UNIVERSITI TEKNOLOGI MARA

CHARACTERIZATION OF POLYLACTIC ACID POLYMER REINFORCED WITH MICROCRYSTALLINE CELLULOSE COMPOSITES EXTRACTED FROM PAPER SLUDGE BY TETRAKIS IONIC LIQUID

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ABSTRACT

The large amount of paper sludge generated from wastepaper industries emphasizes the importance of developing green waste management solutions. Tremendous researchers have reported cellulose extraction from sludge in various sources, such as municipal sludge, domestic sludge, palm oil wastewater, and paper wastewater. This study aimed to isolate microcrystalline cellulose (MCC) from paper sludge using tetrakis (hydroxymethyl) phosphonium chloride ionic liquid combined with (0.1, 1.0, 2.0, 3.0, 4.0 M) hydrochloric acid. The effect of the acid concentrations was characterized using FTIR, SEM, XRD, TGA, and UV-Vis. The disappearance of peaks at 1425 cm^{-1}, 1176 cm^{-1}, and 868 cm^{-1} in the (FTIR) spectroscopy were related to removing the non-cellulose component, while peaks at 1453 cm^{-1}, 1380 cm^{-1}, and 895 cm^{-1} indicated the presence of cellulose. Scanning electron microscope micrograph confirmed that the diameter of MCC was smaller with the increasing acid concentration, where 3.0 M shows the average minor diameter of 29.73 µm. Thermogravimetric analysis showed 3.0 M HCl MCC started to decompose at 268 °C with a maximum temperature of 288 °C. 3.0 M reflected UV-B at 28 % and UV-A at 39 % due to the high crystallinity index (C_{rI}) of 31 %. Results showed that 3.0 M HCl concentration had optimum properties, and further, this concentration was used for composite fabrication. The solvent casting technique was used for composite fabrication. The fiber loadings were varied from (1 wt. %, 2 wt. %, 3 wt. %) and the effect of fiber loading on the properties of the composite was assessed through analysis including (TGA, DSC, FTIR, XRD, FESEM, and UV-Vis). The maximum degradation temperatures of 1 wt. % PLA/MCC was 328 °C with glass transition temperature (T_g) of 82 °C and crystallization temperature (T_c) of 169 °C. 1 wt. % PLA/MCC displayed small domains with typical sea-island morphology and homogeneously dispersed filler, indicating excellent dispersion in composites. UV-A and UV-B transmittance were observed at the lowest transmittance without sacrificing transparency at 29 % and 26 %, respectively. SEM and XRD investigations revealed reduced agglomeration with a higher crystallinity index of 26 % in 1 wt. % PLA/MCC composite film. The novelty of this work is the possible extraction of microcrystalline cellulose from paper sludge using tetrakis (hydroxymethyl) phosphonium chloride ionic liquid to reinforce polylactic acid in film packaging. The findings conclude that the best conditions for cellulose extraction were 80 °C and a ratio of 1:10 ionic liquid, 3.0 M HCl is the optimum concentration for extracting MCC, while 1 wt. % MCC is the optimum fiber loading to enhance interfacial adhesion, promote MCC dispersion in the polymer matrix, improve stress transfer, and avoid filler aggregation.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

The quest for sustainable energy has dramatically expanded because of the escalating energy depletion caused by fossil fuels. Given the large disposal of waste biomass, the biomass "waste-to-energy" idea, which converts waste organics into renewable energy with tremendous benefits, has recently gained widespread attention (Luo et al., 2021). Global waste disposal has been increasing, and paper waste is one of the key contributors to this increase (Xu et al., 2021). By 2025, worldwide paper production will be increased to 500 million metric tonnes at the current consumption rate (Das et al., 2021). Table 1.1 below shows the production of paper waste per year for several countries.

Table 1.1
The production of paper waste from papermills for several countries.

Country	Production (Million tonnes/year)	References
Europe	11	(Zmamou et al., 2021)
China	12	(Lu et al., 2021)
Sweden	1.4	(Jarnerud et al., 2021)
South Africa	0.5	(Rorke et al., 2021)

Because paper sludge is corrosive, it is considered hazardous waste in Europe (EU Directive 2008/98/EC Annex III, criterion H8). Sweden has imposed a fee on waste incineration since April 2020. During a transitional phase in 2021, it will be 100 SEK/ton, with an increase in price in subsequent years. Biofuels, on the other hand, have been given tax breaks. The levy is expected to stimulate a more resource-efficient waste management system and a higher recycling rate. This is a critical step toward Sweden's objective of net-zero greenhouse gas emissions by 2045. Harmful emissions mean that human-caused greenhouse gas emissions are lower than the carbon dioxide absorbed by nature. Harmful emissions are also possible if Sweden contributes to