UNIVERSITI PUTRA MALAYSIA

CHEMICAL RECYCLING OF POLYETHYLENE TEREPHTHALATE WASTE INTO BHET MONOMER USING CONVECTION-CONDUCTIVE AND MICROWAVE ASSISTED GLYCOLYSIS TECHNIQUES

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Abundant amount of polyethylene terephthalate (PET) waste is becoming a serious problem in our country due to high consumption of various products such as soft-drink bottle, food container, etc. The non-biodegradability of PET is the major obstacle to dispose this waste using conventional method such as landfilling and incineration, and thus causing impact to environment, economics and human health. Chemical recycling is one of the option that can be acceptable based on the principle of environmental sustainability, leading to the conversion of waste into the raw materials (monomers) from which the polymer itself is made. It has been reported to be effective for depolymerization of polyethylene terephthalate (PET) that can be carried out under mild condition of temperature 190°C and 1-2 MPa pressure, in which bis-2-hyrdroxyethyl terephthalate (BHET) monomer, can be easily produced. The objective of this study to further investigate the glycolysis

reaction for depolymerization of PET waste into BHET monomer and also studies on heating mechanism using convection-conductive and microwave irradiation. Parameters affecting the glycolysis reaction being investigated, namely the effect of catalyst concentration (ratio PET:catalyst), solvent concentration (ratio EG:PET), glycolysis reaction time, reaction temperature and selection of catalysts. Zinc acetate is found to be the best catalyst compares to zinc chloride, sodium bicarbonate and titanium (IV) oxide. The optimal operating conditions for glycolysis has found at 196°C in 5:1 ratio PET:EG with 1.5% catalyst: PET ratio in the presence of zinc acetate catalyst in 8 hours reaction with conversion achieving 88% and 75% composition of BHET monomer. In microwave heating glycolysis, reaction at 196°C with 5:1 ratio EG:PET, 1.5% catalyst: PET, in 30 minutes of reaction time resulting a product conversion of 76% with 71% BHET. Characterization and identification of glycolysis products (GP) through physical, thermal and chemical analysis conclude that the main component in the GPs consist of bis 2-hydroxyethyl terephthalate (BHET) monomer together with other high chain oligomers and dimers. A comparison between different heating mechanism techniques reported that microwave heating has superior productivity in PET conversion with 8 times shorter time consumption than conventional heating method. It also provides positive result in the economical aspect with the production can reach 14 times higher with 40% cost and 32% energy consumption than that observed in the conventional heating technique.

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KITAR SEMULA KIMIA SISA POLIETILENA TEREPTALAT KEPADA MONOMER BHET MENGGUNAKAN TEKNIK GLIKOLISIS PEROLAKAN-KONDUKSI DAN BANTUAN GELOMBANG MIKRO

Oleh

AMIR SYARIFFUDDEEN MHD.ADNAN

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Lambakan jumlah sisa polietilena tereptalat (PET) menjadi masalah yang serius di negara kita disebabkan penggunaan yang tinggi pelbagai jenis produk seperti botol minuman ringan, bekas makanan dan lain-lain. Ketidaklupusan secara semulajadi PET menjadi penghalang utama untuk melupuskan sisa ini melalui kaedah konvensional seperti timbus tanah dan insinerasi, lantas mengakibatkan kesan pada alam sekitar, ekonomi dan kesihatan manusia. Kitar semula kimia merupakan satu pilihan yang boleh diterimapakai berdasarkan prinsip kelestarian alam sekitar, yang menyumbang terhadap penukaran sisa kepada bahan mentah (monomer) daripada mana suatu polymer itu diperbuat. Glikolisis dilaporkan efektif untuk depolimerisasi PET pada keadaan yang sederhana, iaitu pada suhu 190°C dan tekanan 1-2MPa dimana boleh menghasilkan monomer bis 2-hiroksietil tereptalat

(BHET). Objektif pengajian ini adalah untuk melanjutkan kajian tindakbalas glikolisis untuk depolimerisasi PET kepada monomer BHET. Kajian pada mekanisma pemanasan menggunakan perolakan-konduksi dan pancaran gelombang mikro turut ditekankan. Parameter-parameter yang mempengaruhi tindakbalas glikolisis juga dikaji, iaitu kesan kepekatan mangkin (nisbah PET: mangkin), kepekatan pelarut (nisbah PET:EG), masa tindakbalas glikolisis, suhu tindakbalas dan pemilihan mangkin. Zink asetat didapati menjadi mangkin paling sesuai berbanding zink klorida, sodium bikarbonat dan titanium (IV) oksida. Keadaan optimum untuk glikolisis adalah pada suhu 196°C, nisbah 5:1 (w/w%) EG:PET dengan 1.5% nisbah mangkin:PET dengan kehadiran mangkin zink asetat pada 8 jam tindakbalas, dengan penukaran mencapai 88% dimana 75% adalah komposisi monomer BHET. Keadaan optimum untuk pemanasan gelombang mikro adalah pada 196°C, 5:1 (w/w%) nisbah EG:PET, 1.5% mangkin:PET dalam 30 minit masa tindakbalas menghasilkan penukaran 76% dengan 71% BHET. Pencirian dan identifikasi produk-produk glikolisis (GP) melalui analisis fizikal, terma dan kimia telah mendapati komponen utama GP terdiri daripada monomer BHET bersama oligomer lain dan dimer berantai panjang. Perbandingan antara mekanisma pemanasan glikolisis yang berlainan ini telah mendapati pemanasan gelombang mikro menunjukkan produktiviti yang luar biasa dengan penukaran maksimum PET dicapai dalam masa 8 kali kurang penggunaan masa daripada kaedah konvensional. Ia juga menghasilkan keputusan yang positif dalam aspek ekonomi dengan penghasilan boleh mencapai 14 kali ganda dengan 40% dan 32% pengurangan kos dan tenaga berbanding dengan teknik pemanasan konvensional

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TABLE OF CONTENTS