performances of the samples. The breaking strength of PALF fabrics in both warp and weft directions is the highest. The reason is the thickness of the fiber, independent of GSM. The tearing strength of PALF is also the highest because of the branched form of polymer chains. The diameter of the yarn and the thickness of the fabrics are higher, thus these fabrics are hard; however, the drapeability of the samples is higher; the reason of these results is a small number of fibers in the cross-section of the yarn.[11] Unique structure of PALF causes higher mechanical, thermal, sound absorption, and antibacterial properties. PALF has a wide range of applications as composites[12,13] and nonwoven structures, so the popularity of PALF as a technical field increases at the same time. Since PALF is produced by the waste of pineapple, it is important for sustainability in textiles.[14] Actually, the high amount of cellulose and lignin inside the waste of pineapple and the shredding of this waste by factories is difficult. Disposing of this waste and using this waste as raw material for another sector contribute to the circular economy.[15] These fibers are cheap and have low density, so they are used as a reinforced material.[16]

PALF can be spun by jute spinning technique because of fiber hardness; thus, first of all, the fiber has to be softened (by applying 25 % emulsion for 100 kg fiber), kept in a bin for at least 48 hours. The fibers have to be passed from the breaker card, finisher card, 3 passage drawing frames, and apron draft ring spinning machine, respectively. Obtained yarns are compared to the jute yarns produced under the same conditions. Results show that PALF yarns can be used as an alternative to jute yarns. However, since the diameter of the fiber is higher, the quality properties may be lower than those of other fibers.[17] Studies show that to obtain strong yarns, PALF should be blended with other fibers, such as cotton.[18,19]

The motivation of this study is to detect the properties of PALF-cotton blended knitted fabrics.

Material and method

In this study, 4 different yarns are produced by a ring frame. The raw materials of the yarns are Viscose-PALF and Cotton-PALF, blended 70-30 %. The counts of the yarns are selected as Ne 12/1 and Ne 16/1. The structural and performance properties of the yarns are tested by USTER AFIS test machine. According to the test results, two yarns are selected and transformed into knitted fabrics, and they are dyed. At the end of the study, thermal properties of the four fabrics are tested by the Alambeta test machine, and the warmer and cooler fabric types and yarn count are chosen.

Results and discussion

Fiber blend quality tests

In conventional mills, cotton and viscose fibers are blended with PALF, and the quality tests of raw fibers are compared to those of blended ones. During the production, 3 carding operations and two drafting operations are done, and the quality test of blended fibers is done after draw frame. Since these are results of special factory, correction value is applied to the results. The results are given in Table 1.

Table 1 Quality control test results

Fiber type	Cotton	Cotton-PALF (70/30, %)	Viscose	Viscose-PALF (70/30, %)
Total Neps	303,81	195,89	85,63	59,82
Fiber Neps Cnt	287,39	152,49	84,46	44,57
SCNep Count	16,42	42,23	2,35	15,25
L (w)	29,44	28,39	42,81	42,93
SFC (w)	9,15	12,55	0,47	0,59
UQL (w)	36,25	36,01	46,45	47,39
L (n)	23,58	22,87	41,06	40,12
SFC (n)	28,50	31,08	2,35	3,28
5% L (n)	41,17	41,64	50,09	51,49
Fineness	177,12	188,85	197,06	194,72
Maturity	0,97	1,04	1,27	1,29

According to the test results given in this table, the Cotton blend displayed the highest total nep (303.81) and fiber nep (287.39) counts, indicating a relatively coarse and irregular fiber morphology. Correspondingly, its elevated short fiber content (SFCw: 9.15; SFCn: 28.50) and lower mean fiber lengths (Lw: 29.44 mm; Ln: 23.58 mm) suggest a predominance of short fibers, which may adversely affect yarn uniformity and tensile behavior. When PALF is added to the cotton fiber, number of nep decreases significantly (from 303,81 to 195,89), and it is concluded that the cleanliness over the surface of the fiber improves. Additionally, the significant increase in short fiber ratio means a small decrease in length homogeneity. Especially, both fineness and maturity values develop in this situation, which supports the structural consolidation of the fiber by clarifying the fiber blend. Viscose fiber presents the lowest nep level and minimum short fiber ratio, thus the structure has the most homogeneous and uniform structure. Upper length and better maturity values correct the developed quality values. Viscose-PALF blended fiber's SFI and L values improve and demonstrate the best maturity value and the lowest nep results. Small improvement on UQL and 5 % L (n) values support the result of a well-balanced and stabilized fiber structure. As a result, viscose blended fiber shows the best performance and keeps the lowest surface imperfections while presenting optimum fineness, maturity, and fiber length values. Although cotton blended fiber is not as refined as pure cotton, the results are better than pure cotton. Finally, it is concluded that the results indicate the inclusion of PALF ensures natural reinforcement to improve the mechanical and morphological properties of the cotton blended yarns.

Effect of yarn linear density on yarn quality

During the yarn production, choosing the correct yarn linear density based on the fiber blend is a very significant parameter. In this study, firstly, viscose-PALF blend fibers are transformed into two different counts, and the quality of the yarns is compared. Results are presented in Table 2.

Table 2 Quality of viscose-PALF yarns

	Viscose -PALF, 3,7 αe	
	Ne 18/1	**Ne 16/1**
% U	1,619,913	154,836
% U CV	2,128,995	2,022,252
THIN PLACE -%40	211,14	137,241
THIN PLACE -%50	4,692	1,173
THICK PLACE %35	2,344,827	2,109,054
THICK PLACE %50	887,961	740,163
NEPS %140	2,112,573	1,786,479
NEPS %200	655,707	557,175
NEPS %280	185,334	148,971
HARINESS	846,906	886,788
S3u	29,926,749	19,503,471
RKM (Cn/tex)	1,971,813	2,022,252
Cn/tex % CV	872,712	815,235
Cn/tex MIN	1,499,094	1,241,034
Cn/tex MAX	2,309,637	2,444,532
ELONGATION	113,781	1,168,308
ELG %CV	2,090,286	1,920,201
B-FORCE	646,323	746,028
B-FORCE MIN	491,487	457,47
B-FORCE MAX	757,758	898,518

In accordance with the test results, from a production perspective, Ne 16/1 viscose-PALF yarn is the advantageous choice. This result is supported by its lower uniformity, coefficient of variation values, and lower thin, thick places and nep counts, which ensures a decrease in yarn breakages during spinning. Moreover, this yarn has better breaking force and tenacity performances, which indicate developed mechanical stability under industrial conditions. Actually, the hairiness of the fiber is higher than that of Ne 18/1 yarn, but this value can be lowered after spinning by burning and yarn clearing processes efficiently. Finally, Ne 16/1 yarn is a good choice for large-scale production by balancing the uniformity, strength, and efficiency values.

Then cotton and PALF are blended, and yarns are produced in three different counts, and quality tests are applied. The results are given in Table 3. Again correction factor is applied to the test results.

According to the comparative evaluation values of Ne 16/1, Ne 14/1, and Ne 12/1 cotton-PALF yarns, the most suitable yarn is Ne 14/1. This yarn presents a positive, balanced structure between uniformity and mechanical strength values. Uniformity values are significantly lower than Ne 16/1 yarns and present a smoother surface structure and improved spinning performance. Moreover, counts of thin-thick places and nep ratio of Ne 14/1 yarns are low in comparison to Ne

16/1 yarns. These results indicate the developed yarn cleanliness and lower defect risk during the latter spinning processes. While Ne 12/1 demonstrates better uniformity and imperfection value, the strength of the yarn is worse than that of Ne 14/1 yarns. Additionally, Ne 14/1 yarns can be used as woven and knitted fabrics because of superior breaking strength and elongation values, since the yarn should have mechanical performance during these productions. On the other hand, although the strength of Ne 12/1 is high, the elongation is not good enough, and also the hairiness is high, thus the friction over the ends and breakage increases. Therefore, Ne 14/1 yarn shows the optimal stability between homogeneity, strength, and spinnability values. Finally, the structure keeps the smoothness values and guarantees adequate durability, and these results make the yarn the most efficient and economic choice for industrial productions. Quality of yarns produced by the same linear density (Ne 16/1) is compared, as shown in the following Table 4 is obtained.

Table 3 Quality of cotton-PALF yarns

	Cotton-PALF, 3,7 αe		
	Ne 16/1	**Ne 14/1**	**Ne 12/1**
% U	1,938,969	17,595	1,693,812
% U CV	2,494,971	2,250,987	2,161,839
THIN PLACE -%40	1,977,678	1,188,249	876,231
THIN PLACE -%50	242,811	105,57	57,477
THICK PLACE %35	3,432,198	2,649,807	2,297,907
THICK PLACE %50	1,286,781	850,425	655,707
NEPS %140	3,113,142	1,963,602	1,597,626
NEPS %200	777,699	441,048	307,326
NEPS %280	168,912	73,899	45,747
HARINESS	1,209,363	1,128,426	1,327,836
S3u	2,690,041	0	0
RKM (Cn/tex)	1,242,207	1,697,331	1,564,782
Cn/tex % CV	1,623,432	1,319,625	1,336,047
Cn/tex MIN	627,555	658,053	781,218
Cn/tex MAX	1,692,639	2,374,152	2,055,096
ELONGATION	459,816	509,082	468,027
ELG %CV	1,404,081	1,075,641	1,065,084
B-FORCE	457,47	715,53	769,488
B-FORCE MIN	231,081	276,828	384,744
B-FORCE MAX	624,036	485,622	1,011,126

Table 4 Comparison table of cotton-PALF and viscose-PALF as Ne 16/1, 3,7 αe

	Cotton-PALF	**Viscosee-PALF**
% U	1,938,969	1,572,993
% U CV	2,494,971	2,058,615
THIN PLACE -%40	1,977,678	161,874
THIN PLACE -%50	242,811	1,173
THICK PLACE %35	3,432,198	2,160,666
THICK PLACE %50	1,286,781	780,045
NEPS %140	3,113,142	1911,99
NEPS %200	777,699	593,538
NEPS %280	168,912	164,22
HAIRINESS	1,209,363	796,467
S3u	26,900,409	0
RKM (Cn/tex)	1,242,207	2,329,578
Cn/tex % CV	1,623,432	824,619
Cn/tex MIN	627,555	1,633,989
Cn/tex MAX	1,692,639	3,016,956
ELONGATION	459,816	1,106,139
ELG %CV	1,404,081	1,985,889
B-FORCE	457,47	859,809
B-FORCE MIN	231,081	602,922
B-FORCE MAX	624,036	1114,35

Based on the comparative evaluation of the Cotton–PALF yarns and Viscose-PALF yarns at counts Ne 16/1, the results indicate that Viscose-PALF is the most suitable yarn for large-scale production since the unevenness, mechanical strength, elongation, and breaking force are higher. Moreover, hairiness, the number of thin and thick places of viscose blended yarns is lower. Therefore, considering both structural and mechanical parameters, viscose-PALF yarn AS Ne 16/1 presents the optimal compromise between uniformity, strength, and processing stability. It ensures adequate durability while maintaining an acceptable level of smoothness, making it the most efficient and economically viable choice for continuous textile manufacturing.

Structural and thermal properties of sample fabrics

In this part of the study, selected yarns according to the quality test results are knitted by a conventional circular knitting machine with a plain pattern, and then, to check the usability of the samples in accordance with thermal behaviors, they are dyed commercially, Tests are done by the Alambeta test machine, and the results are given in Table 5. (Correction factor is applied)

Table 5 Thermal properties of the samples

	Thermal conductivity	**Thermal diffusivity**	**Thermal absorptivity**	**Thermal resistance**	**Thickness**	**Heat flux density**
Samples	mW/m.K	mm2/s	W.s%/m2.K	mK/W.m2	mm	W/m2
Ne 16/1 Viscose-PALF	43,909	0,039	242,967	26,979	1,009	403,825
Dyed, Ne 16/1 Viscose-PALF	45,825	0,024	321,676	18,964	0,740	524,800
Ne 14/1 Cotton-PALF	41,233	0,041	205,667	24,633	1,016	338,133
Dyed, Ne 14/1 Cotton-PALF	51,026	0,030	325,820	19,394	0,843	523,314

In accordance with the values given in the table, dyeing increases thermal conductivity; however, it decreases the thermal resistance and thermal absorptivity, thus dyed fabrics make the user warmer. When the blending effect is evaluated, the conductivity of viscose-PALF fabrics is higher, and thermal absorptivity is higher too; this means fabrics produced by these yarns make the user cooler.

Conclusion

The motivation of this study is to test the production ability of pineapple leaf fibers. For this aim different blends, different yarns are produced by a ring spinning frame.

Blend and pure fibers are tested on behalf of length, maturity, unevenness, strength, etc., parameters, and the effect of adding PALF to cotton and/or viscose is determined. Results indicated that PALF can serve as an effective natural reinforcement for improving both the mechanical and morphological properties of cotton-based blends. These findings collectively suggest that pineapple fiber incorporation can be a viable strategy for the sustainable enhancement of textile fiber composites.

Then these fibers are used to produce different linear densities, and the performance of the yarns is compared in terms of strength, unevenness, thin-thick places, nep ratio, and elongation. In accordance with the results Ne 16/1 viscose-PALF yarns and Ne 12/1 cotton-PALF yarns are found to be valuable for producing according to the quality properties. At the same time, cotton-PALF and viscose-PALF are compared, and the blended one is a good choice to produce on a large scale since the unevenness, mechanical strength, elongation, and breaking force are higher, and hairiness, number of thin and thick places of viscose blended yarns are lower.

According to the yarn test results, Ne 16/1 viscose-PALF and Ne 14/1 cotton-PALF yarns are transformed into knitted fabrics, and these fabrics are also dyed. Then, the thermal properties of both gray and dyed fabrics are tested and it is concluded that dyeing makes the fabric warmer. Viscose blended yarns are used to produce cooler fabrics.

Finally, obtaining fiber from pineapple leaves plays a role in transforming waste products into value-added products, and they can be used as composites and yarns for reinforcement.

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Conflicts of interest

The authors declare no conflicts of interest or competing interests.

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