

VARIATION OF POLYETHYLENE AND POLYPROPYLENE ON THE QUALITY OF PLASTIC TYPES

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ABSTRAK

Polietilen (PE) dan polipropilen (PP) memberikan karakteristik yang berbeda terhadap plastik yang dihasilkan. Penelitian ini bertujuan mengkaji pengaruh variasi komposisi PE dan PP agar dihasilkan polipaduan baru dengan sifat mekanik plastik yang kuat dan tidak mudah pecah. Parameter kualitas plastik yang teramati meliputi uji tarik dan kelenturan, tumbukan *izod*, kekerasan (*hardness*), dan FTIR. Telah disimpulkan bahwa polipaduan PP : PE (80:20) menghasilkan plastik dengan karakteristik sifat mekanik yang kuat sekaligus tidak mudah pecah sehingga dapat dimanfaatkan sebagai bahan dasar *plastic ware*.

Kata kunci: Polietilen, Polipropilen, *Plastic ware*, sifat mekanik.

ABSTRACT

Polyethylene (PE) and polypropylene (PP) provide different characteristics to the produced plastics. The focus of this research is to identify the influence of variations in the composition of polyethylene and polypropylene to produce a new polymer blend with strong mechanical properties and resistance to breaking. Quality parameters observed include tensile strength and flexural modulus tests, notched Izod impact, hardness, and Fourier Transform Infrared Spectroscopy (FTIR). It has been found that the PP:PE (80:20) produces plastic with strong mechanical characteristics while being less prone to breakage, thus making it suitable for plasticware materials.

Keywords: Polyethylene, Polypropylene, Plasticware, Mechanical Properties.

INTRODUCTION

Plastic products are widely used in daily life due to their economic value, practicality, and efficiency compared to other materials. The two most common types of plastics are polypropylene (PP) and polyethylene (PE). According to Akbar (2020), PP is a thermoplastic with a melting point of 160°C. It is made from the monomer propylene, characterized by its rigidity, odorlessness, and resistance to chemicals such as solvents, acids, and bases. These properties make it ideal for applications like automotive components, loudspeakers, laboratory equipment, and reusable containers. The versatility of PP extends to its use in fibers, strapping, films, plastic sheets,

injection molding, blow molding, slit film, non-woven fabrics, and blended monofilament textiles. PP is a key plastic material known for its high stiffness, evidenced by good flexural strength, a high transition temperature, and superior physical properties (Maddah, 2016). In contrast, PE is known for its flexibility and stretchability, with distinct applications from PP (Manjula et al., 2017). The main advantages of PE include its water resistance, chemical durability, flexibility, and weather resistance, making it suitable for outdoor products. PE plastics are lightweight, strong, and easily recyclable. Due to their low gas permeability, PE is particularly suitable for wrapping or storing food items that require protection from oxygen and moisture (Deglas, 2023). Research by Johansyah et al. (2014) revealed that PE plastics, specifically in the form of HDPE, are highly effective in delaying color changes in tomatoes, thus extending their shelf life. Additionally, a study by Aminullah et al. (2022) demonstrated that food products stored in biodegradable polyethylene plastics have improved longevity.

Household products made from plastic, commonly known as plastic ware, are often manufactured using pure polypropylene (PP). PP is widely used in daily life due to its versatility (Bora et al., 2020). According to Maddah (2016), while PP is a core material for various plastic products, modifications are recommended to enhance its properties. Although PP is strong, its high rigidity makes products brittle and less resistant to impact. To address this, PP is often blended with other materials with different characteristics, resulting in new types of PP-based products through additional processing (Spitz, 2019). Wang et al. (2006) demonstrated that adding 25% PP to polyethylene (PE) carpet fibers significantly improved tensile strength and flexibility, tripling their performance. Lusiana et al. (2019) showed that incorporating polyethylene glycol using grafting reactions enhanced the tensile strength of chitosan biopolymers. Further, Lusiana et al. (2021) accelerated the biodegradation of bioplastics by adding starch and PVA, while Kamaluddin et al. (2022) modified bioplastics by mixing paper and plasticizers. These studies highlight the importance of ongoing plastic material modifications. Combining PP and PE creates a plastic material with new characteristics. Therefore, research is needed to examine the effects of varying PP and PE compositions to produce durable yet flexible plastics that resist impact. Such studies also help identify suitable applications for the newly developed PP-PE blends. Complaints about the fragility of plastic products, such as food containers and children's water bottles, motivate this research. The successful development of these blends could serve as raw materials for impact-

resistant plastic products, enhancing the marketability of items like food containers, water bottles, basins, storage containers, wallets, bags, sandals, toys, protective fabric fibers, and more.

METHOD

Tools and Materials

The primary instruments used in this study include a mixing tumbler, rotary blender, mini extruder (twin-screw driver), press molding machine, Universal Testing Machine (Orientec Tensilon, RTA 500), Izod Impact Tester (Toyoseiki, 5.5 J), Rockwell Hardness Tester (Matsuzawa RMT-1), Fourier Transform Infrared Spectroscopy (FTIR), and an analytical scales. The materials utilized in the research are polypropylene powder and polyethylene powder.

Procedure

The method used in this study involves the direct mixing of PP and PE powders with varying PP:PE ratios as follows: (100% : 0%), (90% : 10%), (80% : 20%), (70% : 30%), (60% : 40%), (50% : 50%). Lin et al. (2015) conducted a similar study by mixing LLDPE and PP, followed by processing the blend through a single-screw extrusion machine. The extruded material from this plastic blend was then subjected to testing.

PP and PE powders are mixed and blended using a mixing tumbler and rotary blender for 15 minutes for each PP:PE composition. The mixture is then pelletized using a mini extruder (twin-screw design) at a temperature of 210°C, producing plastic pellets from the PP and PE blend. The process of chopping extrudates into pellets is referred to as pelletizing (Morris, 2017).

Pellets from the PP and PE blend are molded into test specimens using a press molding machine. The molded specimens are plaques with initial dimensions of 20 cm in length, 14 cm in width, and 2 mm in thickness, used for measuring tensile strength and flexural modulus. Plaques with dimensions of 20 cm in length, 14 cm in width, and 3.5 mm in thickness are used for hardness and notched Izod impact tests. For FTIR analysis, plastic pellets are formed into specimens measuring 60 mm in length, 35 mm in width, and 0.5 mm in thickness. After the plaques are formed through press molding, the following analyses are conducted:

Tensile and Flexural Test

The testing was conducted using a Universal Testing Machine (Orientec Tensilon, RTA 500). Sample specimens were prepared using a polymer puncher with dimensions of 5 cm in length, 5 cm in width, and 3.5 mm in thickness. Two layers were stacked in the holder, and the indenter was

pressed to obtain measurements in R-scale units. Additional specimens were prepared using a polymer puncher with dimensions of 16 cm in length, 0.6 cm in width, and 2 mm in thickness. The specimens were conditioned for 48 hours in a controlled environment at a temperature of 22°C and 50% humidity. These measurements aimed to gather data on yield strength, break strength, and elongation.

Izod Impact Test

The Izod impact test was conducted using an Izod Impact Tester (Toyoseiki, 5.5 J). Specimens, prepared using a polymer puncher with dimensions of 60 mm in length, 13 mm in width, and 3.5 mm in thickness, were conditioned for 48 hours in a room at 22°C and 50% humidity. This test measures the energy absorbed, reported in joules.

Hardness Test

The hardness test was performed using a Rockwell Hardness Tester (Matsuzawa RMT-1). Specimens were prepared using a polymer puncher with dimensions of 50 mm in length, 50 mm in width, and 3.5 mm in thickness. Two specimen layers were stacked on the sample holder and pressed with an indenter to obtain hardness values recorded in R-scale units.

Fourier Transform Infrared Spectroscopy (FTIR) Test

Plastic pellets, prepared with dimensions of 60 mm in length, 35 mm in width, and 0.5 mm in thickness, were heated for 2 minutes at 230°C and then cooled for 2 minutes at 25-30°C. The samples were then directly tested using FTIR to analyze the ethylene content within the polypropylene.

RESULTS AND DISCUSSION

Li et al. (2021) reported that during the production of polypropylene, the conversion rate from reactants to products decreases exponentially as pressure increases. Reducing the partial pressure of hydrocarbon compounds can enhance the conversion rate. In addition to pressure, high temperatures (530–680°C) are required during the reaction. However, elevated temperatures may lead to side reactions such as thermal cracking, deep dehydrogenation, coke formation, and reduced catalyst lifespan (Docherty et al., 2021). These issues can be mitigated by using platinum-based catalysts treated with a special oxygen-chlorine process. This treatment helps re-disperse platinum in agglomerated catalysts (Dong et al., 2021). Most polymer processing is conducted physically by melting the material without solvents to achieve a well-dispersed blend and a

material that balances the properties of its components (Lin et al., 2015). The addition of LLDPE or other thermoplastic polymers improves the mechanical strength of PP (Khavilla et al., 2019). The flexibility of PE makes the plastic more suitable for applications requiring elasticity and load-bearing capacity without cracking. This study successfully produced plastic materials that are not only strong but also exhibit excellent flexibility.

The test results presented in Table 1 show the measurements of tensile strength and flexibility. The data obtained are consistent with the findings of Kadhim (2017), which state that PP has better strength but is limited in flexibility. On the other hand, although PE has lower tensile strength, it offers higher elasticity. As a result, increasing the amount of PE in the composition variations reduces the tensile strength of the resulting blend.

Table 1. Tensile strength data of the blend

Composition PP:PE	Tensile Strength (Mpa)
100 : 0	36,0
90 : 10	33,6
80 : 20	31,1
70 : 30	28,8
60 : 40	24,7
50 : 50	20,5

The Izod impact test is a method used to determine a plastic's resistance to impact. Toughness refers to the material's ability to withstand sudden shock loads (Saragi, 2023). The Izod impact measurement results indicate the polymer's ability to resist impact per unit area, as shown in Table 2.

Table 2 . Notched izod impact data of the blend

Composition PP:PE	Izod impact (joule/m)
100:0	27,1
90:10	27,1
80:20	29,4
70:30	32,5
60:40	33,3
50:50	34,4

The test results show that the Izod impact value increases with the addition of PE. This is because PE's structure is flexible, which enhances the plastic's flexibility. The carbon chains in the PE compound can stretch upon impact, absorbing the energy from the collision. The presence of methyl groups at each carbon atom in the linear structure of PP results in relatively low toughness, so the addition of PE improves the toughness of the resulting product (Khavilla et al., 2019). However, there were no significant changes observed in the PP:PE variations (100:0 and 90:10), as well as in the PP:PE variations (70:30 and 60:40).

The flexural modulus is a mechanical characteristic that indicates the stiffness of plastic. The stiffer the material, the higher the flexural modulus value (Nugroho, 2005). Reda and Arscott (2024) used micromechanical techniques to measure the flexural modulus accurately. The results of the flexural modulus test are presented in Table 3.

Table 3. Flexural modulus data of the blend

Composition PP:PE	Flexural Modulus (Mpa)
100:0	1740,2
90:10	1532,8
80:20	1406,1
70:30	1235,1
60:40	1008,2
50:50	874,4

The results of the flexural modulus test showed a decrease with the addition of PE. As the flexural modulus value decreases, the stiffness of the plastic also reduces. This is due to the presence of PE, which adds flexibility to the plastic. The flexural modulus data indicate that the PP:PE 100:0 (pure PP) variation has the highest stiffness level at 1740.2 MPa, meaning the resulting plastic is the stiffest. The stiffness decreases as more PE is added, with the PP:PE 50:50 variation reaching a value of only 874.4 MPa.

The ability of a material to resist surface deformation and maintain its shape is referred to as hardness (Nugroho, 2005). In this study, hardness testing was conducted to evaluate the plastic's resistance to applied loads (compression) or scratches. The hardness test results are presented in Table 4. It can be observed from Table 4 that the addition of PE compounds leads to a decrease in the hardness level of the resulting plastic material. For the 100:0 variation (pure PP), the highest hardness value was recorded at 105.5, which gradually decreased to 49.1 in the 50:50 variation.

The inclusion of PE, such as LLDPE, is proven to reduce the hardness of pure PP plastic because PE imparts ductility and flexibility to the blended plastic.

Table 4. Hardness data of the blend	
Composition PP:PE	Izod impact (R-Scale)
100:0	105,5
90:10	95,5
80:20	82,5
70:30	73,6
60:40	59,2
50:50	49,1

FTIR analysis was conducted to identify the ethylene content in the polymer blend and ensure that the mixing process of PP and PE was homogeneous. FTIR operates based on the principles of spectroscopy. Detection and spectrum analysis are performed using infrared spectroscopy with the Fourier transform technique (Anam and Firdausi, 2007). The FTIR analysis graphs of the polymer blend are presented in Figures 1–6.

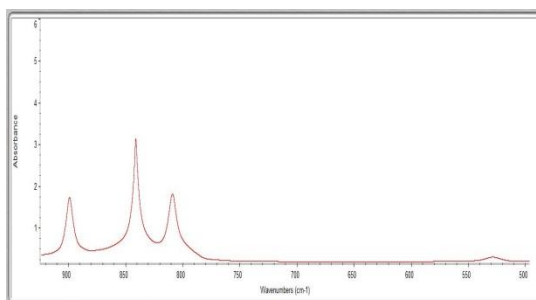


Figure 1. FTIR Graph of PP:PE Blend with 100:0 Variation

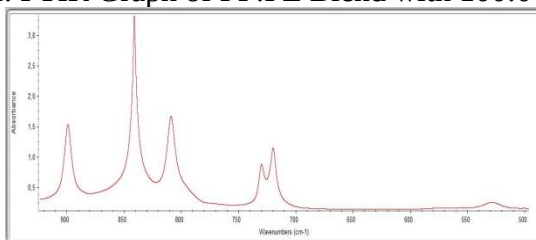


Figure 2. FTIR Graph of PP:PE Blend with 90:10 Variation

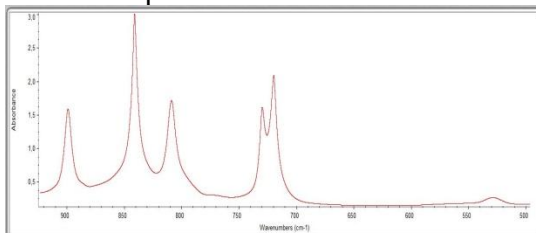


Figure 3. FTIR Graph of PP:PE Blend with 80:20 Variation

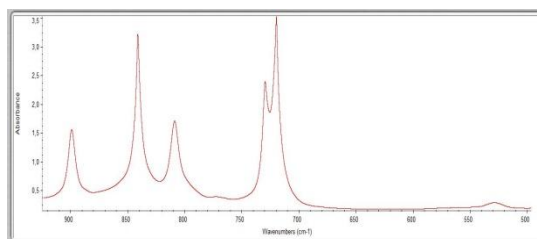


Figure 4. FTIR Graph of PP:PE Blend with 70:30 Variation

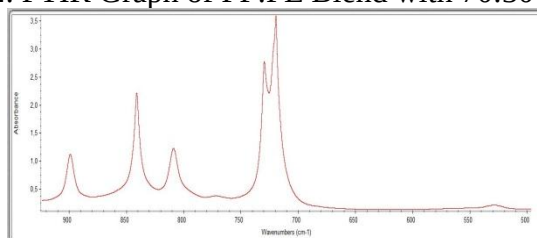


Figure 5. FTIR Graph of PP:PE Blend with 60:40 Variation

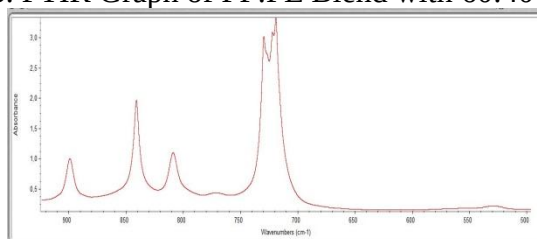


Figure 6. FTIR Graph of PP:PE Blend with 50:50 Variation

From Figures 1 to 6, it can be observed that increasing the PE content in the blend enhances the intensity of the ethylene peaks in the FTIR analysis. This is evidenced by the rise in peaks at wavenumbers 730–733 cm^{-1} . Physically, it is apparent that PE has mixed homogeneously with PP.

To determine the optimal composition and identify the best blend variation for use as a base material in upstream plastic industries, a comparison of tensile strength and Izod impact values was conducted, as shown in Figure 7. An intersection point between tensile strength and Izod impact values occurs in the PP:PE blend with an 80:20 variation, where the tensile strength is 31.1 MPa, and the notched Izod impact is 29.4 J/m. Additionally, the 80:20 PP:PE blend exhibits a flexural modulus of 1406.1 MPa and a hardness value of 82.5. These results suggest that the resulting blend possesses both strength and ideal flexibility, making it more impact-resistant and less prone to breaking. The addition of PE improves the physical shortcomings of PP, which is typically brittle. Consistent with Das and Kumar (2023), blending PP with PE enhances the elasticity of the plastic. Furthermore, no negative effects were observed on the mechanical performance parameters or crystallinity.

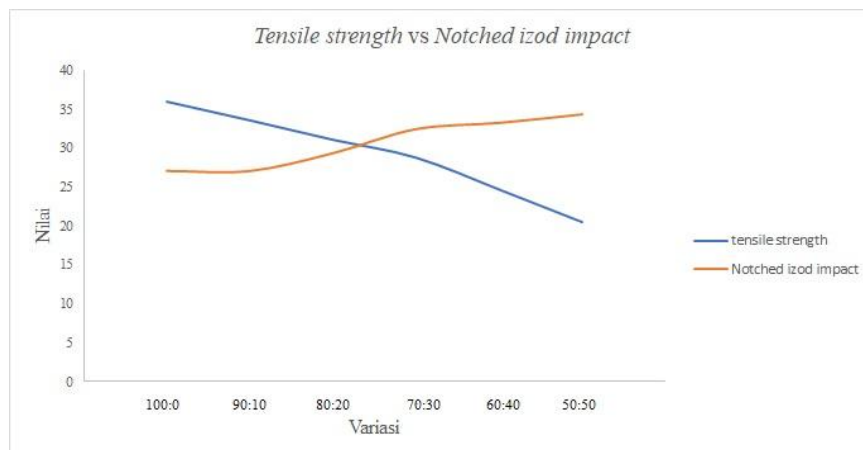


Figure 7. Comparison of Tensile Strength and Izod Impact Values

Based on the research data, to produce household plastic products (plastic ware) that are both strong, flexible, and impact-resistant, a PP:PE blend with an 80:20 composition can be utilized as a raw material. This blend combines the advantages of PP thermal resistance, lightweight, and strength with those of PE water and chemical resistance, flexibility, and durability. Plastic ware made from this blend can be applied to various everyday products, such as food containers, drinking cups, vegetable/fruit washing basins, storage containers, bottles, ice cube molds, wallets, bags, sandals, toys, protective fabric fibers, packaging plastic, automotive components, and more. According to Freinkel (2011), the plastic industry has evolved significantly and remains highly marketable, with plastic even replacing other materials such as wood in furniture, steel in the automotive industry, and glass in drinking vessels. The study's findings can be applied to develop a wide range of new products (plastic product diversification) with superior physical and mechanical properties, meeting market demands effectively.

CONCLUSION

The addition of PE to polypropylene homopolymer alters the mechanical properties of the blend, making it more flexible. This is reflected in the increased Notched Izod impact value and the corresponding decrease in tensile strength, hardness, and flexural modulus. The success of the blending process is evident from the presence of ethylene peaks at wavenumbers 730–733 cm^{-1} in the FTIR analysis. Furthermore, a higher PE content increases the intensity of these ethylene peaks.

The PP:PE blend with an 80:20 composition demonstrates a Notched Izod impact value of 29.4 J/m, a tensile strength of 31.1 MPa, a flexural modulus of 1406.1 MPa, and a hardness value

of 82.5. These properties result in a plastic product with a combination of strength and flexibility, making it more impact-resistant and less prone to breaking. Plastics with such mechanical characteristics are suitable as raw materials for manufacturing everyday plastic products such as food containers, drinking cups, vegetable/fruit washing basins, storage containers, bottles, ice cube molds, wallets, bags, sandals, toys, protective fabric fibers, packaging plastics, automotive components, and more.

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