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MECHANICAL PROPERTIES OF STARCH COMPOSITE REINFORCED BY PINEAPPLE LEAF FIBER (PLF) FROM JOSAPINE CULTIVAR

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ABSTRACT

Nowadays, there is an increase in research about renewable natural fiber as an alternative solutions in replacing synthetic fibers such as glass fiber as reinforced composites materials that are non – biodegradable and non – ecofriendly to the system. Natural fibers are also known for its low cost production yet have excellent mechanical properties and is environmental friendly. One of the natural fiber resource is pineapple leaf fiber (PLF) which is planted widely in Malaysia. From current research, PLF contains high cellulose and exhibits good mechanical properties especially from Josapine family. In this study, the PLF from Josapine is used as reinforced materials and starch (SH) is used as the binder. Additionally, the effects of PLF loading and PLF fiber length on the mechanical properties of PLF/SH composites is also analyzed. Compositions ratio of PLF/SH composites is fixed at 50/50, 60/40 and 70/30. The lengths of the fiber are fixed to 2 cm, 4 cm and 6 cm. Before the fabrication, PLF has underwent alkaline treatment to increase the strength of fiber. All nine samples has underwent four different tests to determine the mechanical properties which are tensile test, hardness, density and microstructure analysis. PLF loading of 70% with 6 cm in length shows the higher values of tensile stress, density and hardness which are 14.53 MPa, 33.63 and 1.20 g/cm^3 respectively.

Keywords: pineapple leaf fiber, starch, josapine, biodegradable, fiber-reinforced plastics.

INTRODUCTION

Green composites are the combination of two or more natural resources materials basically made up of two materials that are fibers/reinforced and matrix/binder. This combination gives unique properties especially in mechanical properties where properties are difference from their each material. The examples of fibers/reinforced materials are extraction of natural fiber from various sources such as banana leaf, pineapple leaf, kenaf, bamboo and coconut (Yusoff, *et al.*,2010), (Selamat, *et al.,* 2014), (Dhal, *et al.,* 2013), (Wambua, *et al.,* 2003). The example of matrix/binders materials are starch, epoxy, polypropylene and etc. Based on the past history, the mankind has used composites materials as an innovation to improve the quality of life. An example is to make mud bricks become more studier where mud is combined with straw, also known as adobe. In this case, mud will become the binder by holding the straw together. This increases the strength of the construction of the building itself.

In recent years, natural fibers or green composites are being increasingly used as reinforcement in polymer composites and have high potential in replacing the fiber glass reinforced composites. This is due to their low cost and low density, but have good sets of mechanical properties as compared to fiber glass reinforced composites. On top of that, natural fiber offers many technological and environmental benefits when used in reinforced composite such as high strength and good stiffness quality, despite being low density. Besides that, natural fibers comes from many resources that are originally from the contained of fiber in the plant itself such as bamboo fiber, coconut fiber, pineapple leaf fiber, hemp fiber and jute fiber. Literature too reveals many industries increasingly used natural fiber composites as one of the materials used in their production (Kengkhetkit *et al.,* 2014), (Wisittanawat, *et al.,* 2014). For example, Mitsubishi tried using bamboo fiber to produce automobile interior parts. There are also other such examples done from previous research (Drzal, *et al.,* 2001), (Kazuya, *et al.,* 2004), (Keiichiro, *et al.,* 2010). This developments show that the natural fiber consume lesser energies during production, cause lesser abrasion to the machines and cause no risk to human health especially during inhalation. Other than that, it also contains less carbon dioxide imitation and biodegradable that makes it more environmental friendly. Based on previous studies, natural fibers also have good thermal permeability and the strength of the fiber will be increased if it undergoes a chemical treatment.

Recently, natural plant fibers have been used in scientific research as potential alternatives to glass fibers (GF) in fiber-reinforced plastics (FRP). Relative to glass fibers, these lignocellulose fibers have lower densities, cost relatively lower, consume lesser energies during production, pose no abrasion to machines and have no health risk when inhaled. Furthermore, natural fibers are also widely available, renewable, recyclable, and biodegradable and made of carbon dioxide (CO_2) neutral (Wambua, *et al.,* 2003), (Kalapakdee, *et al.,* 2014), (Chandramohan & Marimuthu, 2011). The used of synthetic fiber as reinforced composites will affect the environment and cause pollution to the soil as they are non-renewable, non-biodegradable and not eco-friendly despite of its good mechanical properties (Abdul Khalil *et al.* 2006). In Malaysia the focus of the pineapple industry

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is only on fruit. Other parts of the pineapple such as leaves have produced abundant bio waste and normally is just composted or burnt, thus wasting the good potential of fiber sources. The burning process of the leaves leads to environmental pollution problems (Mohamed, *et al* 2009 & Mohanty, *et al.* 2005).

From a large selection of plant fibers, pineapple leaf fibers (PLF) obtained from the leaves of pineapple plant of Josapine have the highest cellulose contents which make the fibers mechanically sound (Vinod *et al.* 2013). PLF exhibits excellent mechanical properties due to rich cellulose content of more than 70% which are potential to be used as reinforcement in polymer composites (Mohamed *et al.* 2010). The combination of PLF used as reinforce material and the starch (SH) based composite as the matrix materials that are totally green composites materials used to produce PLF/SH composite may reveal a good potential result in mechanical properties especially for plastic industries product. This research will study the effects of PLF loading and PLF fiber length on the mechanical properties of PLF/SH composites. The various ratio of PLF/SH composite will be selected and the ratio of composition in the PLF/SH composite was fixed at 70:30, 60:40 and 50:50. Meanwhile the PLF length will be fixed with the length of 2 cm, 4 cm and 6 cm. An alkaline treatment will be conducted to extract thin PLF bundles and enhance the PLF properties before the formation process of PLF/SH composite used hot press. The mechanical properties of the PLF/SH composites will be determined used tensile test, flexure test, hardness test, density measurement and microstructure analysis.

METHODOLOGY

The materials used in the fabrication of FRP composites are PLF and SH. Figure-1 (a) and (b) shows the image of PLF and ST. Meanwhile, the composition of this composite is listed in Table-1 and Table-2 shows the specific mechanical properties of PLF.

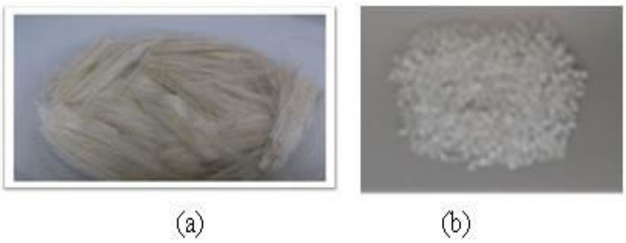

Figure-1. Photograph image: (a) PLF ; (b) Starch.

Before the PLF can be used as reinforcement material, an alkaline treatment was done. The PLF was cut into small pieces with the approximately length of 2, 4 and 6 cm and Pineapple leaves from Josapine cultivars were collected from cultivation areas in Pontian, Johor Malaysia. The extraction process of PLF was extracted by a decortications machine named Pineapple Leaf Fiber Machine. Extraction process was performed to get the fibers by feeding the pineapple leaf into the Pineapple Leaf Fiber Machine. This machine used blades to remove the waxy layer on the pineapple leaf instead of forcing it out by crushing (Yusuf, *et al* 2015). After the extraction process the fibers undergo an alkaline treatment process which was immersed in 5% concentration of the NaOH. The 1% concentration of the HCL was used to neutralize the PLF. The functions of chemical treatments are to clean all the impurities, treat the fiber surface and also to stabilize the molecular orientation. Vinod and Sudev (2013) state that by undergoing the chemical treatments the mechanical properties of the material can be improved. Before the formation process, the starch is heat until melted and then mixed with PLF. After that the mixer is pressed by using a hot compression mold at temperature about 60 ^{0}C and pressure about 25kg/cm^2 for one hours. After that the sample is set to a cooling down process to room temperature before taken out from the mold. Some mechanical testing was conducted that are tensile test (ASTM D 3039/D 3039M-00), shore hardness test, density measurement and microstructure analysis.

Table-1. Composition of PLF/SH composite.

PLF %	Length (mm)	SH%
70	20	30
	40	
	60	
60	20	40
	40	
	60	
50	20	50
	40	
	60	

Table-2. Specific mechanical properties for cultivars of PLF.

Mechanical Properties	Cultivar Josapine
Tensile Strength (MPa)	293.08
Young's Modulus (GPa)	18.94
Elongation at Break (%)	1.41

Tensile test is performed according to ASTM D 3039: Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. The specimens having dimensions of 140 mm length, 13 mm width and 3 mm thickness were tested using Instron Universal Testing Machine (Model 5585H) controlled by Bluehill 2 software with a 1 kN load test and operated at constant head-speed tests of 2 min/mm. The density of PLF/PP composite was measured using Digital Electronic Densimeter (MD-300S). The hardness of PLF/PP composite was measured using an Analogue Shore Scale "D" type Durometer according to ASTM D1957. The hardness of the samples was measured by the depth of the indentation and the reading was registered on the dial indicator.

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RESULTS AND DISCUSSION

Effect of PLF length based on PLF loading on tensile

Based on the Figure-2, the result obtained shown that the tensile stress has increased as the fiber content has been increased. According to the fiber lengths, the fiber lengths of 2 and 4 cm shown the steady state of increment as the fiber loading has been increased. However, for fiber with the length of 6 cm has shown significant increment as fiber loading has been increased. Meanwhile according to the length, fiber with the length of 2 cm shows the lower value for all fiber loading. This may cause by two main situations which are, the presence of voids and weak bonding interface between binder and reinforcement materials (Kumar, 2014).

It also shows that, tensile stress is higher at 70% of fiber loading as compared to the other two fiber loadings, which is the higher value is 14.53 MPa at 6 cm fiber length. This because more fiber loading or content enhances the strength of the composites. Here the function matrix is to transfer the forces to the fibers. Hence, if the fiber loading is increased, it can withstand higher forces as compared to lower fiber contents.

The result obtained from this experiment contradicted with the result that had been found by Kasim *et al* (2015) which used long PLF with the length of 10 cm long and the matrix used was PP, the tensile strength of the PLF/PP was increased as the fiber content decreased. PLF used by the researcher is from the state of Perak. Table-3 shows the data of Tensile Test result. The data tabulated in table were Tensile Stress σ (MPa), Young Modulus E (GPa) and Strain (ε) before yield. The data were tabulated according to their PLF Loading (%) for 50, 60 and 70 for each 2cm, 4cm and 6 cm of length. From the table, it shows that, the PLF Loading (%) of 70 with 6cm in length has the highest value of σ and E which are 14.53 MPa and 2.39 GPa respectively. In contrast, it has the lowest value strain ε which is 0.030.

Table-3. Data of tensile test.

PLF Loading (%)	Length (cm)	Tensile Stress, σ (Mpa) ± 0.05	Young Modulus, E (Gpa) ± 0.05	Strain, ε ± 0.05
50/50	2	2.07	0.25	0.090
	4	3.87	0.28	0.110
	6	3.67	0.11	0.080
60/40	2	4.18	0.43	0.080
	4	4.58	0.49	0.070
	6	6.91	0.47	0.050
70/30	2	4.08	0.56	0.040
	4	4.98	0.52	0.060
	6	14.53	2.39	0.030

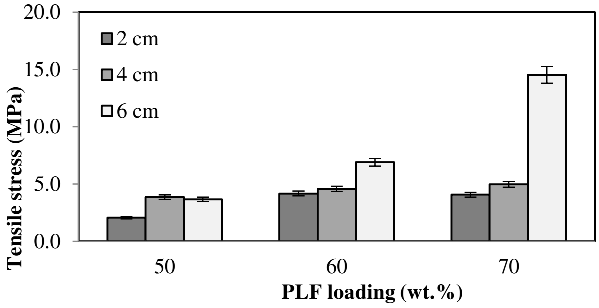


Figure-2. Graph of tensile stress (MPa) against PLF loading (%).

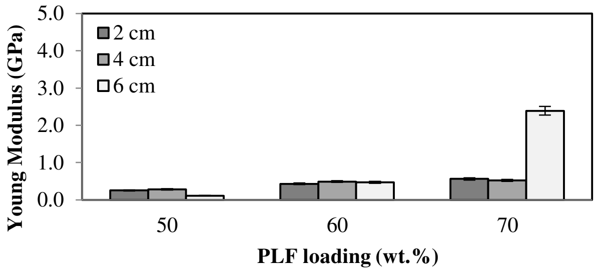


Figure-3. Graph of young modulus, E (GPa) against PLF loading (%).

Figure-3 show the graph of Young Modulus (GPa) against the PLF loading (%). From the graph, it can be seen that, all the values were slight increased for 2 cm and 4 cm. However, for 6 cm, after the 60% of PLF loading the graph shows significant increased. In overall result, it shows increasing graph patterns for each different length followed by their PLF loading (%).

Based on the research that had been done by Mohamed *et al.* (2010) it shows that, the Josapines cultivars has the highest values of tensile stress because it has the finest fibers which is the diameter of the fibers only 105 – 300 μm as compared to the other two types of cultivars from Moris Gajah and Sarawak. In this experiment, the cultivars of PLF used was from Josapines.

Effect of PLF length based on PLF loading on hardness

Based on the graph in Figure-4, it shows that, the hardness has increased with the increment of fiber loading for all sample. The hardness result obtained for the fiber length of 2 cm does not show much different for all fiber loading. Meanwhile for the fiber lengths of 4 and 6 cm it show significant increment as fiber loading has been increased. For fiber loading, it can be seen clearly that, 70% of fiber loading has shown the highest values of the hardness for all fiber lengths. The hardness has decreased as fiber length decreased. This may be caused by unsmooth surface finishing of the samples because the samples cannot withstand the wear resistance of the composites.

In a research by Danladi & Shu,aib (2014), the materials used was long fiber PLF and HDPE as matrix and George *et al* (1995), materials used was short PLF with lengths of 2, 6, 10 mm and LDPE as matrix. The results shows that the hardness of the composites increased as the increment of fiber loading. The result obtained by this researchers are in lined with the result obtained in this experiment.

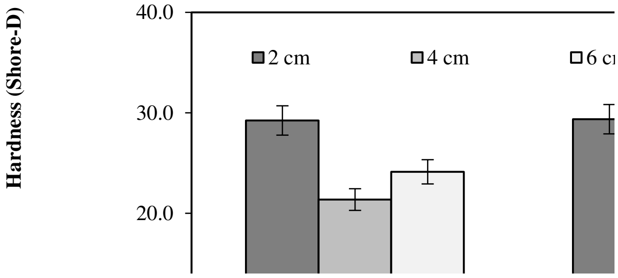


Figure-4. Graph of shore hardness – D against PLF loading (%).

Effect of PLF length based on PLF loading on density

Based on the graph in Figure-5, the lowest density is in 50% of PLF Loading and the highest density is at 70% of PLF loading. So, as the PLF fiber loading has been increased, the density will also increase. The same goes to the length of the fiber. The fiber length is directly proportional to the density. It can be concluded that, the length of fiber and the loading of the fiber can affect the density of the composites. For composition of PLF/SH (%) 50/50 and 60/40 it has greater value of matrix content as compared to 70/30 composition. In this situation, the starch matrix is fully covered with fiber and makes it less water absorption through the samples.

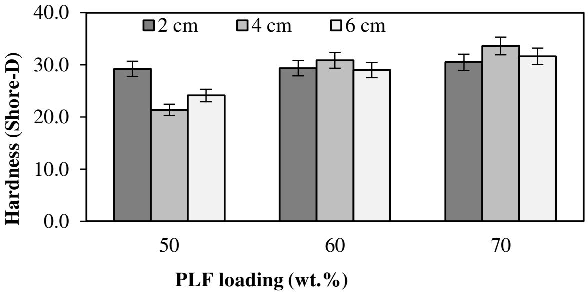


Figure-5. Graph of density (g/cm^3) against PLF loading (%).

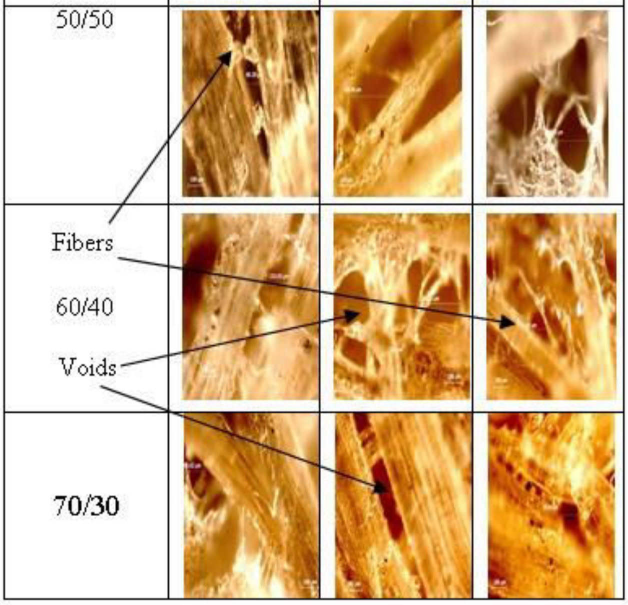
The PLF fiber is hydrophilic in nature thus it has poor resistance to the moisture and incompatible to the hydrophobic polymer matrix. The incompatibility will result in poor fiber/matrix interface and reduce the mechanical properties of the composites itself (Jeyanthi & Rani, 2012).

Microstructure analysis

Table-4 shows that, for higher fiber loading, it will have lesser void compared to lower fiber loading. Even though the high volume content of matrix presence in fiber loading of 50% and 60%, however, in terms of quantity of void it has higher void compared to 70% fiber loading. The effect of length in each fiber loading cannot be determined clearly and is not varied too much.

Table-4. The Microstructure view for each length followed by the composition of PLF/SH.

Composition PLF/SH (%)	Magnification 20X/Length (cm)		
	2 cm	4 cm	6 cm
50/50			
60/40			
70/30			



The presence of void will affect the mechanical properties such as tensile strength, hardness and impact strength. Besides, the longer fiber length will have good adhesion between the fibers and the matrix that will result to stronger bond between each other. The presence of the small gap and the voids may cause by incomplete wettability between the starch matrix and PLF reinforcement (Kumar 2014).

The results obtained in this experiment are contradicted with Arbi *et. al* (2009), which the researcher discovers that with higher composition matrix, will have smaller size of void or lower void. This is because the matrix is effectively cured in the void spaces. In other words, the smaller voids will decrease the density and increase the mechanical properties of the composites. The researcher used long fiber PLF as reinforcement and combine with PP as the binder.

CONCLUSIONS

The main objectives of this research is to study the effect of length on the mechanical properties of the PLF/SH composites. The fiber used as reinforcement and matrix that act as binder in this experiment is totally from biodegradable materials. From the result obtained, useful composites with good mechanical properties could be successfully produced by using the combination of PLF and the SH as the binder. The results also reveal that it can be concluded that, the fiber loading also affect the mechanical properties of the composites. The fiber loading of 70% show interesting results especially in tensile stress and hardness. Nevertheless, the major drawback of the addition of the fiber loading is it will increased the density of the composites too. In this experiment, the 70% fiber loading will gives 14.53 MPa, 33.63 and 1.20 g/cm3 for tensile stress, hardness and density respectively.

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