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Utilization of Eco-Friendly Rice Husk Ash Waste as Reinforcement in LDPE Thermoplastics

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ABSTRACT

The topic of environmental contamination is currently regarded as one of the most urgent and significant challenges in contemporary society. Several strategies must be implemented to mitigate the environmental impact caused by waste materials, such as to rice husks ash, plastic, and other materials. Low-density polyethylene is widely recognized in academic circles for its distinctive property of having a low melting point and demonstrating inferior thermal stability. However, the utilization of RHA has promise for augmenting the thermal LDPE. The inclusion of silica inside rice husk ash functions as a flame retardant, hence augmenting the material's capacity to resist combustion and thermal degradation. The objective of this study is to utilization of eco-friendly RHA waste as reinforcement in LDPE thermoplastics. RHA is produced by the coprecipitation process. Rheomixer is used to make thermoplastic composites by incorporate RHA into LDPE 0, 2, 4, 6, 8, and 10 wt.%. The micrograph of the failure surface of the composite material consisting of LDPE filled with reactive hot-melt adhesive RHA particles reveals significant variations in particle sizes. In adittion XRD graph showed a decrease in intensity when 6% wt and 8% wt RHA were added. The results of thermal analysis with DSC showed an increase in the melting point of the sample with RHA reinforcement from 108.96–109.21°C and 482.47–500.09°C. The incorporation of RHA as a reinforcement in LDPE holds promise for its utilization as a material possessing favorable thermal characteristics suitable for industrial applications such as pipes and protective coatings, which required enhanced thermal resistance. The utilization of rice husk ash (RHA) waste imposes both environmental and economic impacts. RHA has the potential to reduce environmental pollution caused by waste and decrease the costs involved in material production.

Keywords: biomass, composite, termoplastic, reinforcement, thermal

INTRODUCTION

Low-density polyethylene (LDPE) is a kind of thermoplastic polymer that is extensively utilized due to its notable characteristics of flexibility, toughness, and chemical resistance [1, 2]. LDPE exhibits a comparatively diminished capacity to withstand high temperatures when compared to alternative technical polymers. The material exhibits a limited tolerance to elevated temperatures, withstanding approximately 80°C for brief durations. The investigation of composites based on LDPE is now being conducted in order to broaden the scope of potential applications and enhance the overall performance of the material [3, 4]. The objective of researchers is to improve thermal conductivity, electrical characteristics, and flame resistance of LDPE by integrating reinforcements, fibers, or nanoparticles. LDPE thermoplastic serves as a matrix material in the production of nanocomposites, which incorporate a range of reinforcement materials including nano clay, silica, boiler ash, zinc oxide, and titanium dioxide (TiO_2) [5–9]. The aforementioned composites exhibit promising prospects for application in structural components, electrical insulation, and high-performance packaging. Composites with natural reinforcements offer several notable advantages, including their lightweight nature, cost-effectiveness, environmental friendliness, and ability to undergo natural degradation while retaining their stiffness properties [10–13]. The idea of sustainability has experienced substantial growth in recent years due to the economic and social significance environmentally friendly materials. Additionally, there has been an increasing public awareness of these matters and environmental apprehensions regarding the management of solid waste. Agricultural, industrial, and wastes have attracted significant attention as possible sources for the production of bio-based polymers. Nevertheless, the residual wastes such as pulp, shell, and other byproducts that are left behind following the extraction of vegetable oil from oilseed crops exhibit considerable potential as viable raw materials for utilization [14, 15].

LDPE is renowned in academic circles for its characteristic of possessing a very low melting point and exhibiting suboptimal thermal stability. However , the use of RHA has the potential to enhance the thermal stability of LDPE. The presence of silica in RHA serves as a flame retardant, hence enhancing the material's ability to withstand combustion and thermal degradation. However, the presence of RHA particles can serve as effective thermal barriers, thereby impeding the mobility of polymer chains and enhancing the material's capacity to withstand heat-induced deformation. The utilization of rice husk as a primary source for the production of Rice Husk Ash (RHA) has been explored and developed. Moreover, it should be noted that RHA is a byproduct that mostly consists of a significant amount of silica. The utilization of nanosilica as a reinforcement has been observed across several material domains [16–19]. The process of extracting silica from RHA was conducted by a solid-liquid extraction method, wherein an alkaline solution was employed as the solvent [20–23]. The presence of silanol groups on the surface of rice husk ash can enhance its reinforcing properties when used as a reinforcement material. Nanocomposites, which are currently under development, primarily focus on enhancing mechanical, thermal, and electrical characteristics by the incorporation of reinforcements into polymers [24, 25]. The main purpose of this study is to examine the effect of using rice husk ash reinforcement on the thermal characteristics of low-density polyethylene. RHA is synthesized utilizing the co-recipitation technique. The RHA nanoparticles obtained are employed as reinforcements in thermoplastic nanocomposites.

MATERIALS AND METHODS

Materials

Rice Husk Ash from rice factory, 5M HCL, NH_4OH Emsure merck, Low-density polyethylene (LDPE) in the form of pellets , Ethanol absolute Emsure merck.

Methods

Preparation of rice husk ash nanoparticle

Pure RHA is calcined at a temperature of 500°C for 5 hours and then milled for 10 hours at 250 rpm with a planetary ball mill. After that, RHA is mixed with 5 M HCl in a ratio of 1:4 in a magnetic stirrer for 4 hours at a speed of 400 rpm and a temperature of 70^{o}C. RHA was mixed with NH4OH in a ratio of 1:4, stirred for four hours at 70°C, and then filtered through file paper. RHA is regularly washed with aquades and filtered to get a pH of 7. Then, each RHA is dried in an oven set to 150°C for 5 hours.

Preparation of composite LDPE

To incorporate RHA into LDPE, it is typically mixed with the polymer using compounding techniques such as melt mixing or extrusion. The processing conditions, such as temperature and mixing time, should be optimized to ensure good dispersion and interaction between the RHA particles and the LDPE matrix. The Rheomixer is used to make thermoplastic composites. LDPE is put into a mixer at a speed of 60 rpm and a temperature of 150°C for 10 minutes. Then, RHA particle reinforcement was added at a weight percentage of 0, 2, 4, 6, 8, and 10 wt.%. The resulting nanocomposite is then characterized.

RESULTS AND DISCUSSION

Scanning electron microscope

The utilization of scanning electron microscopy (SEM) is a highly effective method for the examination of material surface morphology and microstructure at elevated levels of magnification [26, 27]. SEM can be employed to evaluate the dispersion and distribution of reinforcement components inside the polymer matrix, as well as their interaction with the polymer matrix [28]. Figure 1 shows the morphology of LDPE composites with RHA reinforcements.

The morphological study revealed the existence and dispersion of RHA reinforcement within the LDPE matrix. The widely distributed reinforcements were observed throughout the structure, indicating a clear recognition of their distribution. SEM image reveals the absence of any observable cracks in the area of the reinforcement material. The presence of particulate matter is observed within the low-density polyethylene (LDPE) matrix. The RHA particles have an irregular morphology and possess a propensity to aggregate into agglomerated structures. The micrograph of the failure surface of the composite material consisting of low-density polyethylene (LDPE) filled with reactive hot-melt adhesive (RHA) particles reveals significant variations in particle sizes. This variation is likely attributed to the agglomeration and nonhomogeneous dispersion of the RHA particles within the composite. Insufficient wetness may also contribute to this phenomenon. When wetting is not present, the particles exhibit a tendency to agglomerate rather than achieving uniform dispersion within the molten material [29].

X-Ray diffraction (XRD) characterization

The XRD method is employed for the examination and characterization of the crystalline

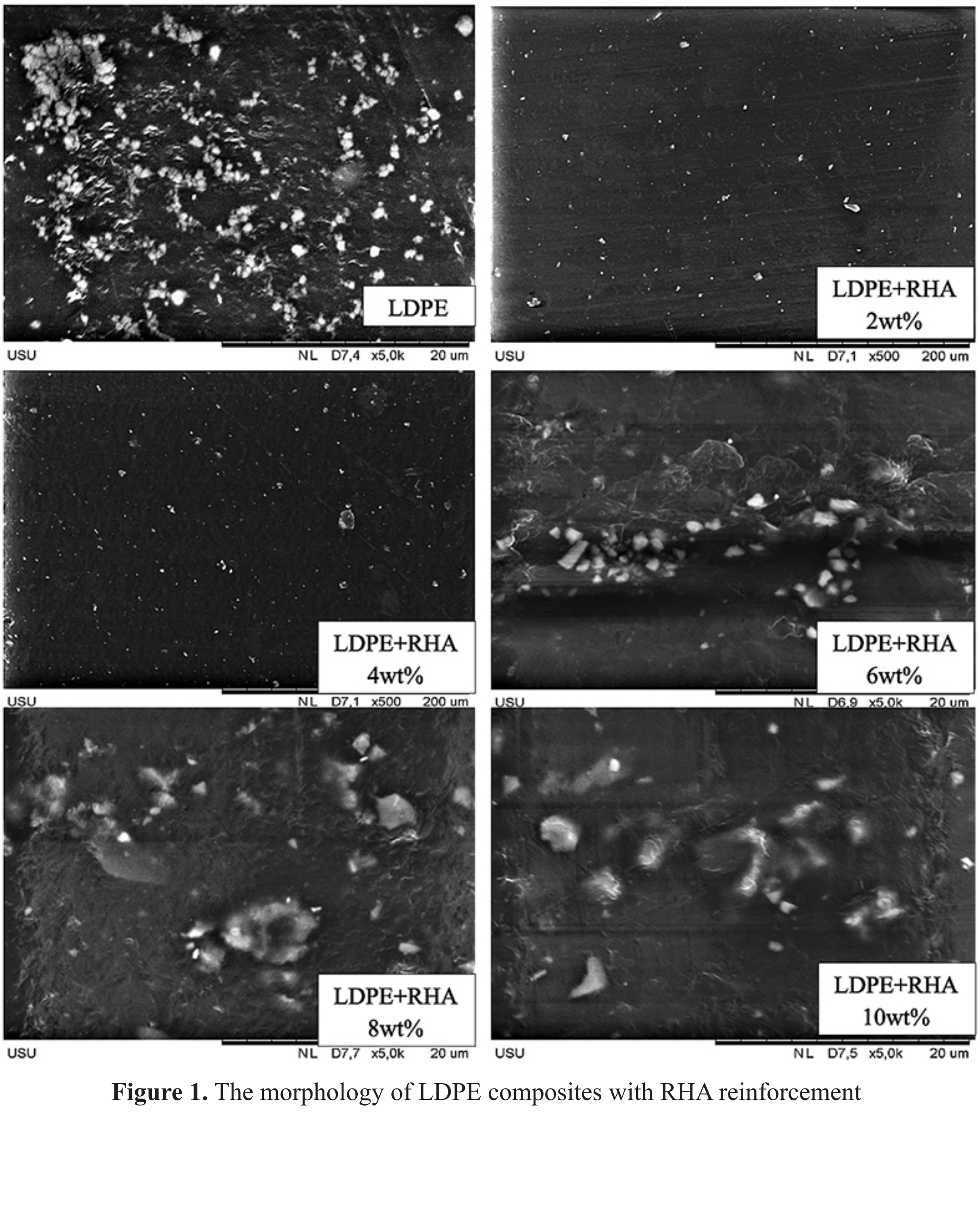

Figure 1. The morphology of LDPE composites with RHA reinforcement

arrangement of various substances. This method has the capability to provide data regarding to the various phases and crystallographic characteristics of a given substance. XRD can be implemented to analyze the impact of RHA as a reinforcement in LDPE thermoplastic, specifically focusing on the modifications induced by RHA on the crystalline structure of LDPE. The incorporation of RHA into LDPE is anticipated to result in discernible alterations in the XRD pattern when compared to LDPE in its pure form as shown in Figure 2. XRD graph showed a decrease

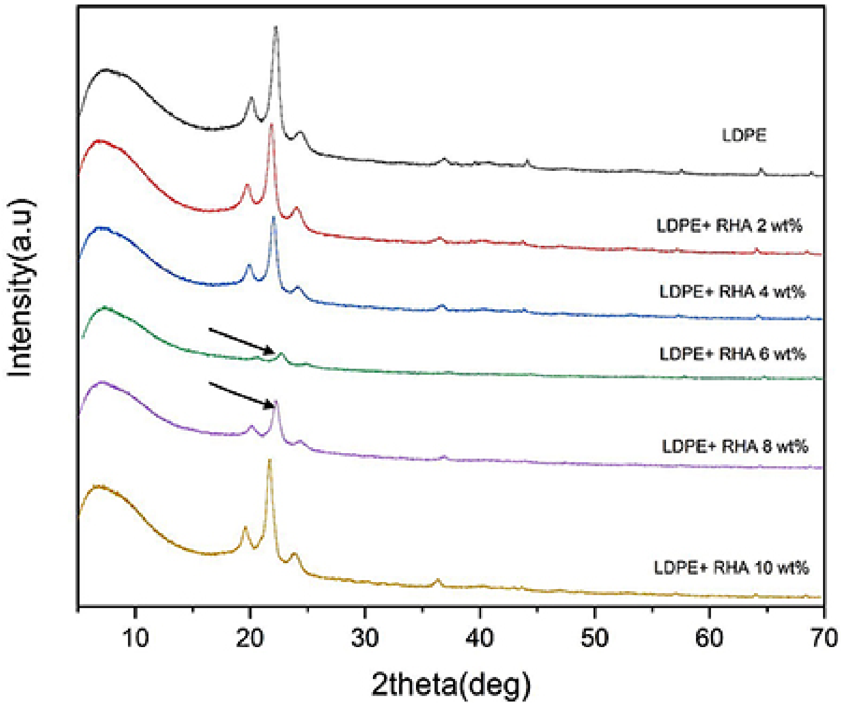

Figure 2. XRD pattern of of LDPE composites with RHA reinforcement

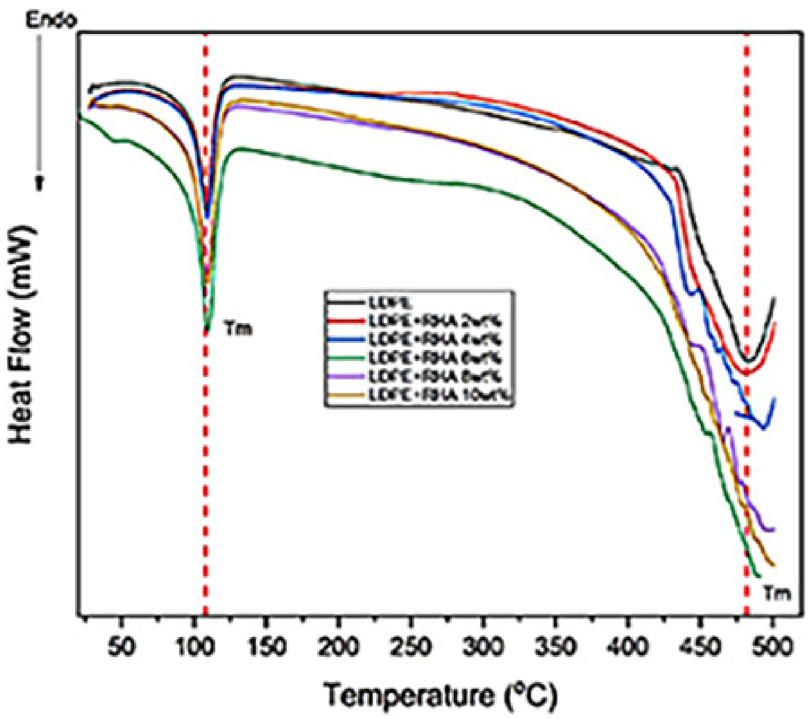

Figure 3. DSC Graph of of LDPE composites with RHA reinforcement

Table 1. Peak Temperature on HDPE thermoplastic with RHA reinforcement

Sample	Peak (°C)	Peak 2 (°C)	On set (°C)	On set 2 (°C)	Endset (°C)	Endset 2 (°C)	Heat (mJ)	Heat 2 (mJ)
LDPE	108.96	482.47	99.09	437.98	116.53	502.09	-408.17	-239.05
LDPE+RHA 2 wt%	108.34	481.35	98.92	430.31	116.00	512.85	-359.93	-371.09
LDPE+RHA 4 wt%	108.79	493.83	98.89	4426.95	116.84	518.17	-391.40	9.10
LDPE+RHA 6 wt%	109.96	379.97	99.88	280.39	118.99	477.07	-581.17	494.34
LDPE+RHA 8 wt%	109.11	497.48	98.83	430.30	119.33	487.31	-521.05	484.75
LDPE+RHA 10 wt%	109.21	500.09	99.23	416.90	117.64	494.57	-592.30	553.43

in intensity when 6% wt and 8% wt RHA were added. The presence of RHA can lead to variations in the strength of the peaks observed in the XRD pattern. The variations in intensity can offer valuable information regarding the level of crystallinity and the dispersion of reinforcements inside the LDPE matrix. Furthermore, the use of RHA led to a noticeable displacement of the peak values at 22.10°, 22.10°, 22.16°, 22.24°, 22.24°, and 22.10°. Changes in the data may point to possible interactions between LDPE and RHA, which could change the shape of the LDPE polymer chains and the structure of the crystalline material that forms as a result

Thermal properties of nanocomposite

The presence of silica in RHA can have an impact on the thermal characteristics of LDPE. The incorporation of the substance into LDPE, which is has the potential to enhance the composite material's heat conductivity on a global scale. This implies that the material exhibits enhanced thermal conductivity, hence facilitating more efficient heat transfer. This characteristic is helpful in specific scenarios that necessitate effective heat dissipation. Differential Scanning Calorimetry (DSC) is a thermal analysis methodology employed for the examination of the thermal characteristics of various materials [30], [31]. The provided data offers insights into the phase transitions, melting characteristics, and thermal stability exhibited by the sample. DSC Graph of of LDPE composites with RHA reinforcements presented in Figure 3.

The results of thermal analysis with DSC showed an increase in the melting point of the sample with RHA reinforcement from 108.96–109.21°C and at peak 2 482.47–500.09°C as shown in Table 1. The elevation of the melting point can be attributed to the enhanced dispersion of the reinforcement RHA inside the LDPE matrix[32]. The employment of RHA as a reinforcement in LDPE shows potential for its application as a material with advantageous thermal properties, making it ideal for industrial uses such pipes and protective coatings that demand improved thermal resistance.

CONCLUSIONS

The examination of the failure surface of the composite material, which comprises low-density polyethylene (LDPE) loaded with reactive hot-melt adhesive (RHA) particles, demonstrates notable disparities in the sizes of the particles. Furthermore, the X-ray diffraction (XRD) graph exhibited a reduction in intensity with the inclusion of 6% wt and 8% wt rice husk ash (RHA). The thermal investigation conducted using Differential Scanning Calorimetry (DSC) revealed an observed elevation in the melting point of the sample containing RHA reinforcement, with values ranging from 108.96 to 109.21°C and 482.47 to 500.09°C. The employment of RHA as a reinforcement in LDPE shows potential for its application as a material with advantageous thermal properties, making it ideal for industrial uses such pipes and protective coatings that demand improved thermal resistance. The utilization of rice husk ash waste imposes both environmental and economic impacts. RHA has the potential to reduce environmental pollution caused by waste and decrease the costs involved in material production.

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