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Thermal Stability of Plasticized Durian Skin Fibre Biocomposite

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ABSTRACT. Packaging is an essential component in food industries. Packaging protects food from spoilage between processing and usage by the consumer. In this study, biocomposites of poly(lactic acid) (PLA) reinforced with durian skin fibre (DSF) were prepared by extrusion and compression moulding. Epoxidized palm oil (EPO) was added into PLA/DSF biocomposite as a plasticizer. The results showed that the thermal stability of PLA/DSF biocomposite with EPO has not much difference compared to without EPO. The degradation time of PLA/DSF biocomposite also faster after it was disposed to the landfill as it took around 65 days to degrade. Fourier transform infrared (FTIR) confirmed the stability of EPO where the oxirane group of EPO existed in the PLA/DSF biocomposite. Therefore, PLA/DSF biocomposite with addition of EPO can be effectively used for food packaging application.

Keywords: Biodegradable polymer, Durian skin fibre, Epoxidized plam oil, Thermal properties;

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1. INTRODUCTION

In recent years, most of the food packaging are made from the plastics in various sizes and shapes. Generally, these plastics are made from synthetic polyolefin such as polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP) and polystyrene (PS) [1,2]. This is due to their good properties as they are light, soft and transparent. However, these plastics are petroleum-based polymers, which are from non-renewable resources. The utilization of these plastics may give an impact to the environment as they are neither fully biodegradable nor environmentally friendly.

The agricultural and agrofood industries is the major cause that lead to large amount of wastes generated. To overcome this problem, the most effective way is to recycle and reuse waste into a new product. Durian produce a lot of waste as it contains only 50-65% of flesh while the rest such as skin and seed are considered as waste [3]. These residues are discarded in the landfills and it may affects the surrounding environment. Thus, durian skin fibre (DSF) that extracted from durian can be used as reinforcement in polymer to produce composite products.

Biodegradable polymer is gaining much attention recently as an alternative material to conventional petrochemical polymers. This is due to its biodegradability, environmentally friendly characteristics and biocompatibility. Polylactic acid (PLA) is a biopolymer synthesized from biomass. It is a natural resources thermoplastic polymer and it can be produced over 140,000 tonnes per year [4]. Generally, PLA is used as a replacement to petroleum-based polymer especially in food packaging containers [5]. The first commercialization of PLA was in 1990 and its production was highly demanded from year to years. Karamanlioglu et al. [5] stated that Japan and USA are the major producers of PLA and by 2020, the worldwide production of PLA is estimated of at least 800,000 tons. However, the drawbacks of PLA such as high brittleness and low tensile elongation limit its application. Therefore, it is essential to add plasticizer into PLA to enhance its properties.

Plasticizer from natural resources such as rubber seed oil, olive oil, corn oil, soybean oil, palm oil and neem oil are widely used due to their lower toxicity, low cost, renewable resources, biodegradability, good lubricity and lower volatility [6]. Ali et al. [7], Chieng et al. [8] and Al-Mulla et al. [9] studied the effect of epoxidized palm oil (EPO) incorporated into PLA on mechanical properties. They found that the flexibility was increased about 16% and elongation at break of PLA also was improved from 60 to 100% when 5 wt.% of EPO was added.

This paper reported thermal stability, functional groups and degradation time of PLA/DSF biocomposite. Epoxidized palm oil (EPO) was added as plasticizer to obtain PLA/DSF biocomposite with enhanced properties in order to produce food packaging.

2. MATERIALS AND METHODS

The inner skins of durian were removed and cut into smaller pieces. After that, durian skins were washed with tap water to remove any dirt and dust. The skins were dried in an oven for 24 h at 70 ºC. The dried skins were crushed and then sieved for 100 µm size to get durian skins fibre (DSF). The DSF was soaked in 4 wt.% of sodium hydroxide (NaOH) solution for 2 hours at room temperature. Next, treated DSF was washed with distilled water to remove any excess NaOH and then was dried at 60 ºC for 48 hours. PLA/DSF biocomposite was extruded using twin screw extruder (Brabender, Germany) at 170ºC. Epoxidized palm oil (EPO) with amount of 5 wt.% was added into PLA/DSF biocomposite.

After extrusion process, PLA/DSF biocomposite was compression moulded for degradable testing specimen. Thermogravimetry analysis (TGA) was carried out in the temperature range between room temperature and 300 ºC at a heating rate of 10 ºC/min in nitrogen gas condition. The degradation time of PLA/DSF biocomposite was investigated by exposing the specimen to the landfill. The functional groups of PLA/DSF biocomposite was obtained through the Fourier transform infrared (FTIR) analysis. FTIR spectra of biocomposite was recorded by FTIR spectrometer between 3500 cm^{-1} and 500 cm^{-1} frequency ranges.

3. RESULTS AND DISCUSSION

Fig. 1 illustrated the thermal degradation curves due to weight loss of neat PLA, PLA/DSF and PLA/DSF/EPO. The onset temperature (T_o), maximum degradation temperature (T_{max}) and final degradation temperature (T_f) were tabulated in Table 1. T_o of neat PLA was 306 ºC and it decreased to 257 ºC after DSF was added. When EPO was incorporated into PLA/DSF, T_o was further decreased to 251 ºC due to the decreasing of relative molecular weight of PLA. The thermal stability of PLA was reduced with the presence of DSF as it is hydrophilic and it contains hydroxyl group. PLA/DSF degraded at 315 ºC while PLA/DSF/EPO had slightly lower degradation peak at 12 ºC. The char residue of neat PLA was low because of the hydrogen and carbon atoms in PLA formed volatile compound as it decomposed at higher temperature.

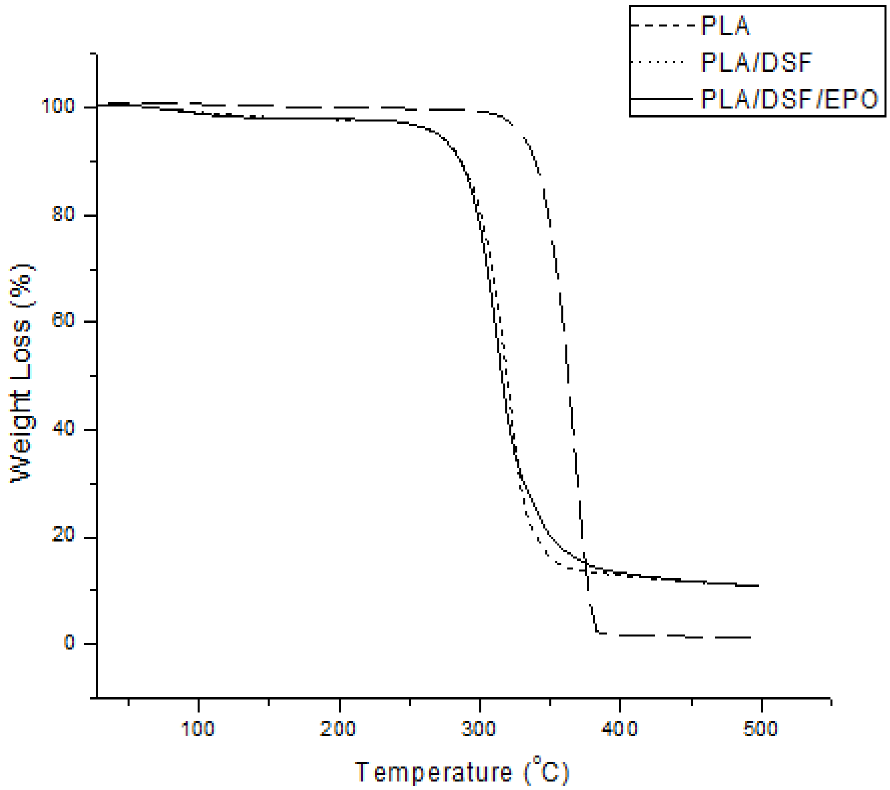

Fig. 1 TGA curves for PLA, PLA/DSF and PLA/DSF/EPO biocomposites

Table 1 Thermal properties of PLA, PLA/DSF and PLA/DSF/EPO biocomposites obtained from TGA

Sample	T_o	T_{max}	T_f	Char residue (%)
PLA	306	360	421	1.1
PLA/DSF	257	316	378	10.8
PLA/DSF/EPO	251	313	376	11.1

Fig. 2 showed the pictures of PLA/DSF/EPO specimens after 65 days left in a landfill. Discoloration of the specimens probably occurs because of the microbial growth after 30 days. PLA/DSF biocomposite decomposed into water and carbon dioxide in less than 90 days. The degradation time was faster compared to the petrochemical polymer which not degraded by microorganisms in the environment and remain until million years. As stated by Shah et al. [10], they revealed that the degradation of PLA initially was through hydrolysis to water soluble compounds and lactic acid. Then, it decomposed into water, CO_2 and biomass by biological activities [5,10].

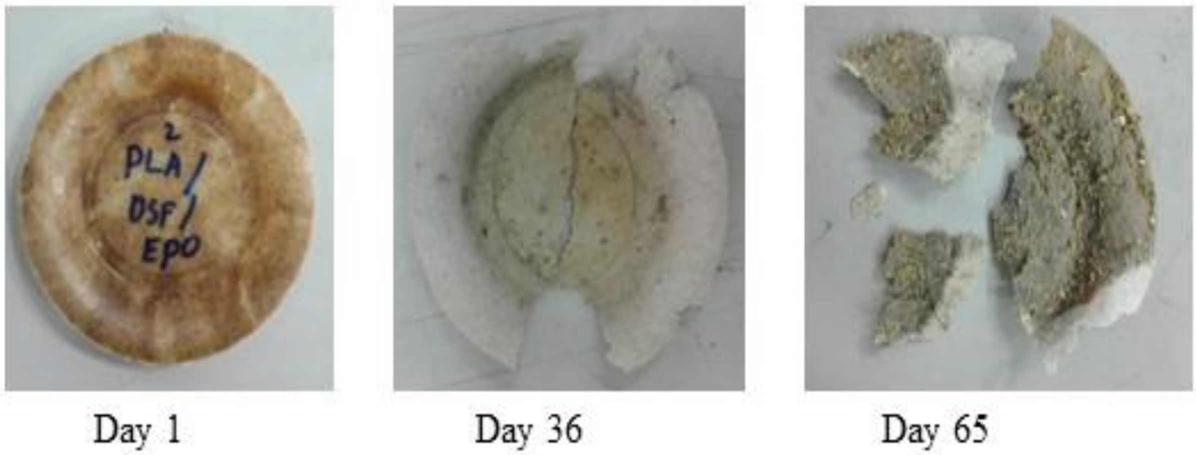

Fig. 2 Degradation time of PLA/DSF/EPO

The FTIR spectra of PLA/DSF biocomposite were shown in Fig. 3 to know its functional groups presence. The peaks located around 1180-1181 cm^{-1} exhibited as O-C=O stretching. The stretching vibrations of CH_2 and C=O in PLA/DSF were 2996 and 1748 cm^{-1} and it shifted to 2916 and 1746 cm^{-1} upon EPO was added. It may exhibited some intramolecular interactions and compatibility between EPO and PLA/DSF. Furthermore, the peak at 868 cm^{-1} and around 1258 cm^{-1} suggest the presence of EPO where C-O-C stretching from oxirane vibrations. The peak at 1258 cm^{-1} usually overlays with others such as C-O ester which presents in oil [11,12]. C-O stretching at peak 1082 cm^{-1} shifted to 1084 cm^{-1} after blend with EPO which showed miscibility and interaction of PLA/DSF and EPO. Tee et al. [6] stated that the interaction between PLA/DSF and EPO occurred from the hydrogen bonding between terminal hydroxyl groups of PLA and the oxirane groups of the EPO.

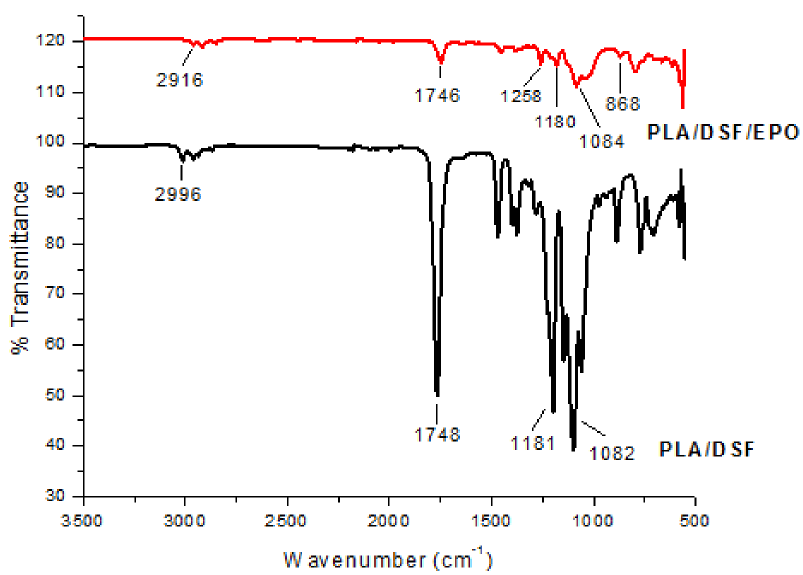

Fig. 3 FTIR spectrum of PLA/DSF/EPO

4. SUMMARY

Polylactic acid reinforced durian skin fibre is a potential material to produce biodegradable food packaging. PLA/DSF biocomposite has good thermal stability and it degraded in soil faster than petroleum-based polymer, thus the volume of waste dumps can be reduced. PLA/DSF biocomposite decomposed naturally and returned to soil, indirectly reduce the disposal of conventional plastics and reducing the volume of waste. PLA/DSF biocomposite is potential to be used as a biodegradable food packaging as an alternative to the conventional plastics.

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