ENHANCED FLEXIBILITY OF POLYLACTIC ACID/EPOXIDIZED PALM OIL/PINEAPPLE FIBER COMPOSITES

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ABSTRACT: The concern about our dependency on non-renewable resources and overwhelming environmental issues such as pollution caused by non-degradable packaging materials has prompted researchers to come up with alternatives to solve this problem. Thermoplastic polylactic acid (PLA) has been gaining interest due to its versatility and easy processability, thus this study was carried out to find out the properties of PLA reinforced with pineapple fibers. However, surface of the natural fibers need to be treated for better properties enhancement in the polymer matrices. Considering this, fibers were treated with 10% (w/v) concentration of potassium hydroxide (KOH) and then continued for mixing with PLA at a fixed ratio of plasticizer by using internal mixer, and then the composites were prepared into sheet via hot press. Characterization for the mechanical and morphological was conducted by using tensile testing and scanning electron microscopy, respectively. After the analysis, it is found that the surface treated pineapple fiber composite showed better elongation at break compared to untreated fiber composite. The enhance properties of PLA nanocomposites has potential to be used in various packaging materials.

KEY WORDS: *Polylactic acid, Epoxidized palm oil, Pineapple fiber, Plasticizer, Natural fiber.*

1. INTRODUCTION

Recently, one third of municipal solid waste (MSW) are consist of packaging waste, thus raising concerns regarding its impact on the environment [1]. Most packaging wastes are stemmed from non-biodegradable petroleum-based polymers. With the increasing awareness regarding environmental safety and sustainability, emphasis is laid in developing substitutes to conventional packaging materials with interest being in materials that could rapidly degrade in the environment [2].

Nowadays, the usage of polymer composites as replacement for packaging materials such as metals, ceramics, and papers are ubiquitously accepted and has increased extensively. These composites are usually comprised of synthetic polymers (e.g polyethylene, polypropylene, polystyrene, polyvinyl chloride (PVC), and polyethylene terephthalate (PET)) acting as the matrix, while the reinforcements being synthetic fibers such as glass, carbon, Kevlar, and boron fibers [3]. These composites are attractive for reasons that they are lightweight, easy to process, low in cost, and their functionality [4]. However, these synthetic materials also impose harmful impact to the environment as they are not degradable in the environment either.

As a result, researchers have developed biodegradable composites as a solution to this problem [5]. One of the popular choice of biocomposites is a thermoplastic polyester known as poly(lactic acid) (PLA), which has attracted significant attention for its versatility, mechanical strength, biocompatibility and biodegradable characteristics. Nevertheless, PLA also has its limits and disadvantages. A lot of research pointed out the brittleness of this material hindering its application [6,7]. PLA also lacks of mechanical properties [8] and it has poor ductibility, slow degradation rate, and poor hydrophilicity [9]. The unanimous solution to these shortcomings is to perform modifications to PLA.

There are two types of modifications that can be done, which are 1) bulk modification, and 2) surface chemistry modification. Bulk modification includes physical modification (blending different polymers with PLA, addition of plasticizers, and addition of filler materials), and chemical modification (copolymerization, cross-linking of PLA). Surface chemistry modification, on the other hand, includes using physical methods (surface coating, entrapment, plasma treatment) and chemical modification [9].

Pineapple fiber (PALF) is a multicellulosic fiber that is smooth and white in colour, and possesses a softer surface compared to other natural fibers. It is a medium length fiber with high tensile strength. PALF has high specific strength and rigidity which makes it an outstanding reinforcing material for composites. Nonetheless, PALF also possess high stiffness. Its high cellulose content makes it hydrophilic in nature, particularly at high temperatures [10]. The high moisture content in PALF can cause swelling or dimensional defect during preparation of composites hence affecting the physical and mechanical property of the final product. One of the most common chemical treatments of natural fibers is alkaline treatment. Alkaline treatment is responsible to disrupt the hydrogen bonding in the network structure, thus increasing the surface roughness. Simultaneously, this treatment also helps in removing lignin, wax, and oils covering the outer surface of the fiber cell wall, depolymerizing cellulose, and exposing the short length crystallites [11].

Therefore, in this research pineapple fiber treated in 10% (w/v) alkaline concentration was prepared and then incorporated into PLA/plasticizer blends in Haake internal mixer. The composites were then characterized for its mechanical properties.

2. MATERIALS AND METHOD

2.1. Materials

The type of polylactic acid (PLA) used in this study was Ingeo 3251D, obtained from NatureWorks LLC., USA. Pineapple leaf fibers were obtained from a pineapple plantation in Kg. Puteri Menangis, Pontian, Johor. Epoxidized palm oil (EPO) was obtained from Budi Oil Enterprise Sdn. Bhd, Port Klang, Selangor. The chemicals used for this experiment were acetic acid solution (Bendosen), and hydrogen peroxide (H_2O_2) solution (Bendosen), as well as potassium hydroxide (KOH) pellets for making KOH solution.

2.2. Characterizations

Tensile test was carried out by using a universal tensile machine, Shimadzu Autograph (Model AGS-X series). Three to five dumbbell / dog bone shaped samples were prepared out of each composition. The values for tensile strength, Young's modulus, and elongation at break were recorded using Trapezium software. The morphology of the composites was studied using Phenom Pro desktop scanning electron microscope.

2.3. Chemical modification of pineapple leaf fibers

The fibers were cut to about 4-5 mm long. Pineapple leaf fibers (PALFs) were immersed in prepared potassium hydroxide (KOH) solution (10%) at room temperature for 24 hours. Next, the mixture was neutralized by slow adding of acetic acid solution. The PALFs were then soaked in hydrogen peroxide, H_2O_2 solution for one hour, before being thoroughly washed with deionized water. Finally, the PALFs were filtered and then dried in an oven overnight at 35ºC.

2.4. Preparations of PLA/EPO/PALF composites

Prior to mixing, PLA beads and treated PALFs (10%, w/v) were oven-dried overnight to remove moisture content. The composites were then prepared using an internal mixer at 180°C with a rotor speed of 50 rpm, with addition of 10 wt% EPO as a plasticizer and 10 wt% of fibers. Composite without treated fiber was also prepared for reference purpose (pPLAUT-10). The composites were then molded using a hot press machine at 180°C with 150 kg/m^2 pressure. Molded samples then were obtained for characterization. The composites ratio preparation and code name were listed as shown in Table 1.

Table 1: Code name and ratio of composites prepared

Sample	Ratio		
	PLA	EPO	PALF
PLA	90	10	0
pPLAUT-10 (untreated fiber)	80	10	10
pPLAT-10 (treated fiber)	80	10	10

3. RESULTS AND DISCUSSION

3.1. Tensile test

Tensile test was carried out on the PLA and PLA composites to investigate the effects of alkaline treatment on the fiber against the mechanical properties of the PLA composites. The stress-strain curves of PLA and PLA composites were illustrated in Fig. 1. PLA composite possessed a high modulus but low elongation-at-break. Higher elongation-at-breaks were observed in chemically untreated fiber composite (pPLAUT-10) and chemically treated fiber composite (pPLAT-10) as compared to PLA. However, the addition of chemically treated fiber showed higher elongation-at-break than the untreated fiber composite. The mechanical properties of the composites were determined by the adhesion between the matrix and the fiber [5]. Ideally, applying surface modification on the fiber decreases its moisture absorption and removes surface impurities. Alkaline treatment disrupts the hydrogen bonds in the structure of the fiber, roughening the surface, hence boosting the interfacial bond strength with the matrix, and consequently, the mechanical properties as well [7].

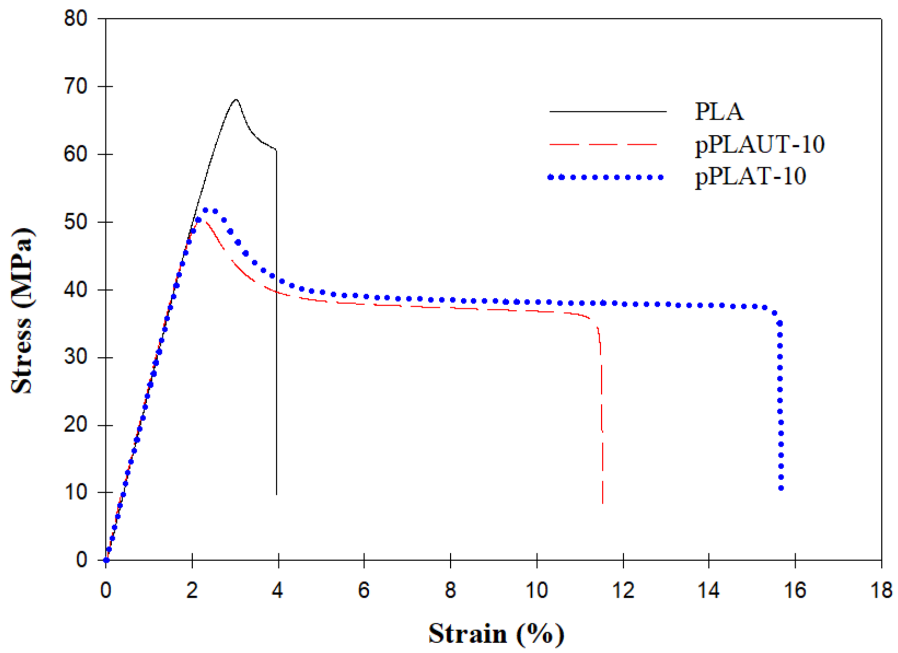

Fig. 1. Stress-strain curve of PLA and PLA composites

3.2. Visual deformation of tensile failed PLA and PLA composites

It can be seen from Fig. 2(a) that PLA was fractured before any yielding occurs, however for both composites with and without fiber treatment, the composites displayed a ductile behaviour with yielding. Both pPLAUT-10 and pPLAT-10 (Fig. 2(b) and Fig. 2(c)) also showed a stress-whitening during the tensile test. Similar behaviour was also observed in other plasticized PLA blends and this is due to the void formation caused by crazing [12].

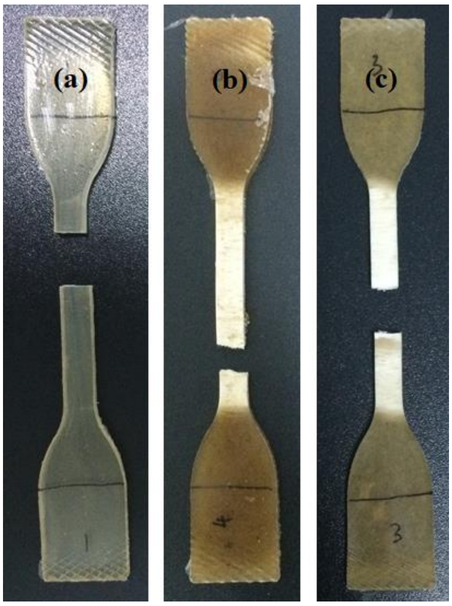

Fig. 2. Tensile failed samples (a) PLA, (b) pPLAUT-10 and (c) pPLAT-10

3.3. Surface morphologies of tensile failed PLA and PLA composites

Fig. 3(a) showed a smooth surface of the PLA composite. After the addition of 10% EPO, plasticization effect took place and voids were visible in the fiber composites [13]. Fig. 3(b) showed the morphology of plasticized PLA composite with the addition of untreated fiber (pPLAUT-10). The fibers are bound together, displaying a packed structure. This also leads to weak bonding between the fibers and polymer matrices. When alkaline treatment is applied (Fig. 3(c)), the fibrils began to unravel, thus increasing the interfacial bonding between the fibrils and polymer matrices [14].

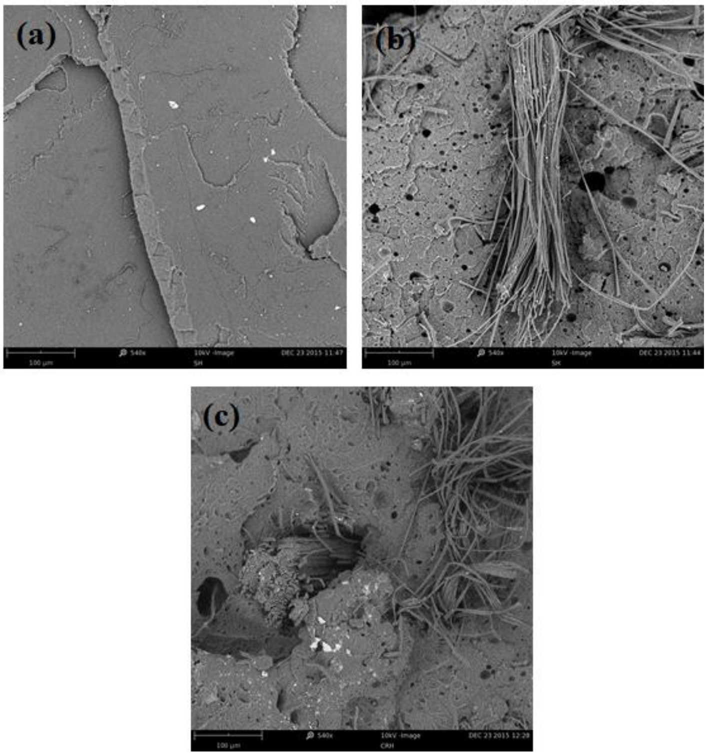

Fig. 3. Surface morphology of tensile failed samples (a) PLA, (b) pPLAUT-10 and (c) pPLAT-10

4. CONCLUSION REMARKS (HEADING 1)

The effect of surface treatment of pineapple fibers in plasticized PLA on mechanical and surface properties were investigated. The composites were prepared through melt mixing method and then moulded into sheets for further analysis. From the mechanical properties, the treated fiber composite showed higher elongation at break compared to untreated fiber composite and PLA. Surface morphologies of tensile failed samples demonstrated the fibrils were unravelled after surface treatment compared to untreated fibrils.

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