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A STUDY ON TYPES OF PINEAPPLE LEAF FIBRES (PALF) REINFORCED POLYLACTIDE (PLA)

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Abstract

Over the past decades, most of biocomposite material is developed from a combination of matrix polymers and a reinforcement of synthetic fibers or a conversely combination. The biocomposite materials have been resulted in superior performance in many applications. However, due to global warming issues and exhausting of petroleum resources have enforced the researchers to substitute the nonrenewable materials with natural basis materials. Thus, for this particular research, both of matrix and reinforced agent are utilizing natural based resources. In Malaysia, one of the most potential natural basis fibers is derived from pineapple wastes. PALF is extracted from pineapple leaf wastes which are easily found during harvesting pineapple plantation. The fibres are extracted from different types of pineapple available in Malaysia which are Moris Gajah, Jasopine, Maspine, and N36. Polylactide (PLA) is used as a natural binding element. The main objective of this study is to investigate mechanical properties of this new green based composite via tensile and bending tests. For a material properties comparison purposes, PALF reinforced polypropelene also was develop. Based on the result, Jasopine fibre shows the highest tensile and flexural strength for the combination of both polymers compared to other types of PALF. The result data on material properties will be useful to optimize material processing which will give information to other application such as design of product using this new composites material.

Keywords: Green composite, Pineapple Leaf Fibres, Polylactide

1. Introduction

Todays, a crucially demand, increasing cost and environmental effect due to application of synthetic fibre reinforced polymers have forced the scientist and engineer to synthesize new materials and composites. Increased environmental awareness and interest in long-term sustainability of material resources has motivated considerable advancements in composite materials made from natural fibres and resins, or biocomposites [1]. Moreover, critical factors such as a non-biodegradability of polymer matrix and the exhausting petroleum resources have triggered the development of bio-based materials which are made only from renewable resources [2].

Previously, most of the researchers have focused on utilizing natural fibres or other sustainable sources as a reinforcement element in bio-composite material, while using a petrochemical resin as a matrix element. However, instead of using the non-renewable material, the matrices or polymeric materials are currently be replaced by a natural or renewable source such as vegetable or animal resins which offer an alternative source in order to maintain the sustainable development of an economically and ecologically attractive technology. Composites manufactured from plant derived fibres and crop-derived plastics are known as green composites [3]. This type of composite has attracted academic and industrial interest as the development of the composites potentially provided the innovations itself in the development of materials from biodegradable polymers, the preservation of fossil-based raw materials, complete biological degradability, the reduction in the volume of garbage and compost ability in the natural cycle, protection of the climate through the reduction of carbon dioxide released, as well as the application possibilities of agriculture resources for the production of green materials [4].

Pineapple or its scientific name was Ananas Comosus is a tropical plantation which is widely cultivated in Malaysia. In a development of plantation crops, pineapple is easily found

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throughout the year. According Malaysian Pineapple Industry Board, there are five types of pineapple successfully cultivated in Malaysia. The types of pineapples are Morris, Sarawak, Maspine, Hybrid N36 and Josapine.

Pineapple Leaf Fiber, PALF is a waste product of pineapple. Current practices by farmers, pineapple leaves are mainly wasted through composting and burning which has led to environmental pollution. These pineapple fibers can be obtained for some value added applications for industrial purposes without any additional cost [5]. Among various natural fibers, pineapple leaf fibers exhibit excellent mechanical properties and performed with high specific strength improved the mechanical properties of the polymer matrix. This fibers are multicellular and lignocellulose.

In addition, recent studies are more demanding on developing a biocomposite by a combination of natural fiber and polypropylene or natural fiber with polyester. Although the composites using the natural fibers, it is still not sufficiently eco-friendly due to the petro-based source as well as non-biodegradable nature of the polymer matrix. Hence, the polymers combined with natural fibers renewable resources will allow many environmental issues to be solved. Therefore, in the last few years, the researcher starts to find other alternative to come out with producing more eco-friendly materials for industrial application such as automotive and building construction. It is highly recommended to solved the problems by embedding bio-fibers with renewable resource based biopolymers such as cellulosic plastic, corn-based plastic, starch plastic and soy-based plastic [6].

Biopolymers are derived from eco-friendly renewable resources [7]. The commercialized biopolymers in the existing market are such starch plastics, cellulosic plastics, polylactic acid and soy-based plastics. One of the renewable resource-based bio-plastic applications is starch plastics which are intended used for packaging and disposables items. The consumption and demand for biodegradable polymers has increased in the last few decades. Among biodegradable matrices, Polylactide (PLA) and Poly (3-hydroxybutyrate (PHB) are frequently used to be combined with natural fibres [8].
Development of fibres reinforced PLA has become more interested as its valuable in some extend application. The interests in polylactides have increased significantly due to their biodegradability and biocompatibility. For the examples, renewable fibres as reinforcements were vastly used in composites of interior parts for a number of passenger and commercial vehicles such as Mercedes-Benz used an epoxy matrix with the addition of jute in the door panels in its E-class vehicles back in 1996 [9]. Furthermore, Toyota also claims to be the leading brand in adoption of environmentally friendly materials as 100% bioplastics. The natural fiber reinforced green composite was used in the RAUM 2003 model in the spare tire cover which made by utilizing PLA matrix from sugar cane and sweet potato reinforced with kenaf fibers . Later examples are the interior components which combine bamboo fibers and a plant-based resin polybutylene succinate (PBS), and floor mats made from PLA and nylon fibers for Mitsubishi motors [9]. Besides using as an interior of car parts, PLA composite also can be utilized in structural application.

2. Materials and Methods

2.1 Raw materials preparation

For the beginning, four types of pineapple leaves were gathered from Malaysian Pineapple Industry Board plantation in Ayer Hitam, Muar,Johor. A few bundle of pineapple leaves for each types of pineapple namely as Moris Gajah, Maspine, Josapine and N36 were collected in plantation area. The leaves then were cleaned using a towel and ready for fibers extraction process. The PALF were extracted from semi-dried leaves. The extraction process was accomplished by manual scrapping using knife or shape edge tool as illustrated in Figure 1 [10,11]. The fibers then were separated from succulent green debris gently.

Figure 1: PALF Extraction Process

Later, the extracted fibers were cleaned by using tape water in order to remove dirt and

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contaminations on the fibers. These washed fibres were treated with 5% of sodium hydroxide (NaOH) solution for one hour at 30^0C. The procedures are necessary for surfaces chemical modification which obtains alkali-treated fibers. This alkali treatment removed the natural and artificial impurities which can improve the fibre-matrix adhesion [10]. The treated fibers then were dried in oven at 70^0C for 24 hours. For development of bio-based composite samples, the fibers were cut in range of 4 to 6 mm into particles sizes which are suitable for processing size. Those fibres were placed into sealed plastic bags with the silicone to avoid moisture absorption.

In order to investigate the differences between a renewable and non-renewable plastic polymer matrix , the secondary element which is the matrices agent of the bio-composites are derived from two different sources which represented by polylactide and polypropelene. These two type of polymers were provided by Innovative Pultrusion Sdn Bhd. Polylactide resin grade 3025D was imported from NatureWorks, USA.

2.2 Preparation of the composites

Overall, there are 10 group samples comprised of two types of composites has been developed which were prepared via two processes that must be done sequentially.

Melt mixing and hot press laminating processes are regular existing processes used to develop composite material. In this particular study, Melt mixing method was used to mix PALF and matrices [10,12].

The composition of PALF and matrices were weighted accordingly and melt mixed for a period of 10 minutes at a 50 rpm of rotor speed using Rapic two-roll mill. Both of the composite samples were used the identical parameters except for a set temperature. In addition, the temperature was used as the optimum processing temperature for polymer matrices but not exceeding than that in order to prevent a reduction in strength and modulus which may be due to the degradation of fibre as a result of higher temperature. Thus, the operating temperature for PALF + Polylactide, was maintained at 165^0C while for PALF + Polypropelene had been heated at 180^0C.

Next, the blended composites were thermoformed via hot press machine. As a preparation of mechanical testing specimens, the composites where hot pressed into 3mm thickness of thin plate. Different kinds of composites had been thermoformed using the similar procedures. However, the parameters are slightly different since both of polymers have different melting point. For PALF combined with Polypropelene composite, the operating temperature was 190^0C with 15minutes of preheat, 10 minutes of compression and 10 minutes for cooling. While for PALF reinforced Polylactide resin, the same timing was used with 175^0C operating temperature. The laminated composites were cut using hacksaw and were machined into shape using grinding machine accordance to the specimen standard for mechanical testing.

2.3 Tensile and Flexural Testing

In general, tensile testing was performed according to ASTM D-638 and three point bending test was followed ASTM D-790 [5,12]. Both of the testing was accomplished using Shimadzu Universal Testing Machine with a load capacity of 10kN.

2.4 Morphological analysis

Scanning Electron Microscope (SEM) was used for morphological analysis. The morphologies of Pineapple Leaf fibre and fractured surfaces of the composites were gathered via Hitachi E-1010 Ion Sputter & Hitachi S3400N SEM. Preparation of fractured sample is necessary before performing SEM analysis. The samples were cut into a reasonable size which can be fitted into the scanning chamber. Then, the fractured composite sample is sputter coated with gold and was placed into the scanning barrel.

3. Result and Discussion

3.1 Tensile Properties

Based on the result, pure PLA has the highest tensile strength 59.0652 MPa among the materials which can accommodate the force up to 3kN. Graphical representation of PLA and PP matrices has separately shown in Figure 2 and Figure 3. As refer to Figure 2, there are huge disparities between pure PLA and reinforced

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PALF fibres. By adding 10%wt of PALF, the tensile strength of those green composite decreased approximately 90% as compared to the pure PLA.

The result is satisfying the existing findings as many studies have been carried out on cellulose fibre-reinforced PLA composites. As cited in Graupner and Mussig (2011) [8], Ibrahim et. al. had investigated, the effect of different fibre loads ranging between 10 and 50 mass% of compression-moulded kenaf fibre-reinforced PLA composites on the mechanical composite characteristics. In comparison to the pure matrix, reduced tensile strength values were measured for the composites . However, tensile strength of the bio-composite made from different types of PALF has no significant difference which the Josapine fibres produced highest tensile strength 4.27851 MPa. Three other cultivars respectively has a strength below 4.0 MPa with the lowest tensile strength is 2.22971 MPa obtained from Moris Gajah.

In contrast, the use of traditional polypropylene as a matrix element in those bio-composite materials has shown not big differences in tensile strength between PALF reinforced PP and original PP. Similar pattern has found as the additional fibres into PP decrease the tensile strength of the materials which has illustrated via figure 3.2. Moris Gajah gives the highest tensile strength 21.7368 MPa. Three other PALF reinforced PP have a tensile strength in the range from 18Mpa into 22MPa.

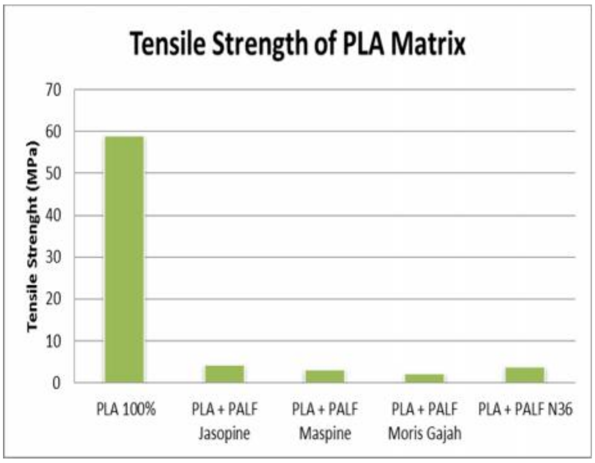

Figure 2: Tensile Strength of PALF Reinforced PLA Matrix

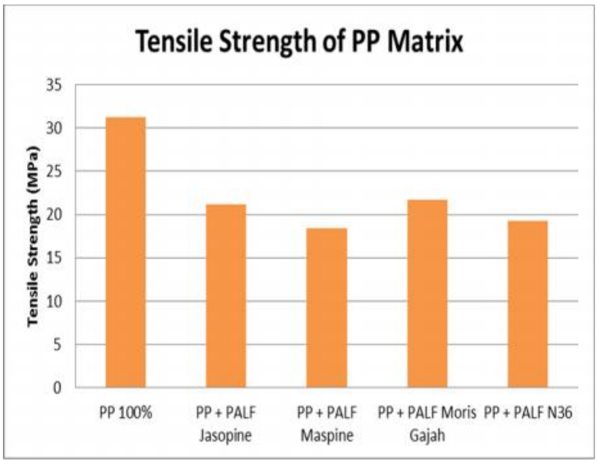

Figure 3: Tensile Strength of PALF Reinforced PP Matrix

3.2 Flexural properties

As a result of three point bending test, the flexural strength increased significantly higher than corresponding tensile strength obtained in experiment. Thus, it means that PALF bio-composite can withstand bending forces better than tensile stress. The results of the flexural bending strength showed similar trends as the results of the tensile test which flexural strength values were higher than tensile strength [8].

Flexural strength for both adhesion matrices were shown Figure 4 and 5 which indicates the similar results pattern. The bend strength for different kinds of PALF have not much differ which has a range of 10 to 18 Mpa for PLA matrix and 30 -37 Mpa for PP matrix. Among of cultivators, Jasopine also has high bend strength when combining with both matrices elements. The highest flexural strength was obtained in Josapine fibres + PLA, 18.1457 MPa while 37.2047 MPa for Jasopine + PP.

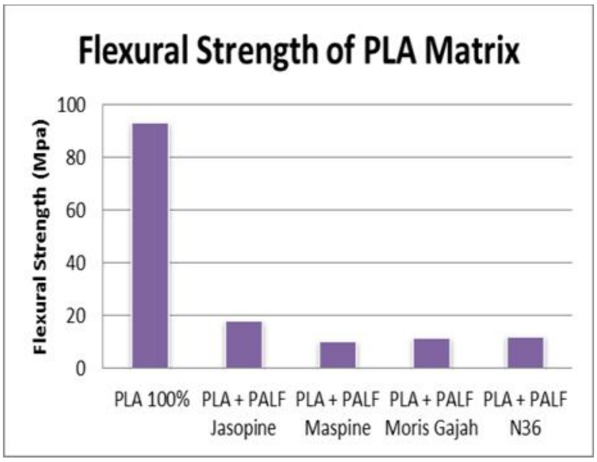

Figure 4: Flexural Strength of PLA Matrix

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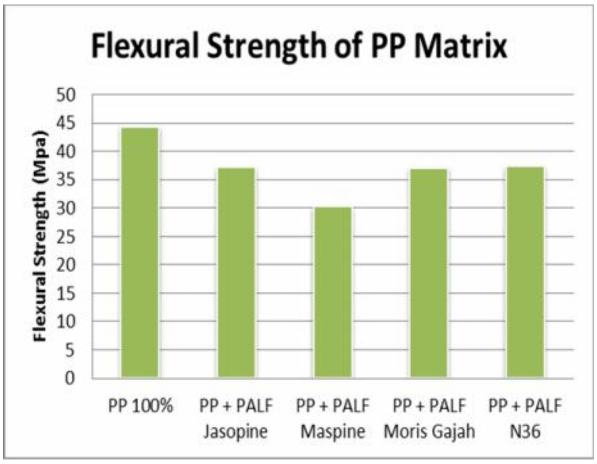

Figure 5: Flexural Strength of PP Matrix

3.3 Morphology of analysis

SEM fractographs of PLA based composites for different kinds of PALF has been taken. Figure 6 to 7 has shown the SEM Fractographs for PLA combine PALF MAspine. It is evident that the maspine fibers have more plate-like morphology while others still maintained the circular structure. At certain places there are the agglomerates formed which have been pulled out of its place leaving behind the big impressions. Biomass fiber-reinforced PLA displays no gap present between the phases. Fibers are either pulled out or seated firmly in the matrix.

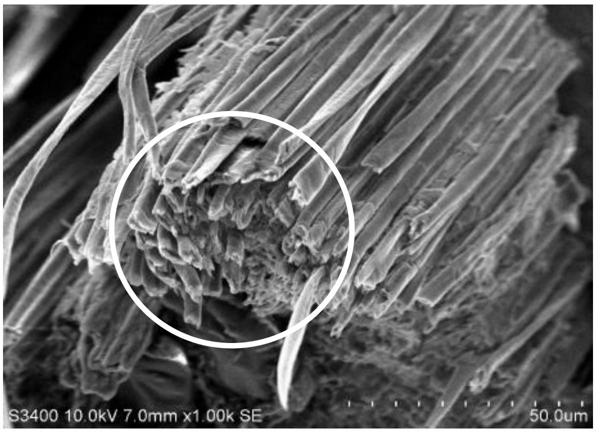

Figure 6: Fibre agglomeration

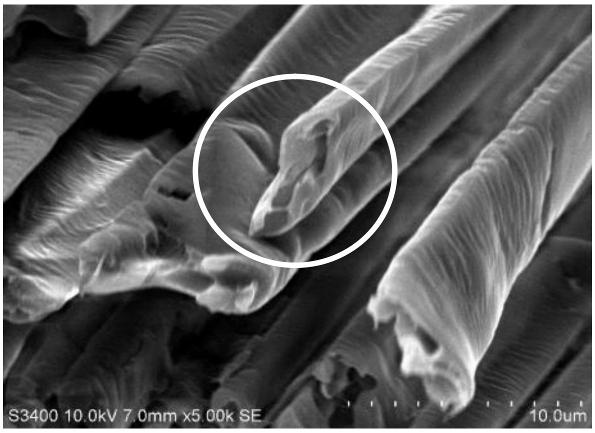

Figure 7: Flatter Fibres

4. Conclusion

Based on the results of this present study showed that natural fibres which is derived from Pineapple Leaf Fibres has a potential to be commercialized from wastes to some extend application that put a value added.

In spite of having a biodegradable ability, there are several factors that influence the possibility of using PLA as a matrix polymer. The different effect of the fibre grades on PLA degradation is a mainly attributed to a difference in fibre–PLA contact surface area, which is related to fibre or fibre bundle diameter [13]. It is concluded that relatively large amounts of moisture present in the fibres did not cause fatal PLA degradation during 13 min of compounding, whereas the PLA processing guides indicate that even small amounts of moisture will hydrolysed PLA in the melt phase.

The result is very much valuable for natural fibre–PLA composite processors. For the purpose of industrial processing scale, the economic feasibility of producing natural fibre – PLA composite is significantly influence by the required level of fibre drying. Thus, it is reported that further processing of the composite which takes more than 10 min will a cause accelerated PLA degradation due to the appears of residual moisture in the composite [13]. Among the four types of Pineapple Leaf Fibres, Josapine pineapple fibres have resulted in high tensile and bending strength. By adding 10% of Josapine PALF into PLA, the tensile strength has exceeded 4.2Mpa and 18.15Mpa for bending strength. Besides having good mechanical properties, the fibres are easily extracted from its leaves due to its features.

As a comparison between utilization of PLA and PP as matrix elements, pure PLA showed the highest tensile and bend strength. However, it is dramatically changes when the matrix is combined with PALF. Result gathered form this study shows that PP combined with PALF is approximately 80% higher in tensile strength and about 51% higher for flexural strength rather than PLA. Even though, the mechanical strength is lower than PP composite, development of fibres reinforced PLA has become more interested as its valuable in some extend application.

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