

Performance of Polylactic Acid Natural Fiber Biocomposite

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Abstract— Polylactic acid (PLA) is a natural based composite which has gained great interest in composite industry due to its biocompatibility and biodegradability. However, PLA has its drawbacks such as brittleness, rigid behavior, low heat distortion temperature and poor thermal stability. These problems can be overcome by blending with natural fibers. This paper reviews the performance of PLA blends with three different natural fiber; namely the Empty Fruit Bunch (EFB), Banana Fiber (BF) and Kenaf Fiber. It can be concluded from reviews that PLA blends with natural fibers have potential to reduce the cost of PLA production and provide alternative composite which is more biodegradable and environmentally friendly.

Keywords— (Polylactic acid, Natural Fiber, Kenaf Fiber, Empty Fruit Bunch, Banana Fiber)

I. INTRODUCTION

Composite fabrication has created much attention in research, developmental sector as well as industry due to high demand in applications such as construction, automotive industries [1]. Composites are becoming an essential part of demanding material due to their advantages; such as light weight, corrosion resistance, high strength and excellent resistance to fatigue, creep and wear.

Polylactic acid (PLA) has received much attention in alternative biodegradable polymers [2]. Even though the cost of producing PLA is high but PLA has been chosen among other available polymers. This is due to the unique properties of PLA including biodegradability [3], biocompatibility [4,5], good mechanical properties and processability. Due to high cost of PLA, researchers continuously looking for an alternative method to reduce the production cost of PLA, such as by means of blending with natural fibers.

The strength and the stiffness of the natural fibers have the same properties as synthetic fibers. The advantages of natural fibers are the availability of raw material, cheapest cost of raw material of natural fibers compared to others, its market

readiness and acceptance, market outlook and trends, product substitution, cost effectiveness and environment concern compared to the synthetic fiber.

II. BLENDING POLYLACTIC ACID (PLA) WITH NATURAL FIBERS

A. PLA with Kenaf Fiber (PLA-KE)

Ngo *et al.* focused on tensile and flexural properties of varied volume fraction of kenaf fibre, V_f (20, 40 and 60%) reinforced polymer composites [6]. It is obtained, when increase in kenaf fibre, the tensile and flexural strength increased which is up to the maximum value and the properties were decreased at V_f of 40%. Further increase of fibre V_f at 60%, deteriorate occurs. The fibres tend to aggregate which weakens the interfacial area and debonding tends to take place between the fibres and matrix that at V_f greater than 50% [7,8].

Ochi [9] investigated V_f of kenaf fibers in the specimens which composition varied from 30-70%. "Fig. 1(a)" and "Fig. 1(b)" represents the flexural and tensile properties respectively.

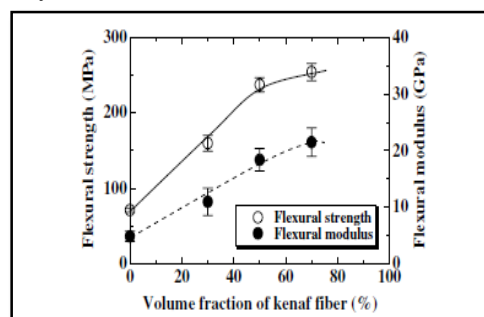


Fig. 1(a). Flexural properties of PLA-KE

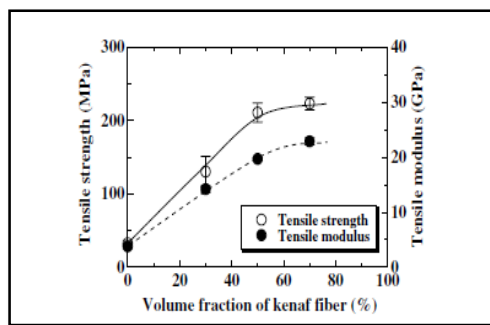


Fig. 1(b). Tensile properties of PLA-KE

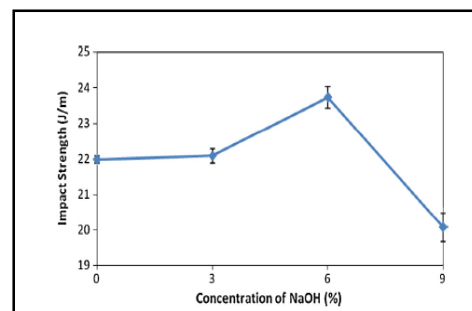


Fig. 2(b). Impact properties of biocomposite

The flexural and tensile properties showed the highest value at V_f 70%. Increasing fiber loading weakened the strength due to fracture of low-strength fibers. Excessive fiber and insufficient amount of resin was found when fiber content is greater than 70% leads to less fiber resin contact.

Based on pre-treatment method conducted by Syukor *et al.* [10], PLA-KE (75:25 wt%) that was treated with 6% NaOH solution gave the highest flexural strength as compared to 3% and 9% NaOH pre-treatment. "Fig. 2(a)" and "Fig. 2(b)" shows both flexural and impact properties of PLA-KE sample. The flexural strength is weakened at high concentration NaOH (ie. 9% NaOH pre-treatment) due to damaged fiber thus reduces the strength of the fiber. Detail justification has been discussed by Mwaikambo and Ansell [11]. The treated PLA-KE at 6% NaOH had higher impact strength compared to untreated PLA-KE which proved that surface treatment enhanced the impact strength of the biocomposite [12].

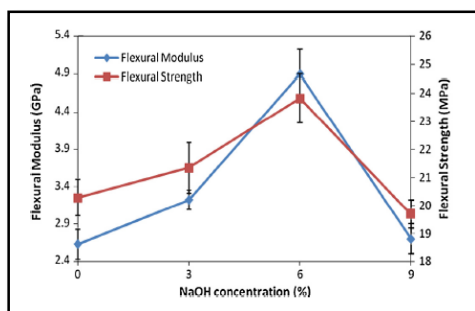


Fig. 2(a). Flexural properties of biocomposite

B. PLA with Empty Fruit Bunch (EFB)

Moshiul Alam *et al.* works on PLA-EFB biocomposite that have been fabricated by using random and fixed-length fibers through extrusion followed by injection molding [13]. Raw EFB fibers with a vary length (random, 10, 20, 30 and 40mm) length. Factors such as length, roughness and surface chemistry of fibers affect the adhesion strength between fiber and polymer matrix. "Fig. 3" referring to the Tensile Strength and Tensile Modulus of the sample.

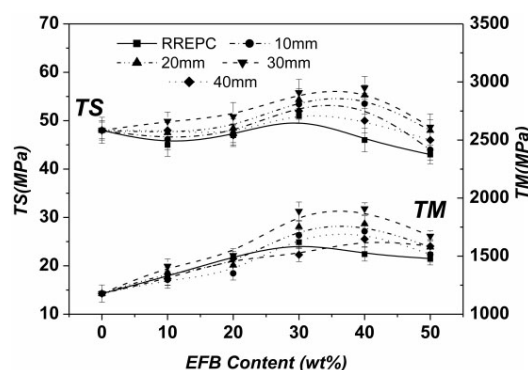


Fig. 3. Tensile strength and tensile modulus of EFB-PLA composites as a function of fiber content for different fiber lengths.

They found that mechanical performance was deteriorated at fiber length larger than 30 mm. This was due fiber entanglement which can cause agglomeration. Fiber dispersion in the matrix became inhomogeneous and hence less interaction between fiber and matrix occurred.

Senawi *et al.* analyse the effects of fiber surface treatments on biocomposite PLA-EFB properties [14]. Surface treatment on EFB was conducted using alkali followed by silane treatment. Treatment of fiber has been done to enhance the compatibility of EFB with the polymer matrix. Comparison of untreated and treated composite has been done. Treated fibers (TF) showed superior mechanical properties compared with untreated fiber due to the enhanced adhesion between the EFB fiber and the PLA matrix. TF showed increase in flexural strength value compared with untreated fiber biocomposite due to any factors affecting the modulus of the biocomposite such as filler loading, aspect ratio and good dispersion or mixing between

the fiber and matrix [15]. Alkali treatment on fiber is efficiently effective to remove all impurities which in mean times rougher the surface of the fiber. The alkaline treatment also will enhance the fiber adhesion, while silane will act as coupling agent which connected between empty fruit bunch and PLA. Alkali treatment removes surface impurities which cause rougher fiber surface [16]. "Fig. 4(a)" and "Fig. 4 (b)" illustrate the Scanning Electron Microscope (SEM) for the untreated and treated EFB. The rough surfaces increase the additional sites of mechanical interlocking and promote more matrix or fiber interpenetration at the surface. John et al [17] claimed that alkali and silane treatment resulted in higher value of tensile properties compared with untreated fiber.

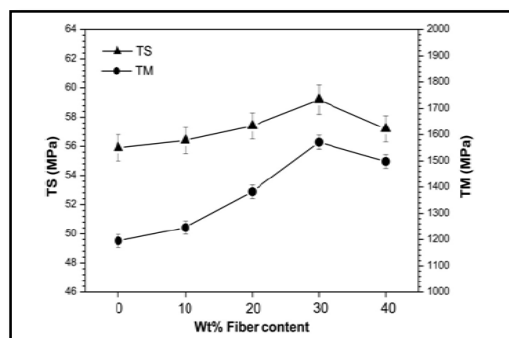


Fig. 5(a). Tensile Strength of PLA-EFB composite.

TABLE I. MECHANICAL PROPERTIES OF TREATED AND UNTREATED FIBER BIOCOMPOSITE

Sample	Mechanical Properties of PLA-EFB				
	Tensile Strength [MPa]	Tensile Modulus	Flexural Strength [MPa]	Flexural Modulus	Impact Strength [J/M]
Untreated fiber biocomposite	30.2	0.9	72.1	3.1	31.4
Treated fiber biocomposite	53.0	1.1	84.4	4.4	35.0

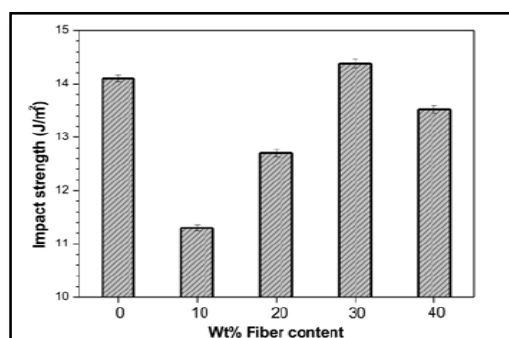


Fig. 5(b). Impact Strength of PLA-EFB composite.

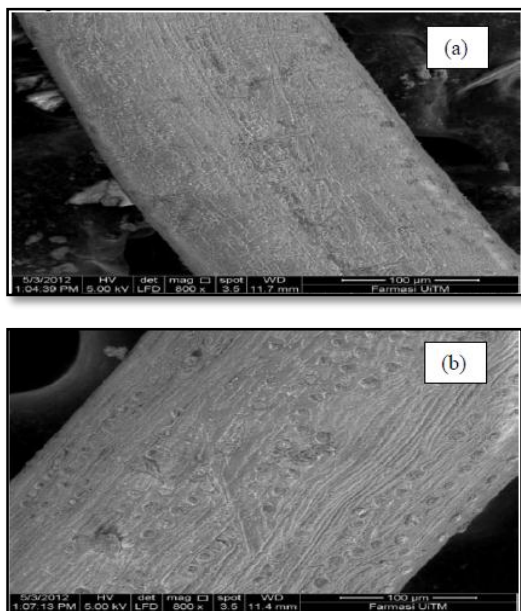


Fig. 4. SEM images of EFB fiber, (a) Untreated fiber (b) Alkali treated.

Beg *et al.* conducted a research to observe the effect of fiber treatment on PLA-EFB composite [18]. "Fig. 5(a)" and "Fig. 5(b)" showing the mechanical test conducted on PLA-EFB composite. Mechanical testing showed an improvement of up to 23.5% and 33.6% respectively for tensile strength and tensile modulus of treated fiber composite above untreated fiber composite. 30wt% treated fiber loading shows the higher impact compared to others.

Excessive fiber would lead to the overcrowded materials when the fibers are too close to each other leading to agglomeration of fiber. Agglomeration within the composite would cause excessive break in stress transfer between matrix and fiber and reduce the biocomposite performance [19]. 30 wt% is the critical fiber loading that can withstand the impact applied. Impact result for 10 and 20wt% shows lower value than pure PLA could be affect by the low population of fiber within the composite and formation of concentrated areas for local stress [20,21].

Hatta *et al.*, conduct a research with EFB fibers were treated by APS and coated with PLA in varied percentage (5, 10 and 15 wt%) [22]. "Fig 6(a)" and "Fig. 6(b)" shows the flexural testing strength and modulus response of the composite. Treated composites shows higher flexural value compared to the untreated composites, resulted from better stress transfer from matrix to fiber due good bonding between the matrix and fiber.

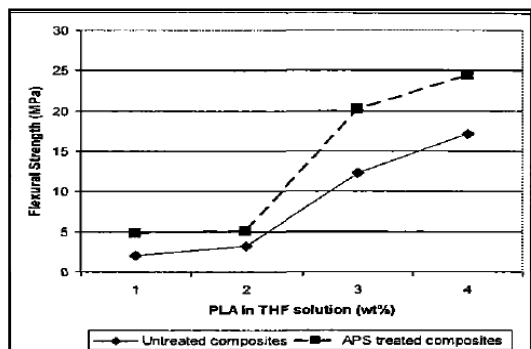


Fig. 6(a). Flexural Strength of the composites.

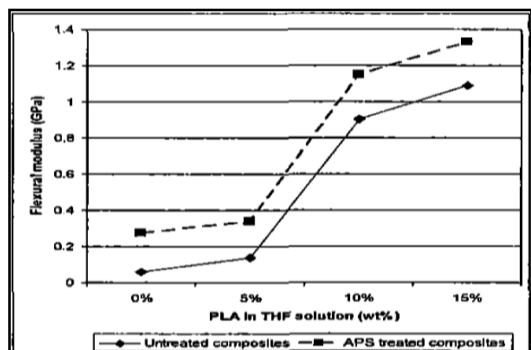


Fig. 6(b). Flexural Modulus of the composites.

C. PLA with Banana Fiber (BF)

Research done by (Yeng-Fong Shih *et al*, 2011) [23] study effect of ratio of the PLA-BF composites. The mechanical properties of the PLA were dramatically elevated through the incorporation of varied BF (0, 20, 40, 60) phr. Tensile strength and modulus of the reinforced PLA are greater than pristine PLA. Tensile and flexural strengths of the composites increased with the fiber content when reinforced with 40 phr fiber. However, the impact strengths of composites are decreased with the increased content of fibers. Rigidity of PLA is improved by the addition of fibers, but leading to the brittleness.

“Fig. 6(a)-(c) shows SEM analysis on untreated banana fiber, alkaline-treated banana fiber and chemical modification banana fiber. Untreated banana fiber full covered with impurities. Alkaline banana fiber treatment produce cleaner appearance compared to untreated, while chemically modified fiber was covered by a thin layer of silane.

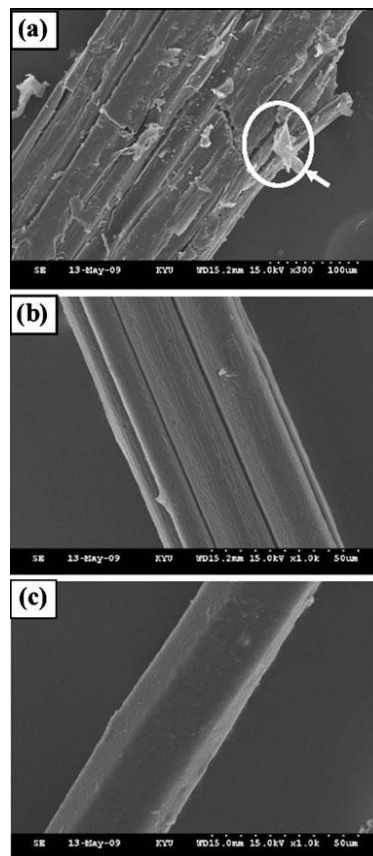


Fig. 6. SEM micrographs of the (a) untreated banana fiber, (b) alkali-treated fiber and (c) modified banana fiber

TABLE II. MECHANICAL PROPERTIES OF PLA AND THE COMPOSITES

Sample	Mechanical Properties of PLA-BF				
	Tensile strength [MPa]	Tensile Modulus [GPa]	Elongation at break [%]	Flexural strength [MPa]	Impact [J/m]
PLA	39.3	1.17	2.53	39.4	22.2
PLA20	53.8	2.35	1.29	49.4	17.2
PLA40	78.6	7.20	0.24	65.4	17.1
PLA60	65.1	11.35	0.08	64.1	15.0
PLA20*	46.3	6.63	0.23	46.6	17.1

Jandas *et al.* study the effect fiber loading towards of PLA/BF properties [24]. Banana fiber was chemically modified using coupling agents like APS, [bis-(3-triethoxysilylpropyl) tetrasulfane] (Si69) and mercerized using NaOH solution.

TABLE III. TENSILE PROPERTIES OF SINGLE BANANA FIBER AS A FUNCTION OF SURFACE TREATMENT

Sample	Mechanical Properties of single strand banana fiber		
	Tensile strength [MPa]	Tensile Modulus [GPa]	Elongation at break [%]
UBF	1,572 ± 29.33	67 ± 1.2	1.45 ± .03
Na-BF	1,272 ± 32.14	65 ± 3.7	2.04 ± .13
APS-BF	1,812 ± 21.23	70 ± 2.1	2.29 ± .10
Si69-BF	2,125 ± 26.33	76 ± 1.9	2.89 ± .06

Si69-BF gave a better mechanical performance for banana fiber. Silane also can act as coupling agent in order to enhance the tensile of BF. Mechanical properties of PLA Banana Fiber composite with vary of fiber loading (0-40 wt%), are conducted to choose the best fiber-matrix ratio.

TABLE IV. MECHANICAL PROPERTIES OF PLA/BF COMPOSITES AT DIFFERENT FIBER LOADING

Sample	Mechanical Properties of PLA-EFB			
	Tensile strength [MPa]	Tensile Modulus [GPa]	Elongation at break [%]	Impact [J/m]
V-PLA	38.00 ± .35	3,546 ± 36.66	2.91 ± .32	24.70 ± 2.3
PLA/BF (90/10)	10.55 ± .42	3,963 ± 44.58	1.45 ± .26	14.66 ± 1.6
PLA/BF (80/20)	13.00 ± .65	4,210 ± 56.12	1.14 ± .61	15.18 ± 1.9
PLA/BF (70/30)	14.61 ± .44	4,631 ± 38.26	1.08 ± .28	19.10 ± 1.2
PLA/BF (60/40)	7.76 ± .45	4,705 ± 33.91	.90 ± .51	13.52 ± .91

PLA/BF biocomposites tensile strength decreases start at 10 wt% of fiber loading, which further increased consistently with the increase in fiber loading. Beyond 30 wt% of BF, a significant decrease in tensile strength was observed may due to a higher fiber content agglomeration of fibers takes place, which results in poor stress transfer across the interface.

III. CONCLUSION

Blending of PLA with natural fiber is a simple and efficient method to improve PLA properties and reduce the cost of production. This review summarizes that the presence of natural fibers affect the properties of PLA. Blending PLA with natural fiber would increase the biodegradability of PLA and make the biocomposite more environmental friendly.

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