Jurnal Indah Sains dan Klinis
https://ejournal.sumateraconnect.or.id/index.php/jisk
e-ISSN: 2747-1942
Vol. 05 No. 02 (2024): 19 – 24

The Influence of Adding LDPE-g-AO Compatibilizer on the Properties of Polyethylene/Polyamide Blends

Barita Aritonang[1*], Ahmad Hafizullah Ritonga[2], Karnirius Harefa[3], Herlina[4], Dicky Yuswardi Wiratma[5]

[1,2,3,4,5] Institut Kesehatan Medistra Lubuk Pakam, Indonesia

*baritaaritonang11@gmail.com; ahmad.hafizullah.ritonga@gmail.com; karniharefa74@gmail.com; herlinabsz@gmail.com; dickywiratma@yahoo.co.id

Received: 13 Juni 2024; Revised: 15 Juli 2024; Accepted: 10 Agustus 2024
DOI: https://doi.org/10.52622/jisk.v5i2.05

Abstract

Background: The primary reason for the immiscibility of polyethylene (PE) and polyamide (PA) lies in their differing polarities and surface tension energies. **Objective:** This study aims to investigate the impact of LDPE-g-AO compatibilizer on PE/PA blends. **Method:** The method employed involves blending using an internal mixer. **Results:** SEM analysis reveals that the morphology of PE/PA blends without LDPE-g-AO compatibilizer is non-homogeneous and incompatible. However, the addition of 2% LDPE-g-AO compatibilizer results in improved compatibility of the PE/PA blend, characterized by homogeneous and compatible surface adhesion properties, with no visible voids. **Conclusion:** In conclusion, this research underscores the effectiveness of LDPE-g-AO compatibilizer in bridging two previously immiscible polymers, PE and PA, thereby enhancing their overall compatibility.

Keywords: *Polyethylene, polyamide, compatibilizer, LDPE-g-AO, polymer blend*

INTRODUCTION

Polymer composites are gaining increasing attention in the industry due to their superior mechanical, thermal, and chemical properties. The two primary polymers used in these composites are polyamide (PA) and polyethylene (PE), each possessing distinct advantages. PA is renowned for its high tensile strength, abrasion resistance, and excellent thermal properties, while PE offers flexibility, chemical resistance, and exceptional electrical insulation capabilities [1]–[3].

However, blending PA and PE often encounters compatibility challenges due to their differing polarity and chemical structures [4]. One effective strategy to enhance their compatibility is by incorporating compatibilizers and fillers. Compatibilizers are designed to enhance the adhesion between these two polymers, thereby improving stress distribution and cohesion within the composite material [5]. Optimal use of compatibilizers, such as LDPE-g-AO (low-density polyethylene modified with oleic acid), can markedly enhance the mechanical strength and thermal stability of the polymer blend [6]. LDPE-g-AO creates a uniform and stable interface layer that facilitates improved interaction between PA and PE, thereby enhancing the distribution and uniformity of the blend [4], [7].

Several previous studies have successfully improved the compatibility of polymer blends that were previously immiscible, such as those conducted [8], [9], who successfully blended two polymers with different polarities using compatibilizers. Another study [10], also successfully blended PCL/PLA alloys using a compatibilizer. Findings from [11] further support the compatibility of Polyamide/Polyethylene alloys using a compatibilizer.

This research aims to investigate the effect of adding LDPE-g-AO compatibilizer on the properties of PA/PE blends. The resulting products will be characterized through morphological, mechanical, and thermal analyses. Morphological analysis using electron microscopy will provide insights into the dispersion and interaction between polymer components. Mechanical properties such as tensile strength, elongation, and elastic modulus will be evaluated to assess the improvement in material strength and flexibility. Fourier Transform Infrared (FT-IR) analysis and Scanning Electron Microscopy (SEM) techniques will be employed to understand changes in functional groups and surface morphology of the materials [12], [13].

This research is expected to significantly contribute to the advancement of polymer materials for critical industrial applications such as automotive components, electronic devices, and packaging materials that require high strength, flexibility, and thermal stability. Additionally, this research is also expected to drive innovation in the development of high-performance polymer composite materials through chemical modifications.

RESEARCH METHODS

The primary materials used in this research include polyethylene, polyamide, and the LDPE-g-AO compatibilizer (low-density polyethylene modified with oleic acid). The equipment utilized in this research encompasses electron microscopes (SEM/TEM) for morphological analysis and FTIR. Additionally, a mixer and extruder were employed to prepare the polymer blend samples.

Preparation of The PE/PA Alloy without The LDPE-g-AO Compatibilizer.

The preparation of the PE/PA alloy without the LDPE-g-AO compatibilizer was carried out using a Thermo Haake Polydrive internal mixer. The formulation concentrations of the PE/PA alloy are detailed in **Table 1**. Initially, 20 grams of PE, as specified in Table 1, were placed into the internal mixer set to a temperature of 170°C and a rotor speed of 60 rpm for 8 minutes. Once the PE had melted, 80 grams of PA were added to the mixer following the mass ratio outlined in **Table 1**. The mixing of PE and PA was then continued for 4 minutes to achieve a homogeneous and compatible blend. After the mixing process was completed, the PE/PA alloy was removed from the internal mixer while still hot and stored in a container for 24 hours at room temperature [14], [15].

Table 1. PE/PA Alloy Formulation

Sample Code	PE (% w/w)	PA (% w/w)
PE/PA	80	20
	70	30
	60	40

Preparation of PE/PA Alloy Post Addition of LDPE-g-AO Compatibilizer

PE/PA alloy with LDPE-g-AO as a compatibilizer was prepared using an internal mixer. The composition formulations for the PE/PA/LDPE-g-AO alloy are detailed in Table 2. A specific amount of PE (as specified in **Table 2**) was added to the internal mixer, which was set to a temperature of 160°C with a rotor speed of 60 rpm. After 8 minutes of melting, a measured quantity of PA and LDPE-g-AO was added according to the mass ratio provided in **Table 2**. The mixing process between PA and PE continued for 4 minutes to ensure thorough homogenization. Upon completion of the mixing process, the PA/PE/LDPE-g-AO alloy was discharged from the internal mixer while hot and stored in a plastic container for 24 hours at room temperature before undergoing further testing [14], [15].

Table 2. Formulation of PE/PA Alloy Using LDPE-g-AO Compatibilizer

Sample Code	PE (% w/w)	PA (% w/w)	LDPE-g-AO (% w/w)
PE/PA/LDPE-g-OA	80	20	1 2

RESULTS AND DISCUSSION

Analysis of The FT-IR Spectrum of PE and PA Blends without Using LDPE-g-AO Compatibilizer

The FT-IR spectrum analysis of the PE and PA blend without using the LDPE-g-AO compatibilizer shows that this blend is immiscible and incompatible. This blend forms large phase separations with weak interfacial bonding, as the PE phase does not easily distribute into the PA matrix. The primary factors causing the immiscibility of PE and PA are differences in polarity and surface adhesion [16]. Functional group analysis was performed using FT-IR to identify that the PE and PA blend is immiscible. Characterization with FT-IR spectrophotometry was conducted to qualitatively identify the polymer material through functional group analysis. The absorption peaks appearing in the spectrum were analyzed and compared with reference data from various sources. The FT-IR spectrum of the PE/PA blend can be seen in **Figure 1**.

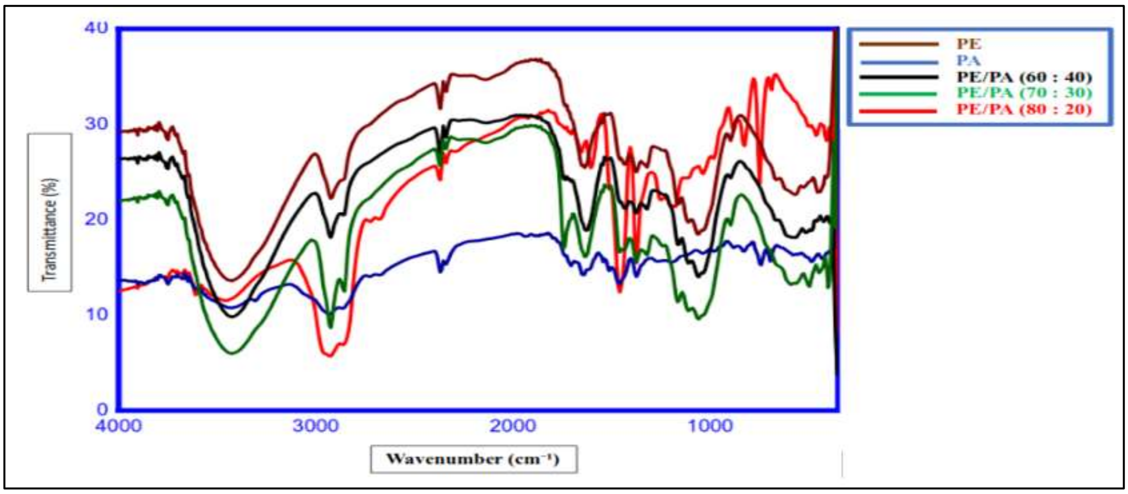

Figure 1. FT-IR Spectrum of PE and PA Alloy

Figure 1, shows the spectrogram of the FT-IR test results for the PE and PA alloy in the wave number range of 4,000-500 cm^{-1}. The FT-IR spectrum is divided into three parts to facilitate the explanation of the characteristics of the PE and PA alloy.

Part One: The FT-IR spectrum of PE shows: A weak and broad absorption peak at 3449 cm^{-1}, indicating O-H stretching vibrations from carboxylate groups and their interaction with water molecules. A sharp absorption band at 2924-2862 cm^{-1}, indicating the presence of methyl or methylene C-H stretching groups. An absorption band at 1604 cm^{-1}, distinguishing the spectra of PE, PA, and PE/PA alloy due to C=C stretching from the cyclic plane of PE. A band at 735-825 cm^{-1}, indicates C-H bending vibrations from the deformation of the substituted trialkyl polyisoprene structure [11], [17].

Part Two: The FT-IR spectrum of PA shows: A weak and broad absorption band at 3425 cm^{-1}, indicating the presence of hydroxyl OH groups. An absorption band at 3294 cm^{-1}, indicates secondary amide N-H groups, supported by a band at 1577 cm^{-1} indicating N-H bonds from primary amide groups [18]. A sharp absorption band at 2932-2862 cm^{-1}, indicates the stretching vibration of methylene C-H groups [19], [20].

Part Three: The FT-IR spectrum of the PE/PA alloy with composition variations (60:40), (70:30), and (80:20) shows: The same absorption band regions without significant differences, only experiencing a shift in absorption regions, indicating no chemical reaction between PE and PA. An absorption band at 3445 cm^{-1}, indicates the presence of hydroxyl OH groups. An absorption band at 2920-2824 cm^{-1}, indicates the presence of aliphatic and aromatic C-H bonds, and stretching vibrations. A band at 1468 cm^{-1}, indicates the presence of aliphatic hydrocarbons, including linear and cyclic chain hydrocarbons, with C-H bending vibrations, particularly for CH$_2$ from methyl and methylene groups. The FT-IR spectrum of the PE and PA alloy (80:20) shows no chemical interaction between PE and PA during the mixing process, only predominantly physical interactions.

SEM Analysis of The Morphology Structure of PE and PA Alloy without The Use of LDPE-g-AO Compatibilizer

Characterization of surface morphology structure using SEM was employed to investigate the enhancement of compatibility between PE and PA alloy (80:20), transforming it from an immiscible to a miscible state. The morphology structure of PE and PA alloy before the addition of LDPE-g-AO compatibilizer can be seen in **Figure 2a-c**.

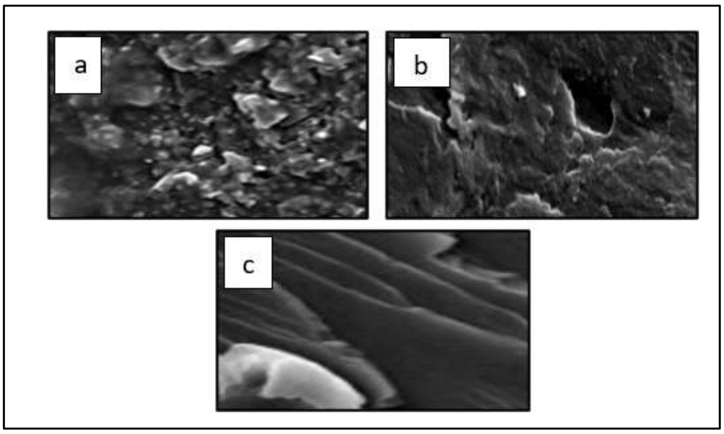

Figure 2. Shows The SEM Image of The Morphological Structure of PE **(a)**, PA (**b**), and PE and PA (80:20) Alloy without Using an LDPE-g-AO Compatibilizer (**c**).

Figure 2(c) depicts the morphology structure of PE and PA alloy without using LDPE-g-AO compatibilizer, resulting in a non-homogeneous and incompatible mixture. PE tends to aggregate within the PA matrix, leading to phase separation and non-uniform distribution. The morphology structure shows clusters and stacks of large porous grains unevenly dispersed in the PA matrix, due to poor surface adhesion between these two polymer materials. Research findings from [21], [22] support that the immiscibility of PE and PA alloy is caused by differences in polarity and low surface adhesion. To enhance the compatibility of PE and PA alloy, an LDPE-g-AO compatibilizer is utilized [20]. This compatibilizer functions to blend polymers that are initially immiscible into a homogeneous and compatible state. By adding LDPE-g-AO into the PE and PA alloy, particle phases can be evenly dispersed within the matrix [23].

SEM Analysis of The Morphology Structure of PE and PA Alloy Using LDPE-g-AO Compatibilizer

Characterization of surface morphology structure using SEM was employed to understand the enhancement of compatibility between PE and PA alloy (80:20), transitioning from an initially immiscible state to a miscible state. The morphology structure of the PE and PA alloy after the addition of LDPE-g-AO compatibilizer can be seen in **Figure 3a-b**.

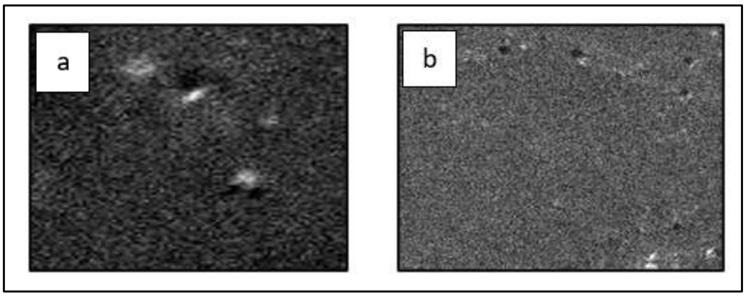

Figure 3. Shows The SEM Image of The Morphological Structure of The PE and PA (80:20) Alloy with The Addition of 1% LDPE-g-AO Compatibilizer **(a)**, and The PE and PA (80:20) Alloy with The Addition of 2% LDPE-g-AO Compatibilizer **(b)**

Figure 3(a) shows the morphology structure of PE and PA alloy with 1% LDPE-g-AO compatibilizer, demonstrating a homogeneous and compatible mixture compared to without LDPE-g-AO compatibilizer (**Figure 2(c)**). The formed particles are small and evenly dispersed homogeneously, although there are still some voids due to the relatively small amount of compatibilizer added. This compatibilizer effectively bridges polar and nonpolar polymers that were previously immiscible, enabling physical interactions between the PE structure and the PA surface. This finding is supported by studies from [23], [24], which illustrates that adding small amounts of compatibilizer to polyamide/polypropylene alloys can enhance surface adhesion, resulting in a homogeneous and compatible blend.

Figure 3(b) displays the morphology structure of PE and PA alloy with 2% LDPE-g-AO compatibilizer, showing better homogeneity and compatibility compared to those without LDPE-g-AO compatibilizer (**Figure 2(c)**) and with 1% LDPE-g-AO compatibilizer (Figure 3(a)). The produced particles are densely packed and uniformly dispersed within the PA matrix, without any voids. Increasing the amount of LDPE-g-AO in the PE and PA (80:20) blend significantly enhances surface adhesion. Studies by [25], [26] affirm that increasing the amount of compatibilizer improves surface adhesion, resulting in a homogeneous and compatible morphology structure

CONCLUSION

Based on the results of the research conducted, the following conclusions can be drawn FT-IR spectrum of the PE and PA alloy (80:20) shows no chemical interaction between PE and PA during the mixing process, indicating the dominance of physical interactions. The addition of 2% LDPE-g-AO compatibilizer to the PE and PA blend significantly improves the compatibility of the PE/PA alloy, resulting in a homogeneous and compatible mixture. SEM morphological structure analysis confirms the presence of chemical interactions between PE and PA. The LDPE-g-AO particles are uniformly and homogeneously dispersed within the PA matrix, eliminating voids on the surface of the PE/PA alloy.

ACKNOWLEDGMENTS

We would like to express our gratitude to the entire research team for their moral and spiritual support in completing this study.

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