




## Article

# Evaluation of Physico-Mechanical Properties on Oil Extracted Ground Coffee Waste Reinforced Polyethylene Composite

Hoo Tien Nicholas Kuan <sup>1,\*</sup>, Ming Yee Tan <sup>1</sup>, Mohamad Zaki Hassan <sup>2</sup> and Mohamed Yusoff Mohd Zuhri <sup>3,4</sup>

<sup>1</sup> Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, Kota Samarahan 94300, Malaysia

<sup>2</sup> Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, Kuala Lumpur 54100, Malaysia

<sup>3</sup> Advanced Engineering Materials and Composites Research Centre, Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, Serdang 43400, Malaysia

<sup>4</sup> Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, Serdang 43400, Malaysia

\* Correspondence: khnicholas@unimas.my

**Abstract:** The current work discusses ground coffee waste (GCW) reinforced high-density polyethylene (HDPE) composite. GCW underwent two types of treatment (oil extraction, and oil extraction followed by mercerization). The composites were prepared using stacking HDPE film and GCW, followed by hot compression molding with different GCW particle loadings (5%, 10%, 15% and 20%). Particle loadings of 5% and 10% of the treated GCW composites exhibited the optimum level for this particular type of composite, whereby their mechanical and thermal properties were improved compared to untreated GCW composite (UGC). SEM fracture analysis showed better adhesion between HDPE and treated GCW. The FTIR conducted proved the removal of unwanted impurities and reduction in water absorption after the treatment. Specific tensile modulus improved for OGC at 5 vol% particle loading. The highest impact energy absorbed was obtained by OGC with a 16% increment. This lightweight and environmentally friendly composite has potential in high-end packaging, internal automotive parts, lightweight furniture, and other composite engineering applications.

**Keywords:** polyethylene; composite materials; ground coffee waste; impact; TGA



**Citation:** Kuan, H.T.N.; Tan, M.Y.; Hassan, M.Z.; Zuhri, M.Y.M. Evaluation of Physico-Mechanical Properties on Oil Extracted Ground Coffee Waste Reinforced Polyethylene Composite. *Polymers* **2022**, *14*, 4678. <https://doi.org/10.3390/polym14214678>

Academic Editor: Swarup Roy

Received: 28 September 2022

Accepted: 12 October 2022

Published: 2 November 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

The escalating demand for synthetic fiber has led to over exploration of natural resources causing environmental pollution as they are resistant to degradation. The production and disposal treatment processes of synthetic fiber contribute to environmental pollution as well. In order to protect the earth, natural fiber-reinforced biodegradable polymer matrix and bio-composite have gained attention from researchers worldwide as they are green and eco-friendly materials. Natural fiber is an eco-friendly resource obtained from wood [1], bamboo [2], and agricultural waste [3–6] such as straw [7] that comprises cellulose, hemicellulose, lignin and aromatics, waxes and other lipids, ash, and water-soluble compounds [8]. It is biodegradable, sustainable, economically viable, low density and possesses good specific strengths and moduli [9–14]. Both the natural filler and polymer matrix used in this study are fully biodegradable at the end of their life cycles.

Coffee beans are seeds of the genus flowering plant, *Coffea*, a member of the botanical family of *Rubiaceae* which comprises almost 500 genera and more than 6500 species [8]. They are normally distributed in tropical and sub-tropical regions. Coffee is the world's second largest traded commodity, and the top five world leading countries in coffee production are Brazil, Vietnam, Indonesia, Colombia, and Ethiopia [15]. In accordance with the International Coffee Organization, world coffee consumption was about 9 million tons or 149.82 million bags (60 kg per bag) in 2014, an increment of 1.8% since 2013 [16].