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ORIGINAL ARTICLE

Permanganate Treatment Optimization on Tensile Properties and Water Absorption of Kenaf Fiber-Polypropylene Biocomposites

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ABSTRACT – Kenaf fiber has been studied for biocomposites reinforcement due to its renewable and carbon neutrality. Meanwhile, polypropylene sheets are easily processed and considered a prospective thermoplastic matrix source for biocomposites. Hence, the combination of both materials is expected to form an attractive biocomposite. This study aimed to optimize permanganate treatment on tensile properties and water absorption of kenaf-reinforced propylene biocomposites. It thermally tested kenaf fibers and PP using differential scanning calorimetry (DSC) before performing compression molding at 185°C and 70 bars using the film stacking method. The kenaf fiber variables were untreated, alkaline pre-treated, and alkaline-permanganate treated to low concentrations of 0.01 to 0.05 wt% of $KMnO_4$. Furthermore, this study conducted Yarn tensile test and Weibull distribution to find a strength variability statistically. Composite tensile and burn tests were performed to obtain tensile strength, constituent materials, and void volume fractions. Composites fractography was implemented to examine the effect of permanganate on composite water uptake behavior using scanning electron microscopy. This study used low concentration in permanganate treatments than several previous studies. The results showed that biocomposites have a tensile strength of 125 MPa, higher than in previous studies that found a value less than 80 MPa. This study has contributed to the green optimization treatment using lower chemical concentrations but with better results on impregnation, interfacial, water absorption, and mechanical properties of kenaf or polypropylene composites.

INTRODUCTION

Non-wood lignocellulose materials, also known as natural fibers are being studied for use as potential environmentally friendly composites that reduce or replace synthetic fibers and polymers [1]. The advantages of using natural fibers include their highly specific properties, resource abundance, minimized CO_2 emission, and low-cost processes [3], [4], [5]. Another advantage is carbon neutrality, implying a balance between emitting and absorbing carbon from the atmosphere in carbon sinks [2]. Unfortunately, Weibull analysis showed that naturally-based fibers such as kenaf and bamboo have high variability properties and low compatibility with the matrix [6],[7]. Kenaf is a natural fiber sourced from plants [8] with high cellulose content of 45-57% [9]. Due to their superior toughness and high aspect ratio, kenaf fibers have good mechanical properties, replacing glass fiber performance [10]. Kenaf fiber polymeric composites applied in nonwoven [11],[12] and woven forms [13] exhibit good tensile and flexural properties in hybrid composites. In line with this, optimization aims to obtain the best combination of maximum or minimum fitness function variables. Natural polymers such as polylactic acid (PLA) are green and biodegradable but expensive [14], [15]. In contrast, synthetic polymers such as polypropylene are less costly and are easily recycled. Polypropylene (PP) matrices are applied because of their recyclability [16]. A highly viscous PP matrix is impregnated easily in a sheet form into the fiber bundles [17]. Furthermore, the use of PP sheets as a matrix help in the recycling process of plastic products [13] to obtain a new biocomposite material. Previous kenaf-PP biocomposites have used PP in waste rather than in virgin form [18], [19].

Biocomposites made from kenaf fiber and PP sheets may serve as a new, greener material in producing composites. However, there may be a low resistance to water absorption due to the hydroxyl structure of natural fiber [20]. Water absorption into the biocomposites damages the fiber-matrix interface [21]. This would cause micro-cracking, resulting in the abrupt degradation of tensile properties [22]. Nevertheless, some considerations need to be studied to reach the well-developed tensile properties of biocomposites. For instance, the high viscosity of polypropylene, low fiber degradation temperature, and poor fiber-matrix interfacial strength should be optimized. Additionally, chemical treatment optimization should be conducted to improve the interfacial quality of the fiber matrix. According to [21], biocomposites' tensile and water absorption properties improved after permanganate and alkali treatment, respectively. Permanganate treatment triggers cellulose radical by forming MnO3- ion [25]. Several previous Kenaf/PP composites studies investigated how close were natural fibers properties such as hemp, kenaf, jute, coir, and sisal, to the synthetic ones such as glass fibers. The results showed that the maximum tensile strength of kenaf-polypropylene, kenaf, jute, and coir were

less than 60 MPa [26]. Another study on kenaf/PP composite examined fiber permanganate treatments at a fixed concentration of 2% KMnO4. The results showed a maximum biocomposite tensile stress value of 74 MPa [27]. In comparison, the biopolymer matrix used in kenaf/PLA composites [28] only reaches tensile strength of less than 70 MPa. A low permanganate treatment of 0.125% KMnO4 was conducted in sugar palm [29], but the composite tensile stress was still less than 10 MPa. Moreover, studies of Kenaf/Sisal hybrid green composites showed water absorption quality improved to semi-structural utilization [30], but the tensile strength is still less than 60 MPa. A kenaf-thermoset composite review was published recently [31]. However, there is no publication on permanganate optimization for kenaf fiber and its PP biocomposites. Therefore, this study aimed to investigate the optimal composition of permanganate and its effect on the tensile and water absorption properties of kenaf-polypropylene fiber biocomposite.

METHODOLOGY

Materials Preparations

This study used polypropylene sheets as a matrix with a density and thickness of 0.02 gr/cm^2 and 0.21 mm, respectively. Kenaf fiber preform was used as a reinforcement stitched unidirectional, with a thickness of 1 mm. The prefom came from Balai Penelitian Tanaman Pemanis dan Serat (BALITTAS) in Malang, East Java Indonesia [31]. The propylene sheets are plastic film supplied from Daichi Plastic Co., Ltd., Japan, with the local trade name DAICHI. The composite was prepared using a 50% weight fraction for matrix and reinforcement.

This study denoted biocomposites based on a variation of kenaf preform as R, A, and P, for the raw, 5% alkaline pretreatment and 5% alkaline with permanganate treatment, respectively. The numbers 1 to 5 were used to identify permanganate concentrations as 0.01% to 0.05%, as shown in Table 1. A total fiber loading of 45% was used to optimum kenaf-polypropylene biocomposite strength. Before composite processing, kenaf preform was rinsed with demineralized water and oven-dried at 105°C for 30 min.

Table 1. Kenaf preform treatment, permanganate concentrations, and sample codes.

| No. | Preform treatments | KMnO₄, (wt%) | Biocomposite codes | |
			As hot pressed	Water absorbed
1	Raw Kenaf	-	R	WR
2	Alkaline*	-	A	WA
3		0.01	P1	WP1
4	Alkaline -	0.02	P2	WP2
5	Permanganate	0.03	P3	WP3
6		0.05	P5	WP5

*5 wt% NaOH; P1-P5 are permanganate-treated fibers with 0.01%-0.05 wt% KMnO4.

Processing Kenaf-Polypropylene Biocomposites

Kenaf-polypropylene biocomposites were manufactured using a hot compression film stacking method [26] at 185°C and a pressure of 70 bars. The pressure was gradually increased at 25 bars every 10 min and kept constant at 75 bars by the hydraulic after 30 min [27]. This was followed by demolding after cooling at 25 °C in the mold within the pressure. Three layers of stitched kenaf preform were sandwiched with the sheets of PP plastic waste to ensure the 50 wt% fiber loading, as presented in Figure 1.
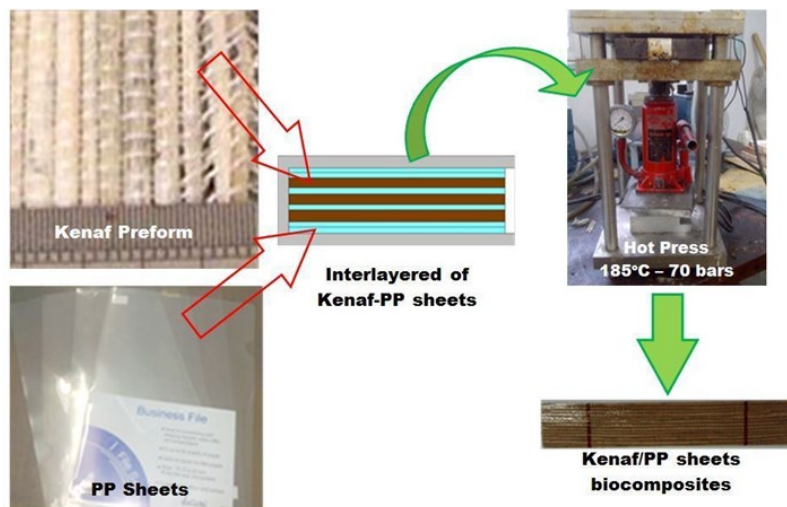

Figure 1. Kenaf/polypropylene biocomposites processed by hot compression molding film stacking method.

Characterizations

Physical properties

Thermal properties of fiber and matrix were characterized through thermal measurements. Fiber diameter and density were also measured to calculate fiber and void volume fractions. Thermal measurements were conducted by differential scanning calorimetric (DSC) instrument of Parkin Elmer DSC 7 to verify melting point of matrix and thermal stability of fiber reinforcement. Measurement conditions were 10 °C/min heating rate in a nitrogen environment to a maximum temperature of 250°C.

Ten samples of kenaf fibers were randomly selected from each fiber treatment and measured three times at the smallest diameter location. The fiber tensile strength was calculated based on its average value and the assumption of a perfectly round diameter. The diameter significantly affects biocomposite tensile strength due to its function as reinforcement to the matrix. For the same tensile load value, a smaller diameter fiber would increase the tensile strength of fiber and biocomposite. The density testing according to ASTM-D792 [32], was confirmed to the compress-molded PP/kenaf biocomposites. Fiber density and Kenaf-PP biocomposites were characterized using the pycnometry method and calculated using the following equations.

$$\rho_{oil} = (o - e)/(w - e) \tag{1}$$

$$\rho^{(23/(23°C))} = (s \times \rho_{oil})/(s + o - p) \tag{2}$$

$$\rho^{(23°C)} = \rho^{(23/(23°C))} \times 0.9975 \tag{3}$$

Where 0.9975, ρ_oil and $\rho^{(23°C)}$ are the water, oil, and specimen densities at 23 °C, respectively. The subsets e, w, o, and p represent the mass of pycnometer in empty, water-filled, oil-filled, and specimen plus oil-filled conditions, measured at 23 °C. Alternatively, the subset s and $\rho^{(23°C)}$ are the mass of the dry specimen and its specific gravity, respectively. Volume fractions of biocomposites constituent materials were calculated after-burn test according to ASTM -D3171 [33] using the following equations.

$$W_f = \frac{M_f}{M_C}; \; W_m = \frac{M_m}{M_C} \tag{4}$$

$$V_f = \left(W_f \times \frac{\rho_C}{\rho_f}\right); \; V_m = \left(W_m \times \frac{\rho_C}{\rho_m}\right) \tag{5}$$

$$V_V = \left(1 - \left(V_f + V_m\right)\right) \times 100\% \tag{6}$$

where W_f and W_m are the fiber and matrix weight fractions, respectively; M_f, M_m, and M_c are the fiber, matrix, and biocomposites mass, respectively; V_f, V_m and V_V are the fiber, matrix, and biocomposites volume fractions, respectively; and ρ_f, ρ_m, and ρ_C are the fiber, matrix, and biocomposites densities, respectively.

Tensile testing

The tensile properties of the fiber and yarn were tested at 23 °C with a gauge length of 50 mm, following the ASTM D3822 standard. Fiber tensile test used Textechno Favigraph (Textechno, Chemnitz, Germany), and yarn tensile test used Testometric tensile machines (Rochdale, UK). Ten samples were picked up from each fiber batch treatment, while a crosshead speed of 7.5 mm/min and 2 kgF load cell was used. Fiber tensile strength (MPa) was converted from the applied load (kgF) over the cross-section (mm²). Diameters were measured using an optical microscope (Kemet Intl. Ltd., Maidstone, UK). This study the fibers to have a constant cross-sectional area over its length. The data were statistically calculated using the Weibull distribution method [34], [35], [6] to examine the fibers' strength variability.

The strength of compression-molded kenaf-PP biocomposites was tested according to ASTM D3039 standard by Tarno Grocki universal testing machine using a strain rate of 10 mm/min at 200 kgF. The specimen dimensions were cut into sections measuring 25×140×2 mm³, with a 100 mm gauge length. Specimen conditions are based on fiber reinforcement as untreated and permanganate-treated and water-absorption treatment [36].

Fractography was used to evaluate the fiber-matrix interface, chemical bonding, surface roughness, and mechanical interlocking qualities. Biocomposite fracture surfaces were analyzed using a JEOL JSM-6360 LA scanning electron microscope (SEM) TEKNOLA Bindo Penta Perkasa Jakarta, Indonesia. The SEM method was taken based on previous reliability results [39], [27], [24], [38], [30].

Moisture uptake behavior

Water absorption tests were conducted based on the procedures described in the ASTM-D570 standard to evaluate the effect of fiber permanganate treatment on composites' moisture uptake behavior [37], [38]. The specimen dimensions

were $60 \times 15 \times 2$ mm^s. The initial oven-dried (M_B) and water-absorbed (M_A) specimens were weighed and immersed in boiled and distilled water, respectively. Water gain, ΔM in the specimens were calculated using Eq. (7).

$$\Delta M = \frac{M_A - M_B}{M_A} \times 100\% \tag{7}$$

where M_A is the weight of water-absorbed specimens recorded every 30 min for 24 h and M_B is the weight of 24 h – 50 °C oven-dried specimens.

RESULT AND DISCUSSION

Characteristics of Matrix, Yarn, and Fibers

The curve of DSC result in Figure 2 represents absorbed energy to temperature changes in propylene and kenaf fibers. The energy peak shown in Figure 2 indicates that the melting point of polypropylene is 176.75°C. It shows a relatively straight curve for the kenaf fiber without indicating a significant energy absorption peak. This means that the kenaf fiber is still stable when exposed to temperatures up to 250 °C, and no degradation occurs. Based on Figure 2 and the optimum result from [27], the compression molding process for the kenaf – PP composite could be conducted at 185°C.
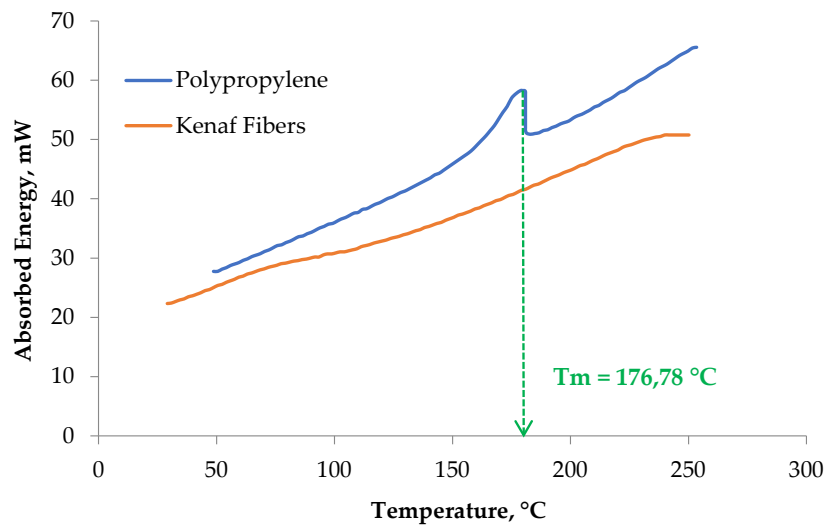

Figure 2. DSC curve of propylene matrix and kenaf fiber.

Table 2 shows yarn strength and optical microscopic diameter measurement results in correlation to Weibull distribution parameters Figure 3). Compared to [27], this study reveals significant improvement in strength, fiber diameters, Weibull parameters, and a small chemical amount. The previous study used 2% KMnO4 to obtain strength of 113 MPa, while this study used only 0.01% KMnO4 (P1) and obtained a strength of 203 MPa. Therefore, it used 200 times lower chemical concentration reduction to obtain an 80% increase in yarn strength.

Table 2. Weibull distribution parameters as per low concentration kenaf yarn treatments.

Yarn	Dia. (μm)	Strength (MPa)	Weibull parameters*		
			m	C	σ_0 (MPa)
R	66 ± 15.10	165 ± 53.0	3.4967	-18.239	184.21
A	63 ± 12.05	170 ± 55.0	3.2502	-17.073	191.12
P1	69 ± 11.58	203 ± 98.2	2.5174	-13.708	231.67
P2	64 ± 20.36	168 ± 62.5	3.1526	-16.518	188.57
P3	85 ± 25.28	139 ± 53.6	2.4845	-12.592	158.89
P5	68 ± 18.96	153 ± 53.6	3.0919	-15.912	171.80
Judawisastra [27]	71 ± 15.62	113 ± 65.4	1.9323	-9.1608	114.53

*Linear regression method

Fiber diameter reduced due to hemicellulose and lignin removal during chemical treatments with alkali and permanganate solutions [17], [40], [27], [41], [38]. As the outer layer of lignocellulose covers, lignin is washed first, followed by hemicellulose. Consequently, as the final constituent responsible for mechanical strength due to its crystalline structure, cellulose showed strength improvement. Smaller fiber diameter implies lower density due to the smaller surface transverse of the fiber. Therefore, a smaller diameter increases fiber volume fractions and composite strength.

Figure 3 shows Weilbull modulus (m), indicating strength distribution. The results showed that kenaf fibers had 2.48~3.25. Alves [42] found a similar value for sisal with 3.70 and curaua fibers with 2.20. In comparison, Mesquita [43]

found a higher value for carbon fibers with 4.3~7.0. Lower m values imply higher variability properties. The anomalous phenomenon due to lower m value is shown in Table 2.
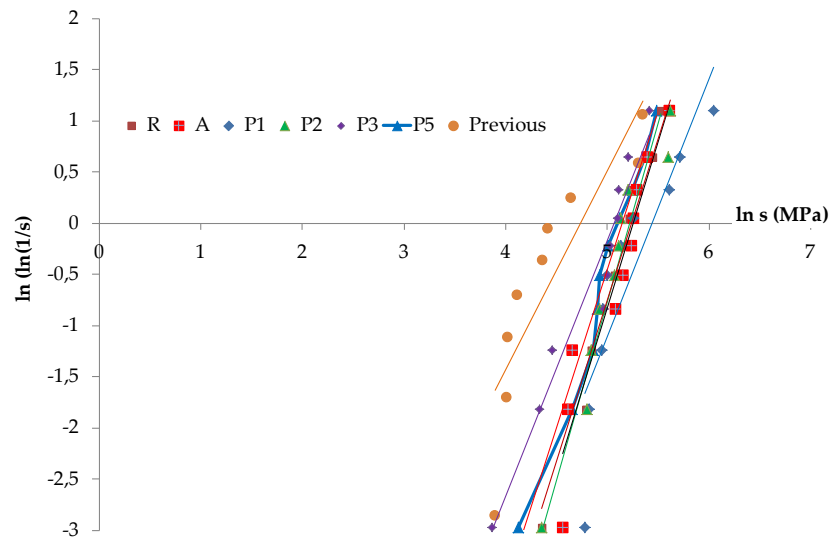

Figure 3. Low concentration permanganate treatment increases Weibull modulus.

Figure 4 shows kenaf yarn strength as a potential reinforcement fiber to propylene matrix. A low permanganate treatment of 0.01 wt% $KMnO_4$ improved yarn strength above 20% compared to raw and alkaline pre-treated kenaf. The P1 maximum strength of 203.5 MPa shows that permanganate treatment significantly tuned up cellulose crystallinity by removing hemicellulose and lignin in the kenaf fiber [44]. The matrix removal would improve the orientation of cellulose crystals in the kenaf fiber, resulting in better fiber strength [45]. Permanganate treatment breaks hydrogen bonding between hemicellulose and cellulose surfaces. This increases yarn strength due to the increased cellulose fraction of kenaf yarn [46]. However, permanganate treatment adversely affects the yarn strength when conducted in a longer immersing time and a higher concentration [25]. These two factors degrade fiber surface quality and form shorter cellulose chains with lower strength. Based on these considerations, 0.01 %wt KMnO4 is the optimum permanganate treatment concentration.
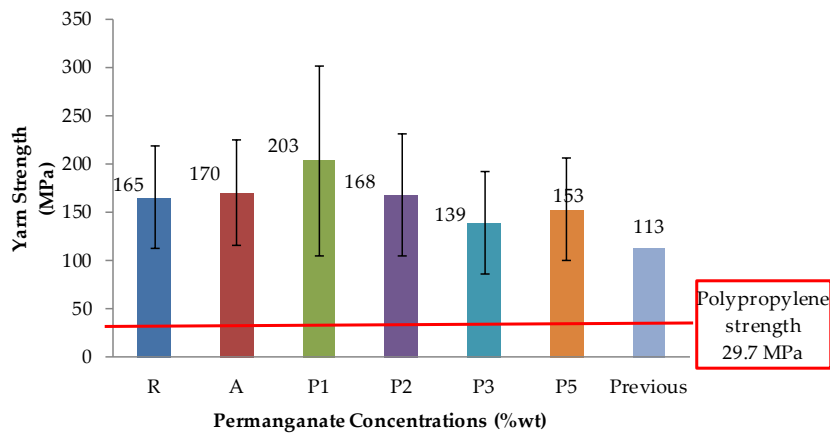

Figure 4. Kenaf yarn strength at various low permanganate concentrations (0.01-0.05% KMnO4) compared with [27] – 2% KMnO4 (P2-185°C)

Biocomposites Characteristics

Table 3 shows kenaf-PP biocomposites' physical and mechanical properties in terms of density, the volume fraction of fiber, V_f, the volume fraction of void, V_v, and tensile strength, respectively. All the properties are tabulated in the conditions before and after the water absorption test differentiated with a letter W. The lowest fiber volume fraction (V_f) is 0.03 %wt KMnO4 (P3 and WP3). These values have been introduced by higher anomalous yarn diameters (in Table 2) than the other samples. However, their normalized strength was still higher when compared with raw (R and WR) and pretreatment (A and WA). These could be related to improving cellulose crystallinity and graft copolymerization after permanganate treatments. Compared with [27], the normalized strength of P3 has a higher value of 104.67 MPa, greater than 74.31 MPa.

Table 3. Physical and mechanical properties of kenaf-PP biocomposites.

Sample codes	Density (g/cm³)	Volume fractions (%)		Tensile strength (MPa)	
		Fiber, V_f	Void, V_v	Based on riil Vf	Normalized, 45% Vf
R	1.013	44.63 ± 1.30	3.75	89.54 ± 4.90	90.58
A	1.005	41.29 ± 1.35	2.83	69,53 ± 5.80	76,03
P1	1.031	45.15 ± 1.89	5.59	120.37± 0.21	120.37
P2	1.024	42.73 ± 2.32	5.01	118.4 ± 14.94	125.18
P3	1.017	38.10 ± 1.39	3.33	85.02 ± 16.78	100.75
P5	1.021	39.39 ± 1.52	3.23	91.31 ± 16.61	104.67
Judawisastra [27]	1.029	37.20 ± 0.00	2.44	74.30 ± 5.0	74,31
WR	1.013	(45.33± .08)	(4.44)	21.00 ± 3.51	20,58
WA	1.005	(48.86±2.01)	(4.34)	27.00 ± 0.41	24.87
WP1	1.031	(44.82± .51)	(4.53)	39.15 ± 6.55	39.31
WP2	1.024	(45.12±1.41)	(4.78)	34.12 ± 4.63	34.03
WP3	1.017	(44.4± 1.86)	(5.09)	29.35 ± 6.34	29.74
WP5	1.021	(48.91± .30)	(5.92)	33.36 ± 6.27	30.70

P2 with had reached normalized maximum tensile strength value of 125.18 MPa. Based on Table 2 and Figure 4, P1 with 203 MPa has higher yarn strength than P2 with 168 MPa. Similarly, P1 void content of 5.59% was higher than P2 with 5.01%, indicating that P2 is better than P1, as shown in Figure 5. This study has also revealed a theoretical sense in terms of alkaline pre-treated, where the lower value of A at 76.03 MPa than R at 90.58 MPa is due to lower fiber volume fraction. Since the alkaline process improves hydrophobic characteristics, WA's strength after water absorption is higher than WR. This was supported by a higher fiber volume fraction and a lower void volume fraction. The positive findings also applied to the other permanganate treatments P3, P5, WP3, and WP5. Fiber loading in composites (*Vf*) was influenced by yarn diameter variations at the different cross-sections [47]. Additionally, chemical treatment could decrease void formation in biocomposites due to the fibers' enhanced hydrophobic properties [48].
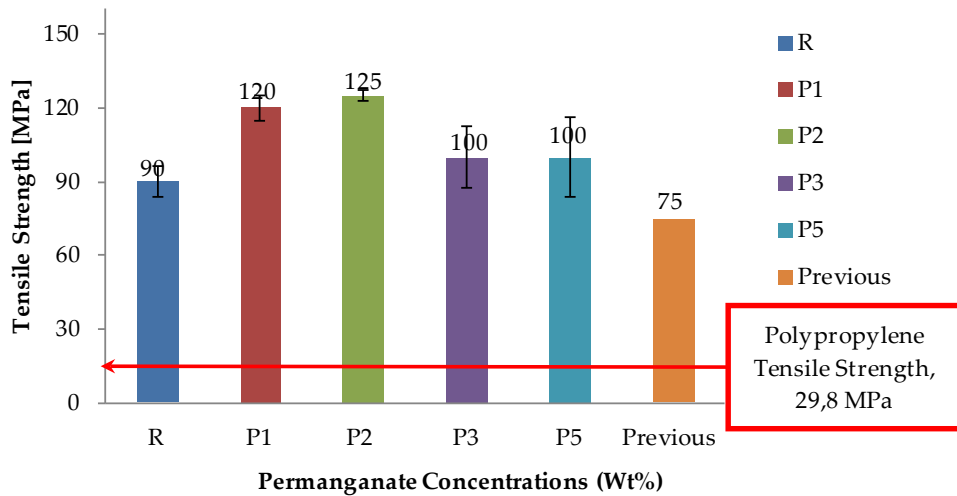

Figure 5. Tensile properties of kenaf-PP biocomposite compare to previous Judawisastra's [27] kenaf-PP composite; and polypropylene matrix.

Water Uptake Behavior

The relationship of water-weight gain versus absorption time in kenaf-PP biocomposites is shown in Figure 6. The entire composite samples absorbed water quickly at the beginning of the treatment and slowed down as it approached saturation state, supporting [49]. In Table 3, raw kenaf (WR) has the highest water uptake due to its chemical and physical properties and the presence of the natural lignocellulose constituent. However, the water uptake is reduced after alkaline pretreatment (WA) and the removal of the extractives. Although WA fiber volume fraction is higher than WR, it has a lower void content and hydrophilic constituents. This lower uptake value was followed by higher strength than the WR. The highest tensile strength after absorption treatment (WP1) was caused by higher yarn strength, lower void content and fiber volume fraction, and reduced water uptake compared with WP2. Furthermore, WP5 is more powerful than WP3 because of its better yarn strength and lower water absorption than WP3, though it contains slightly more voids. According to Guo [45], this maximum strength was supported by a good crystallinity index, resulting in a better cellulose crystal orientation in kenaf fibers. This means that biocomposite strength after water absorption is the function of yarn strength, fiber volume fraction, void content, and water uptake condition. A graphical illustration is shown in Figure 6.
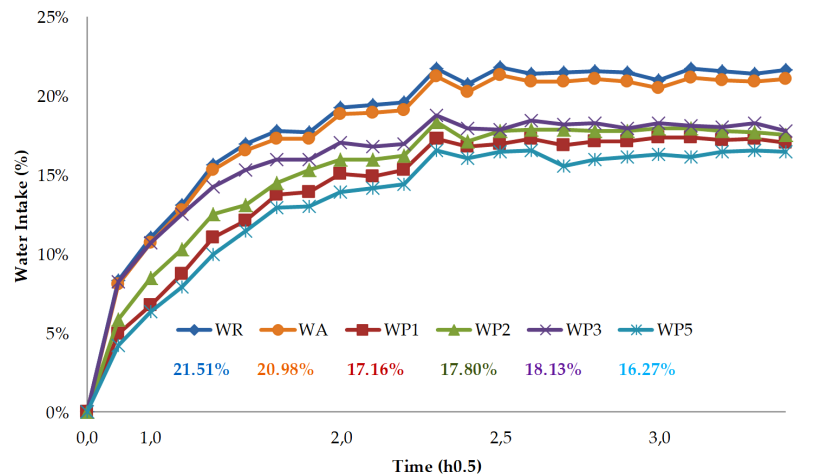
Figure 6. Kenaf/polypropylene biocomposites water intake behavior after fiber permanganate treatments.

As shown in Figure 6, the water intake of all treated fiber biocomposites decreased from above 21% (WR) to below 16.5% (W5). This high moisture uptake characteristic is one of the shortcomings of natural fibers, besides their high variability and low compatibility to the polymer matrix. Moreover, permanganate treatment decreased water absorption because of the reduced hemicellulose as a hydrophilic agent on the fibers [40]. Permanganate treated fiber produces rougher surfaces due to removing extractive constituents, a physical change through SEM confirmation. Chemically, the fiber undergoes hydrogen-bond disrupting through the graft copolymerization mechanism by forming reactive Mn3+ ions [25]. These reactive ions increase hydrophobic fiber fraction by decreasing hydrophilic tendency, reducing the composite's water absorption rate [49]. Thermogravimetric analysis (TGA) or Fourier transformation of infra-red spectroscopy (FTIR) is needed to confirm this chemical change. Aofei [45] stated that hemicellulose weight loss recorded by TGA due to alkaline-permanganate treatment in kenaf fiber was about 7.3% at $220 - 315°C$. This hemicellulose weight loss was not observed by FTIR using peak appearance = CO stretching vibration of the carboxylic acid of 2000-1693 cm^{-1} and -CO stretching of the acetyl group of 1286-1184 cm^{-1} [42-44].

Water penetrates the biocomposites through diffusion into the micro-gaps polymer chain, capillary action via gaps and flaws, and through the micro-cracks in the matrix. However, the breakages of the hydroxyl bond on the fiber surface prevented the water molecules from bonding with the fiber, decreasing the water absorption. Permanganate treatment enhances the fiber-matrix interface by coarsening the fiber surfaces, resulting in more favorable sites for interlocking between fiber and matrix. The fiber-matrix interfacial quality improved due to chemical treatment, as proved by [5,14,32,42,43].

Fractography Analysis

This study used SEM to confirm the improvement of fiber-matrix adhesion and the enhancement of surface roughness quality, as shown in Figure 5(A) to 5(E). Figures 5(A) and 5(B) represent initial conditions, while 5(C) to 5(E) represent situations after water absorption tests. Permanganate treatment induces fiber surface roughness, as shown when the treated fiber has a coarser surface than the raw fiber, in Figure 5(A). In 5(B), more matrix constituents were attached to the fiber surface, indicating improvement in the fiber-matrix interface. This is in line with [50],[51], which found that chemical treatment provides more favorable sites for interlocking between the fiber and the matrix. The tensile test data in Table 3 show that surface quality improvement of the P2 sample or after 0.02% permanganate treatment was supported by a higher strength value than the R sample of raw kenaf fiber.
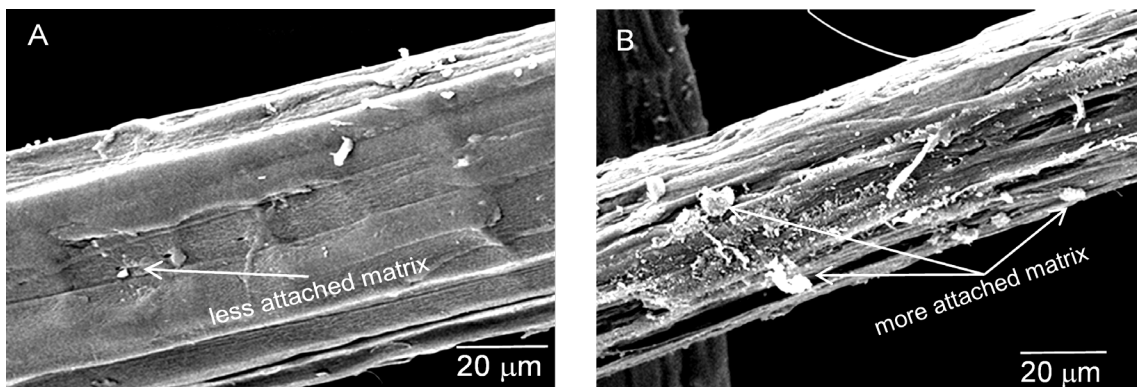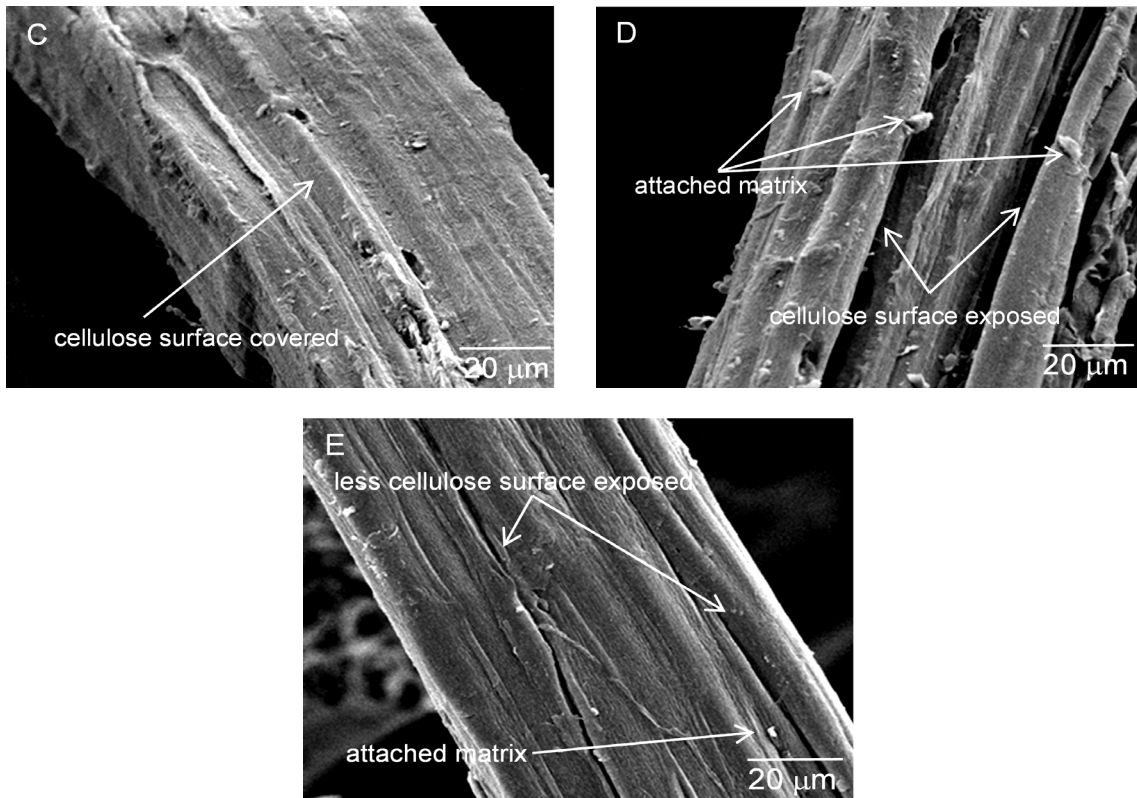
Figure 7. SEM Fractography results of kenaf/PP biocomposite based on fiber treatments. (A) raw kenaf fiber, *R*; (B) 0,02% KMnO4, *P2*; (C) raw fiber after absorption, *WR*; (D) and (E) represent water-absorbed conditions of 0,01% and 0,03% KMnO4, respectively (*WP1* and *WP3*).

The attachments of matrix particles on the fiber surfaces varied with fiber treatments. The WP1 sample representing 0.01% KMnO4 after absorption had more matrix residue on the fiber surface than WR or raw fiber with absorption. This indicates that the fiber-matrix interface quality of the WP1 sample is better than the others. Therefore, treatment with 0.01% wt% $KMnO_4$ is confirmed mechanically and physically. WP3, which represents the lowest tensile strength after water absorption, had more extractive constituents and less cellulose on the fiber surface.

Kenaf Future Studies

This study obtained significant biocomposite tensile properties of kenaf fiber polypropylene. The values are more significant compared with natural and synthetic fibers biocomposite systems. Fu et al. [52] found that polypropylene reinforced with short carbon and glass fibers has composite strength lower than 60 MPa and 52 MPa, respectively. These values are 52% and 58% lower than kenaf-PP, which achieved 125 MPa. In Figure 4, the maximum kenaf yarn strength was 203 MPa and much lower than Fu's carbon and glass fibers strength [52], which found 3,950 MPa and 1956 MPa. This result implies that kenaf fiber-PP matrix quality has improved significantly after alkaline permanganate treatments.

The findings, along with the previous ones, might expose wide opportunities for future kenaf fiber studies. An example is a green composites study on natural matrix utilization such as TPS, PLA, and PBS [48,49,50] reinforced by kenaf fibers in micro and nanoscales. Based on hybridization strategies, composite toughness [56] could also be improved by combining the optimized-kenaf fibers with the other natural or synthetic fibers. These include sisal [30], oil palm [57], pineapple leaf [58], bamboo [59], glass [60], and kevlar [61]. Additionally, future studies could examine composite mechanics to understand biocomposite properties, such as the ductility of the synthetic matrix [62].

CONCLUSIONS

This study conducted optimization based on fiber treatment through alkaline pretreatment and permanganate treatment and evaluated interface quality using the water absorption method. The results showed improvement in the maximum yarn strength of 203 MPa in P1 and biocomposites strength of 125 MPa in P2. Furthermore, WP1 indicated interfacial and impregnation qualities on biocomposite water absorption. These results are more significant than [24–28] by using a lower chemical concentration of 0,01 to 0.05% KMnO4. The results showed better impregnation, interfacial, water absorption, and tensile properties of kenaf/polypropylene composites. This study contributes to a greener biocomposite manufacture using a lower chemical concentration to obtain better impregnation, interfacial, water absorption, and mechanical properties of kenaf/polypropylene composites. Therefore, future studies could use these results to examine an extended biocomposite materials such as kenaf and hybrid kenaf or green sisal composites for automotive, building interiors, and semi-structural utilizations.

ACKNOWLEDGEMENT

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