



Evaluation of Kenaf Fibre for the Development of Kenaf/Polyester Hybrid Yarn

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ABSTRACT

The hybridisation of natural fibres from kenaf and man-made fibres have gained considerable attention in recent years to lessen the environmental effects generated by synthetic fibres. Kenaf/polyester hybrid yarn was developed in this research where the most suitable kenaf fibre processing's condition and the optimum hybrid ratio between kenaf and polyester was determined. Seven types of kenaf fibres with different conditions (willowed fibre, opened fibre, normal combed degummed fibre, normal combed undegummed fibre, degummed fibre, enzyme-treated fibre, and alkaline treated kenaf fibre) were supplied by Kenaf Adsorbent Sdn. Bhd. Each type of the kenaf fibre bundles underwent opening, carding, roving, and ring spinning processes for yarn production. The physical characteristics and diameter of the processed kenaf fibre were analyzed using a microscopic analyser (Olympus Advanced Microscopic - BX53M). The kenaf fibre and yarn strength were assessed using a computer controlled Tensolab Strength Tester. Two different blending ratios were attempted for sliver preparation in the carding process (60:40 and 50:50 of kenaf/polyester by weight percentage). The findings demonstrated that the degummed, alkaline treated, and enzyme-treated fibres exhibited low diameters with good physical and tensile properties in the production of fibre, sliver, and yarn than the untreated kenaf fibre. The 50% weight composition of kenaf exhibited larger sliver size and lower waste percentage than the 60% kenaf composition.

Key words : Hybrid Yarn, Kenaf Fibre, Polyester, Ring spinning.

1. INTRODUCTION

Environmental problem is an emerging issue and pose significant challenges to the textile industry which is known as the world's major contributor to environmental pollution

[1]. Roy *et al.* [2] stated that in 2012, the global production of the textile industry increased by 1.9% to 88.5 million tons. This increase included a rise in the use of synthetic fibres while the use natural fibres decreased. This increase in synthetic fibre usage has contributed significantly to the use of synthetic materials which has affected the human life. Traditionally the use of kenaf is mainly to make cordages, ropes, burlap cloths, and fishnets. Extensive research and development of kenaf has allowed it to be used much more extensively in various industries such as the construction industry, automotive industry, housing and packaging, as well as the oil and chemical absorbents industry [3].

More recently, the bast fibre has been used in the production of textiles (woven and non-woven), industrial socks to absorb oil, and fibre reinforcement in thermoplastics and composite materials. Its core has been utilised as animal bedding, summer forage, soilless potting mixtures, and absorbents for oil and other liquids [4]. The bast fibre of kenaf can replace synthetic fibre such as carbon or glass fibre considering its performance of low density and high specific strength. Moreover, the bast fibre has the advantages of natural fibres, meaning it is cheap and biodegradable [5]. Kenaf fibres generally are coarser and more brittle than cotton. According to a research results by Jonobi *et al.* [6], kenaf's yields are better than jute, flax and hemp, thus providing a more cost-effective raw material. It is also agreed that Kenaf has more lustrous properties, greater resistance to rot and has better tensile strength when compared to jute [3].

Mechanically separated fibres are usually hard to be turned into good yarns because they are stiff. Kenaf fibres tend to be stiff because of the lignin content. It acts as a cementing agent, binding the cellulose fibres together [7]. This is also because fibre surfaces are covered with dispersed impurities. According to Jonoobi *et al.* [6], these impurities are hemicelluloses, lignin, pectin, and waxy substances. In producing kenaf for textile application, various treatments for obtaining soft and pliable fibres were screened and tested to

determine the best process for large-scale production. In order to convert kenaf fibres into good textile fibres, separation technique such as retting is used to soften the fibre either chemically or bacterially retting to remove the lignin content that cause the stiffness of the fibres [8]. Softening with enzymes can also be implemented to improve the quality of the kenaf yarn for textile application [9]. Currently, kenaf treated fibres used in producing blended fibre and yarn makes kenaf a viable textile fashion fibre. Hence, an alternative to the blending of polyester with kenaf fibres to produce yarn will reduce the high usage of polyester and attract the interests of textile manufacturers that are seeking to produce environmentally friendly products in the textile market.

2. MATERIALS AND METHODS

2.1 Materials

The kenaf raw fibres were supplied by Kenaf Adsorbent Sdn. Bhd., Kelantan, Malaysia. Seven types of kenaf fibres were used as received which were the willowed fibre (W), opened fibre (O), degummed fibre (B), normal combed undegummed fibre (NCU), normal combed degummed fibre (NCB), alkaline treated fibre (A), and enzyme-treated fibre (E). B, NCB, A and E were the treated type fibres while W, O, and NCU were the untreated fibres. The fibres were cut into a same length of 70mm.

2.2 Yarn Preparation

Two different weight percentage blending ratios of 60:40 and 50:50 of kenaf/polyester fibres were investigated in this research. After the opening process, the fibres were fed into a carding machine to produce blended sliver. The parameters of the carding machine were kept at constant speeds, whereby the main cylinder speed was 43 rpm, outlet speed was 34.4 rpm, inlet speed was 16.8 rpm, and twister speed was 10.9 rpm. The carded slivers were then drafted in a roving frame to produce finer slivers ready for twisting. The yarn was then produced using a ring spinning machine.

2.3 Analysis and Testing

2.3.1 Sliver Physical Analysis

A cut and weigh method was used to determine the sliver's size of the collected samples. The average length and weight were measured by considering the mass per unit area of the slivers measured in Hank (1 Hank = 840 yards). The waste percentage was determined from the decreased weight of the sliver after the carding operation. The waste percentage for the carded sliver was calculated as in (1).

$$\text{Waste \%} = [\text{Weight}_i \text{ (g)} - \text{weight}_o \text{ (g)} / \text{weight}_i \text{ (g)}] \times 100 \quad (1)$$

2.3.2 Yarn Analysis

The tensile test was conducted using a computer controlled Tensolab Strength Tester machine with a gauge length of 40 mm and a crosshead speed of 2 mm/min on 30 fibre sample for each type. The test was carried with reference to a previous research by Edeerozey *et al.* [10] which studied the tensile strength of the kenaf fibre. The ASTM D3822-2007 standard was used for testing tensile properties of single fibres. The obtained results were in agreement with theoretical calculation. The tensile strengths of the fibres were calculated using Equation (2), where σ is the Tensile strength (Pa), F is the force (N), and A is the cross-sectional area (m^2). The next important parameters are the elongation percentage which can be calculated using Equation (3), where L_f is the final length in meter (m) and L_o is the initial gauge length.

$$\sigma = F/A \quad (2)$$

$$\text{Elongation \%} = [(L_f - L_o) / L_o] \times 100\% \quad (3)$$

The yarn evenness was also determined by using the gravimetric method. Samples of kenaf yarn were cut into a fixed length of 1 m and weighed individually. The standard deviation was calculated by squaring the deviations from the mean and was expressed as the percentage of the overall mean (C.V. %). The coefficient of variation (C.V. %) was used to define variability and was thus well-suited to expressing yarn evenness.

3. RESULTS AND DISCUSSIONS

3.1 Fibre Analysis

Fibre diameter were evaluated using an Olympus Advanced Microscopic (BX53M). The diameters of each sample type analysed are listed in Table 1.

Table 1: Fiber diameter and fibre tensile strength

Sample	Average fibre diameter (μm)	Average fibre tensile strength (MPa)
W	151.80 \pm 11.9	107.809 \pm 0.13
O	115.55 \pm 14.9	105.206 \pm 0.07
NCU	106.18 \pm 8.8	105.662 \pm 0.06
NCB	93.20 \pm 13.7	74.756 \pm 0.18
B	131.16 \pm 7.3	48.145 \pm 0.08
E	105.10 \pm 17.0	121.516 \pm 0.06
A	93.00 \pm 11.6	61.354 \pm 0.05

Based on Figure 1, the W-type indicated the highest fibre average diameter of 151.80 μm compared to the A-type with

93.00 μm . W had the highest diameter because it remained in the natural fibre condition. The willowing process of the W-type only consisted steps of opening and cleaning of fibres. Therefore, no treatment of reducing the diameter was done on the fibre. The A-type had the smallest diameter because the percentage of kenaf fibre diameter decreased with the increased immersion duration of the alkaline treatment. As the alkaline concentration, immersion time, and immersion temperature increased, the kenaf fibre became finer due to the leaching of non-cellulosic materials like hemicellulose, lignin, and pectin [2]. These results are also supported by Mohanty *et al.* [11], who reported that treating fibres with NaOH removes lignin, pectin, wax substances, and natural oils that cover the surface of the fibre cell walls. Similar findings were also reported by Jambari *et al.* [12] that reported the weight of the kenaf fibre reduced by 26% after 8% NaOH treatment. By performing SEM, a research by Hashim *et al.* [12] revealed that the fibre was not purely consist of monofilaments but was a bundle of monofilaments bonded and covered by lignin. Although the fibre was covered with lignin, the diameter still decreased since both processes opened the fibres apart.

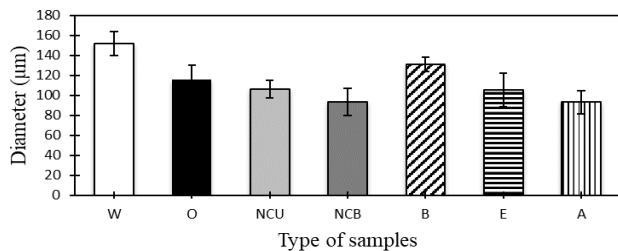


Figure 1: Average diameter of kenaf fiber

E showed a higher fibre diameter than A and NCB but lower than NCU and O. This was because the enzyme treatment indicated the removal of lignin by reducing the fibre diameter compared to the untreated fibres. A study by Wong *et al.* [14] reported that finer and smoother fibres were produced using enzymatic retting of *Aspergillus Fumigatus* R6 Pectinase compared to the other untreated fibres. Besides, fibre diameter for A type is lower than E. This condition might be due to the declining pattern of fibre diameter and cross-sectional area after the alkaline treatment was performed. Othman *et al.* [15] reported an extreme kenaf fibre diameter reduction at high level of alkaline treatment parameters. B was somehow higher in diameter than E even though it decolorized to the brightest fibre appearance. Kamaruddin *et al.* [16], explained that a bleaching process normally utilises a bleaching agent such as sodium hypochlorite and hydrogen peroxide to remove unwanted colours and decolorizes the coloured impurities that were not removed by scouring. Therefore, B diameter was higher than the other fibres. However, NCB which also processed by maceration showed the lowest fibre diameter. This could happen because of the addition of the combing process. The combing process is a process that removes impurities and

short fibres. It brushed the fibres and created only clean and fines fibres with the absence of nap which resulted in the smallest fibre diameter among the fibre types.

The result of the fibre tensile strength test is tabulated in Table 1. The differences in the fibre strength between all fibre type are illustrated in Figure 2. Figure 2 shows that E displayed the highest tensile strength. All other treated fibre which were NCB, B and A revealed lower fibre strength compared to the untreated fibre. A research by Ramesh *et al.* [17], showed that enzymatic and microbial retting preserved the natural fibre structure and resulted in superior mechanical properties compared to alkaline retting, which disrupted the structure and degraded the fibre's quality. Even though E exhibited a lower diameter, it experienced improved fibre strength compared to alkaline which showed the lowest diameter but exhibited lower fibre strength. From the microscopic cross-sectional view of the fibres, it is observed that alkaline retted fibres lost the central pore of the fibre cells, thereby reducing the modulus values compared to pectinase and ocean water retting [17]. Even if the enzyme treatment reduced the fibre diameter of tensile modulus, the tensile strain and tensile strength were improved with optimum concentration [18]. B displayed the lowest fibre strength with an average of 48.145 MPa compared to the others, indicating that maceration contributed to poor condition than the other fibre treatments and high decrement of 45% in tensile strength than W of the untreated fibre with an average of 107.809 MPa. According to Salam *et al.* [19], the rate of bleaching increased with increase in temperature, but higher temperatures tend to make hydrogen peroxide unstable and result in greater degradation of cellulose. The concentration and pH values are also important factors in determining the bleaching condition of the fibres. Based on Figure 2, it could be seen that the untreated kenaf fibres had higher tensile properties as compared to the treated kenaf fibres which have been reduced by the treatment type except for E treated type that showed improved fibre strength.

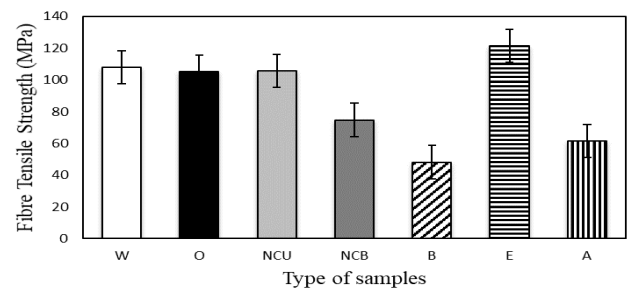


Figure 2: Average tensile strength of kenaf fiber

3.2 Sliver Analysis

An attempt was made to card on 100% kenaf fibre but was unsuccessful. The kenaf fibres did not entangle with each other and created no sliver as the output for the carding process. Thus, a lot of fibre waste was produced, and yarn

cannot be created. Both kenaf/polyester blending composition ratios of 50:50 and 60:40 produced sliver, but the performance varied according to their processing type. Table 2 shows the comparison of sliver properties between the two blending ratios of kenaf/polyester.

Table 2: Physical properties of kenaf/polyester sliver

Sample	Ratio	Size (hank)	Waste percentage (%)
W	60:40	0.32	12.30
	50:50	0.40	9.84
O	60:40	0.34	11.00
	50:50	0.36	9.92
NCU	60:40	0.31	12.60
	50:50	0.38	9.43
NCB	60:40	0.33	9.61
	50:50	0.40	11.80
B	60:40	0.35	10.80
	50:50	0.39	9.19
E	60:40	0.36	10.80
	50:50	0.50	8.97
A	60:40	0.36	11.00
	50:50	0.68	9.02

All types of slivers with 60% kenaf composition appeared to be thinner than the sliver with 50% kenaf composition. The sliver with 50% of kenaf composition appeared to be more compact than the other ratio. Based on Table 2, O showed slight difference in both ratios, but O was more compact than W. The results also indicate that the sliver size of O was larger than W but the produced waste percentage of O was lower than W. The opening process of the O fibre type kept the kenaf fibre apart, thus the entanglement of the fibres became easier. It was observed that NCU showed paralleled structures for 60% kenaf composition while O was more fibrous. This was because the combing process of NCU removed the short fibres and straightened the fibres even though they underwent the blending process. The sliver size of NCU for 60% kenaf composition was smaller than O but showed a higher waste percentage than O. However, for 50% kenaf composition, NCU was more compact and fibrous than O. Each sliver size was measured in mass per 1-meter length and the average weight was calculated for the sliver size in hank. The differences between the samples are shown in Figure 3. Except for the fibre processing type, the size differences were also expected due to the waste percentage produced. The A-type showed the largest sliver size with the lowest waste percentage while NCB had the smallest sliver size with the highest waste percentage. NCU and NCB showed poor condition among the other types even though the kenaf was already combed. E exhibited better sliver size despite having the lowest fibre diameter and softness next to B type.

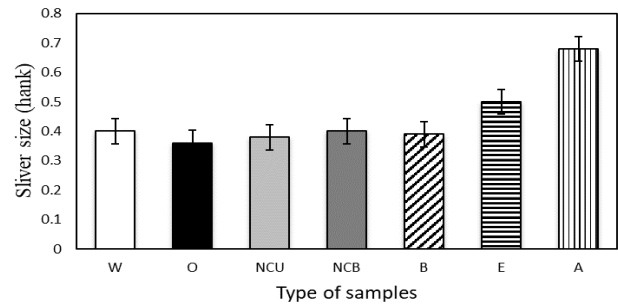


Figure 3: Sliver size of kenaf/polyester sliver

3.3 Yarn Analysis

An attempt to produce yarns was made on the 60% kenaf composition. The results however demonstrated poor condition of yarns produced compared to 50% of kenaf composition. There was high yarn breakage, thin places and uneven yarns with high hairiness were observed. Table 3 displays the overall result obtained from the 50% of kenaf composition yarn. Its physical properties such as yarn diameter, yarn tensile strength, percentage of elongation, and yarn evenness were examined.

Table 3: Physical properties of kenaf/polyester sliver

Sample	Av. Yarn Diameter (µm)	Av. Yarn Tensile Strength (MPa)	Elongation (%)	Av. Yarn evenness	CV%
W	235.80 ± 58.3	23.02 ± 0.09	20.46 ± 0.05	0.042	30.95
O	231.91 ± 26.8	15.68 ± 0.06	20.04 ± 0.06	0.030	25.00
NCU	267.11 ± 45.2	11.81 ± 0.08	17.31 ± 0.06	0.062	12.90
NCB	226.00 ± 36.9	42.78 ± 0.16	21.53 ± 0.07	0.022	36.36
B	199.83 ± 38.0	19.54 ± 0.07	17.94 ± 0.09	0.150	53.33
E	235.10 ± 20.6	28.24 ± 0.12	20.16 ± 0.05	0.040	25.00
A	251.20 ± 60.4	24.24 ± 0.13	20.76 ± 0.07	0.044	25.00

3.3.1 Diameter of kenaf/polyester yarn

The diameter of each sample observed are well illustrated in Figure 4. From the data obtained, NCU showed contrast results of yarn diameter as even though it produced lower sliver size as shown in Figure 3. It also exhibited the highest yarn diameter. Whereas for the treated types, NCB, B, E, and A all showed a similar trend where the higher the size of the sliver, the higher the yarn diameter. However, the untreated types also revealed higher yarn diameters which were in contrast to their sliver sizes.

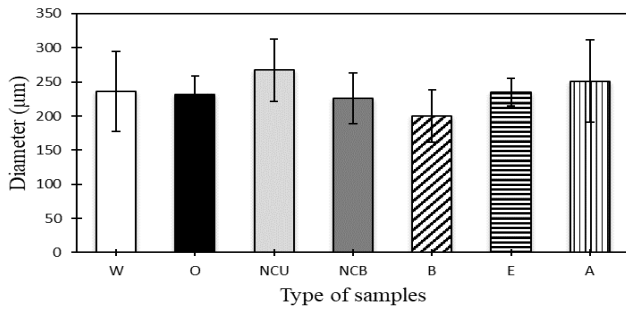


Figure 4: Average diameter of kenaf/polyester yarn

3.3.2 Evenness of kenaf/polyester yarn

Based on the observation during spinning, every single yarn still had uneven parts along the length which caused the continuous yarn breaking. Yarn evenness are calculated based on yarn in gram per unit length. As shown in Figure 5, W, O, and NCU showed lower yarn evenness of compared to the treated types of B, E, and A. NCU showed the lowest yarn evenness while B showed the highest evenness whereby the yarn with the lowest yarn evenness gives a higher value of CV% [20]. A high value of CV% indicates high irregularity of yarn. Coarser or higher kenaf diameter contributed to higher yarn evenness. W, O and NCU kenaf fibres did not underwent any treatment, thus did not show improved fibre surface [14], [21], [22]. This condition affects the evenness of the yarns.

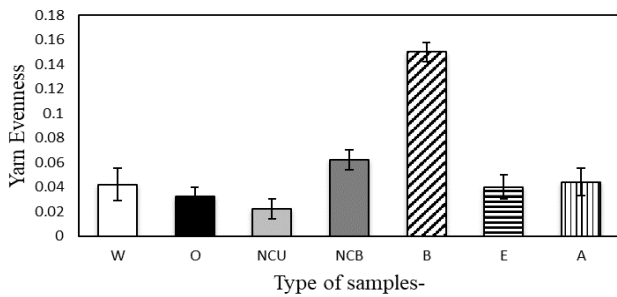


Figure 5: Yarn evenness of kenaf/polyester yarn

3.3.3 Tensile properties of kenaf/polyester yarn

Figure 6 shows the differences in tensile strength between each sample type of blended yarn. NCB exhibited the highest tensile strength while B showed the lowest yarn tensile strength. This was due to the similar conditions of its average diameter where NCB revealed higher yarn diameter and B showed lower yarn diameter. Compared with the sliver size, B displayed a larger size due to lower waste percentage and fibrous compactness of the sliver, but NCB exhibited finer fibre which twist can easily be produced. Both exhibited higher tensile strength than the untreated sample types. The higher tensile strength was also showed by E and A types

which were enzyme and alkaline treated kenaf fibre. Even if the enzyme treatment had reduced the fibre diameter of the tensile modulus, the tensile strain and tensile strength were improved with optimum concentration [18]. It was found that the treated kenaf fibre blended with polyester produced yarns that were stronger than untreated kenaf. W and O of the untreated type exhibited larger diameters but produced lower sliver sizes than each treated type, hence medium yarns diameter was produced. However, the tensile strength of both types was lower than the treated type of blended yarn. Besides, NCU exhibited the lowest yarn strength among all types because it possessed the lowest yarn evenness due to naps, thick, and thin places along the yarn length. E showed better properties of higher yarn diameter, higher yarn evenness, and higher tensile strength but lower yarn strength than NCB. Whereas A exhibited lower strength than NCB and E.

3.3.4 Elongation properties of kenaf/polyester yarn

Figure 7 shows varied measurements of elongation percentage of kenaf/polyester blended yarn. Based on the data obtained, NCB was found to exhibit the highest elongation and tensile strength. This shows that combing plays an important role in the bleaching treatment. Besides, the lowest elongation percentage among all the parameters was O, B and NCU. Treatment with only bleach showed poor yarn tensile strength and elongation. The treatment reduced the mechanical properties compared to the enzyme and alkaline treatments. Besides, E type showed better yarn properties than W, O, and NCU types which concluded that the enzyme treatment is compatible to be used for kenaf extraction.

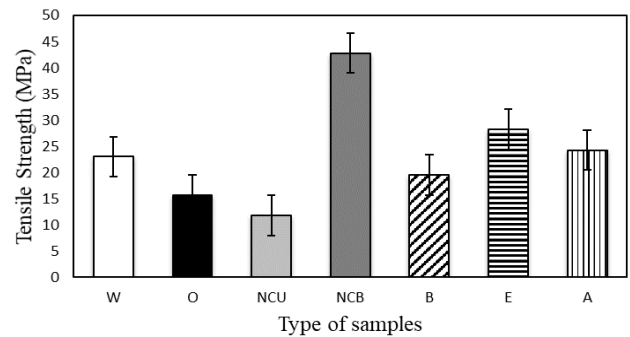


Figure 6: Tensile strength of kenaf/polyester yarn

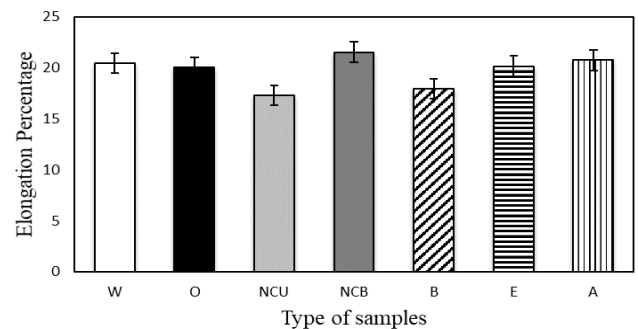


Figure 7: Percentage elongation of kenaf/polyester yarn

5. CONCLUSION

Blended kenaf/polyester yarns were successfully developed with all the obtained kenaf fibre conditions. It was found that the degummed kenaf type showed the lowest diameter of hybrid yarn while the untreated type (normal combed degummed) blended polyester yarn exhibited the highest diameter. Except for degummed, the diameters of the other treated kenaf hybrid yarns were slightly different than the untreated kenaf hybrid yarns. It displayed the highest yarn evenness. The treated type kenaf/polyester hybrid yarn produced higher yarn evenness compared to the untreated hybrid yarn. The normal combed degummed yarn exhibited the highest tensile strength among all other yarn type. The treated type of kenaf/polyester hybrid yarn produced higher tensile strength than untreated hybrid yarn. In terms of elongation percentage, normal combed bleached treated kenaf/polyester hybrid yarn possessed the highest elongation percentage.

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