CONFERENCE PROCEEDING

Depolymerization of Polyethylene Terephthalate (PET) from 3D Printed Waste via Thermal and Alkaline Hydrolysis

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Abstract

Additive manufacturing sector is an exponentially growing industry which contributing high usage of plastic which has also seen an increase of waste generation throughout the world. Polyethylene Terephthalate (PET) is one of the widely used polymer as 3D printing filament materials. The time taken for the polymer to degrades naturally could not catch up with the number of plastics productions annually. Thus, experts emphasize that there should be other alternative methods to degrade polymers. This study aims to investigate the degradation rate of PET via kinetic study of thermal hydrolytic and alkaline hydrolysis treatment. 3D printed waste from PET were crushed into fragment size and undergone thermal hydrolytic and alkaline hydrolysis at different reaction time and PET content. The degradation rate for both thermal and alkaline hydrolysis showed increment as prolong reaction time. TPA yield follow the same trend of PET degradation. Meanwhile, higher PET content has reduced the degradation rate of PET. FTIR analysis proved the formation of TPA after the hydrolysis process has took placed with the formation of O-H and C-H which corresponding to the formation of carboxylic acid and ethylene glycol in the TPA. The results indicate that PET degradation can occur at low cost and on this basis, it is recommended that environmental organizations attempt other methods to degrade polymers.

Keywords: *3D printed waste; Depolymerization; low cost; Terephthalic Acid* (*TPA*); *thermal hydrolytic*

INTRODUCTION

More than half a century ago synthetic polymers started to substitute natural materials in almost every area and nowadays plastics have become an indispensable part of our life. In 1993, the total world demand for plastics was over 107 million tones. But now, by 2020, we are producing over 300 million tons of plastic waste every year (Shah *et al*., 2008). Polymers, due to their favorable mechanical properties, are widely used as 3D printing filament. Out of all, PET become the trending polymer used as filament because of its flexibility and made of natural fiber composites are cost effective, sustainable, and environmentally friendly (Fathirrahman *et al*., 2019).

Polyethylene is one of the most common plastics that is widely used for various one-trip resulting it to the most contributed plastic waste in daily life (Leja & Lewandowicz, 2010). The environmental impact from PET package waste management is highest in landfill treatment followed by incineration and recycling. Degradation via chemical processing of PET is performed by carrying out chemolysis with one of several compounds, resulting in depolymerisation of the plastic via chain

scission mechanism that results in the formation of carboxyl end groups and a progressive reduction in molecular weight (Xie *et al*., 2011). Hence, this study aims to investigate and compare the degradation rate of PET 3D printed waste via thermal hydrolytic and alkaline hydrolysis treatment. Rate of degradation between these methods will be investigated to produce the highest yield of degraded polymer. The functional groups of TPA acid produced was analysed using FTIR analysis.

METHODOLOGY

Materials

PET was obtained from crushed 3D printed waste from Universiti Kebangsaan Malaysia (UKM). Sulphuric acid and sodium hydroxide pellets were purchased from MERCK.

Experimental Procedure

Thermal hydrolysis process was carried out in a water bath to investigate degradation rate of PET at different concentration of PET content. Consequently, after undergoing thermal hydrolysis, all PET samples were filtered using vacuum filter and dried in an oven. The final weight of PET was then weighed and recorded. Meanwhile, sodium hydroxide pellets and distilled water was added and mixed in a laboratory glass bottle for alkaline hydrolysis. The solution mixture was heated on a stirring hotplate and PET was added into the solution. After the alkaline hydrolysis reaction has completed the mixture was cooled immediately by adding chilled distilled water to quench the reaction process. Then, the mixture was filtered using vacuum filtration and was dried in an oven. Both samples from alkaline and thermal hydrolysis were neutralize using concentrated sulphuric acid and white precipitate (Terephthalic Acid (TPA) was formed. The percentage of conversion of PET was calculated and the functional groups changes were observed by Attenuated Total Reflectance Fourier transform infrared spectroscopy (ATR-FTIR).

RESULTS AND DISCUSSION

The percentage value of PET conversion of thermal hydrolysis at different reaction time is shown in Figure 1(a). The degradation rate increased with increasing temperature and this is illustrated by the data at 1 day, 3 days, 5 days and 7 days of reaction time. However, the degradation rate of PET under thermal hydrolysis was decreased when the content of PET was increased as shown in Figure 1(b).

In alkaline hydrolysis, PET conversion was increased as increased the reaction time and the highest PET conversion of 48% was observed for reaction time of 120 min as shown in Figure 2. During alkaline hydrolysis process, PET was hydrolysed in NaOH and the yield obtain is the disodium salt, TPA-Na_2 and ethylene glycol. Consequently, TPA-Na_2 salt acidified with 98% H_2SO_4 to precipitate of TPA obtained.

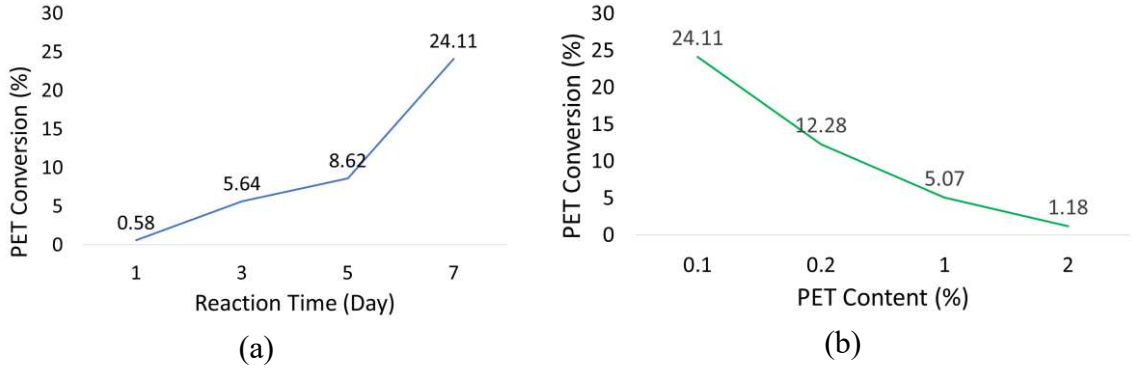

Figure 1. PET conversion on thermal hydrolysis (a) different time and (c) PET content

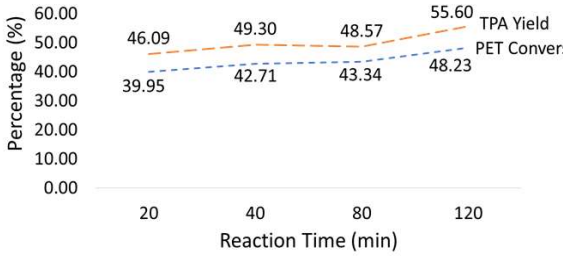

Figure 2. PET conversion on alkaline hydrolysis process and TPA yield at different time

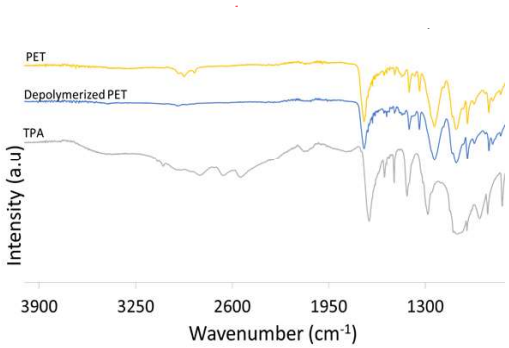

Figure 3. FTIR Spectrum of PET, Depolymerized PET and TPA

The changes in the functional group for PET, depolymerized PET and TPA are shown in Figure 3. In the FTIR spectrum of depolymerized PET, the band at 1370 cm^{-1} which attributed to the broadening of the gauche C-H^2 wagging band is decrease as compared to original PET due to the decrease in crystallinity during degradation process. The decrease in intensity of the weak band at 1040 cm^{-1} also indicates an increase in trans `ethylene glycol' content of the depolymerized PET which shows that degradation process has took placed on the PET sample (Sammon *et al*., 2000).

CONCLUSION

In this study, the degradation of PET under thermal hydrolytic and alkaline hydrolysis showed an increment on PET conversion by the formation of TPA acid as shown in FTIR spectrum. However, the more PET in the system, degradation reduced due to insufficient amount of water molecules to cut the PET chain. From the results, alkaline hydrolysis showed better process which produce higher PET conversion value at shorter reaction time as compared to thermal hydrolytic. The degradation of PET under alkaline hydrolysis would help to solve the abundance of plastic pollution on the Earth.

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