

# Research on Recycled Plastic with Reinforced Kenaf for Automotive Application

A. S. Rahaida<sup>\*1</sup>, Z. M. Haris<sup>2</sup>, M.H. M. K. Hafizi<sup>2</sup>, A. M. A. Firdaus<sup>2</sup>, A. Firdaus<sup>1</sup> and W. M. Uzir<sup>3</sup>

<sup>1</sup> Mechanical Eng. Dept., Politeknik Sultan Azlan Shah, 35950 Behrang Stesen, Perak, Malaysia

<sup>2</sup> Mechanical Eng. Dept., Politeknik Ibrahim Sultan, 81700 Pasir Gudang, Johor, Malaysia

<sup>3</sup> Fac. of Chemical and Energy. Eng., Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

\*Corresponding author: rahaida@psas.edu.my

ORIGINAL ARTICLE

Open Access

## Article History:

Received  
11 Jul 2024

Accepted  
15 Aug 2024

Available online  
1 Sep 2024

**ABSTRACT** – *This study focuses on the development of rPET / rPP composite with a mixture of Kenaf and Sodium hydroxide (NaOH). The rPET sample preparation is from post-consumer waste. This involves a mixture of various compositions to obtain the best ratio for blending with Kenaf and 6% NaOH at 60°C for three hours. The mechanical properties of the mixture were studied using a tensile test. The distribution effect between rPET / rPP and kenaf mixture with NaOH has been studied under mechanical testing. All the materials will be placed into a blending machine to make sure all the materials are homogeneously mixed, depending on weight portions. The results showed there was an increase in the brittleness of composites when adding a higher percentage of kenaf.*

**KEYWORDS:** Recycled PET, Recycled PP, composite, Kenaf, Sodium Hydroxide, Automotive

Copyright © 2024 Society of Automotive Engineers Malaysia - All rights reserved.

Journal homepage: [www.jsaem.my](http://www.jsaem.my)

## 1. INTRODUCTION

Sustainability concerns are increasing following the significant increase in packaged water consumption. Since the material of packaged water is mainly bottled and made from plastic, especially polyethylene terephthalate (PET) and/or polypropylene (PP), it is difficult to degrade in nature (Raj et al., 2023; Andreasi Bassi et al., 2021). Furthermore, the changes in people's way of living to get better and healthier quality water increase the demand for packaged water. These materials are the primary focus of recycling since the quantity of post-consumer packaged water containers rises yearly. Recycling packaged water container waste is more economical compared to chemical processing, which uses complicated and costly procedures. The recycling process consists of two major processes, chemical recycling and mechanical recycling. However, during the recycling processes, the polymer chain of recycled materials was decomposed and degraded, ultimately leading to a decline in the materials' mechanical and chemical properties (Karayannidis & Achilias, 2007; Hopewell et al., 2009; Schyns & Shaver, 2021).

This study involves the development of an rPET / rPP composite with a mixture of Kenaf and Sodium hydroxide (NaOH). rPET sample preparation from post-consumer waste. To determine the best ratio of rPET/rPP depending on the viscosity so that it can be processed using common thermoplastic processing techniques, i.e., extrusion and injection molding. To investigate the effect of KF and NAOH on the mechanical properties of rPET/rPP. This proposed research will develop acceptable properties in terms of mechanical (tensile testing) and thermal properties for rPET/rPP reinforced KF and NAOH. The success of this research will widen the applications of rPET/rPP reinforced KF with and without NAOH, such as for door panels, seat backs, headliners, package trays, dashboards, and interior parts, with thermoplastic and thermoset matrices (Holbery & Houston, 2006). There are five main materials proposed in this research. The materials are recycled PET (rPET), recycled PP (rPP), kenaf fiber (KF), and sodium hydroxide (NAOH).

In this study, a mixture of sodium hydroxide (NaOH) and kenaf fiber (KF) is used to develop a recycled PET/recycled PP (rPET/rPP) composite. The rPET samples are produced from post-consumer waste. The study aims to determine the optimal rPET/rPP ratio based on viscosity, enabling processing through conventional thermoplastic methods such as injection molding and extrusion. Additionally, it investigates the effects of KF and NaOH treatment on the mechanical properties of the rPET/rPP composite. The proposed work seeks to achieve acceptable mechanical (tensile) and thermal properties for rPET/rPP reinforced with KF and treated with NaOH. The success of this research will broaden the applications of rPET/rPP reinforced with KF – with or without NaOH treatment – in both thermoplastic and thermoset matrices, for use in components such as dashboards, package trays, headliners, door panels, seat backs, and other interior parts (Holbery & Houston, 2006).

## 2. METHODOLOGY

Sample preparation will consist of several steps, such as preparation of rPET and rPP flakes from post-consumer plastics waste, preparation of KF, preparation and characterization of rPET/rPP blends in various compositions, and melt processing of the best ratio of rPET/rPP blends with KF and NaOH.

### 2.1 Experimental Setup

The rPET and rPP bottles will be crushed into smaller sizes using a crusher before they are washed with water and soap to remove any substances (Figures 1 and 2). After that, rPET and rPP flakes will be dried in a vacuum oven at temperatures of 120°C and 80°C, respectively, for 24 hours to prevent moisture-induced thermal degradation of rPET and rPP.



**FIGURE 1:** The rPP bottles will be crushed into smaller sizes using a crusher



**FIGURE 2:** The rPET bottles will be crushed into smaller sizes using a crusher

## 2.2 Preparation of Kenaf Fiber (KF)

KF preparation will be done according to the procedures of Saiman et al. (2014) (Figure 3). KF should be washed, ground, and sieved to obtain a uniform particle size (Figures 4 and 5). After that, KF should be treated using 6% sodium hydroxide (NaOH) at 60 °C for 3 hours. Then, KF should be rinsed with distilled water until NaOH is eliminated and then dried in an oven at 80°C for 24 hours.

The rPET/rPP blends with 95/5, 90/10, 85/15, and 80/10 (wt./wt.%) compositions will be prepared by melt blending in a twin-screw extruder. To obtain the best ratio of rPET/rPP blends, each composition of the extruded rPET/rPP blends will be injection molded into a standard specimen test of tensile testing using an injection-molding machine. All the materials will be placed into a blending machine to make sure all the materials are homogeneously mixed. To evaluate the additive effect of KF and NAOH. They will be mixed in different weight proportions. The compositions of KF and NAOH that will be added simultaneously to the rPET/rPP blend (with the best ratio composition) will be varied from 1 wt.%, 3 wt.%, and 5 wt.% (relative to the total weight of the blend). Then, the materials will be prepared by melt compounding of rPET/rPP blends, KF with and without NAOH, in a twin-screw extruder. The mixture will be extruded and fed to a pelletizer to generate pellets for the compounding process. The extruded material will be pelletized and injection-molded into standard tensile and Izod impact test specimens.



**FIGURE 3:** Kenaf Fiber – KF



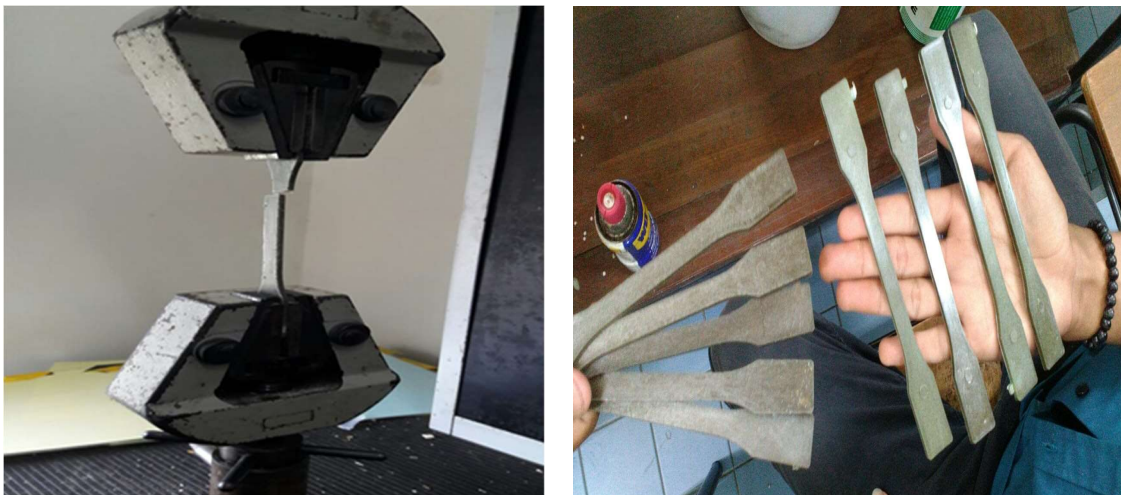
**FIGURE 4:** KF should be rinsed with distilled water until NaOH is eliminated and then dried in an oven at 80°C for 24 hours



**FIGURE 5:** KF should be washed, ground, and sieved to obtain a uniform particle size

### 2.3 Measurement Parameters

The tensile testing in this project involves applying controlled tension to a sample until it fails (Figure 6). The results are typically used for material selection, quality control, and predicting how the material will perform under different types of forces. A tensile test directly measures properties such as ultimate tensile strength, maximum elongation, and reduction in area. It also provides data to determine Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. The specimen, having either a circular or rectangular cross-section, is bent until fracture or yielding using a three-point flexural test. Flexural strength represents the highest stress experienced within the material at its moment of yield.



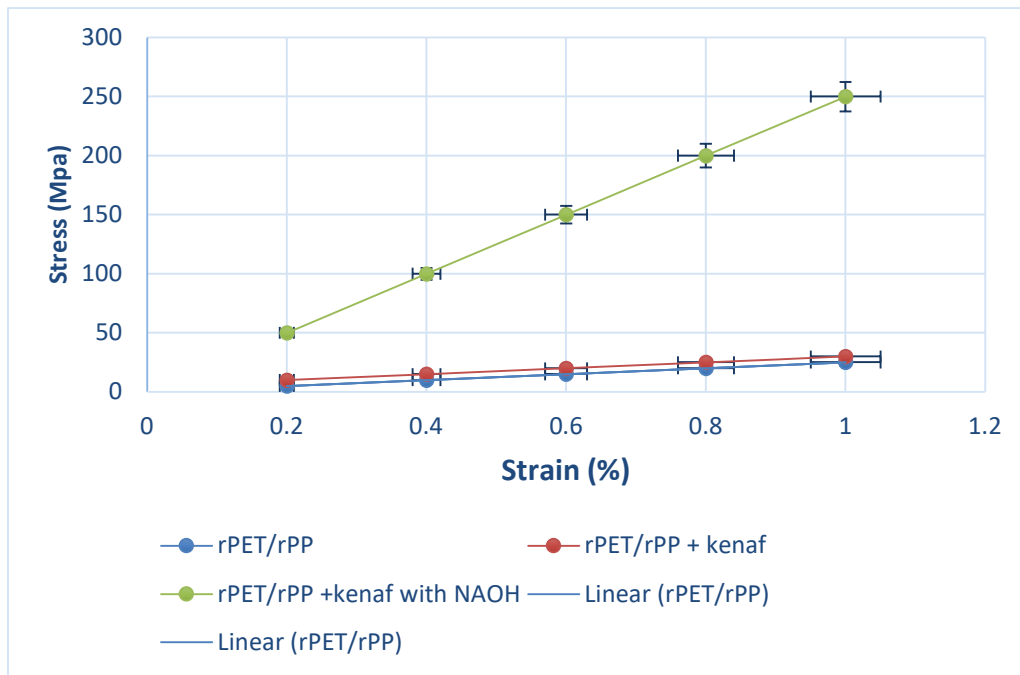
**FIGURE 6:** Tensile testing – sample is subjected to controlled tension until failure (left); Tensile sample (right)

## 3. RESULTS AND DISCUSSION

The rPET/rPP + kenaf with NaOH The addition of NaOH treatment results in a curve that is like the kenaf composite but might show higher strength. NaOH is a chemical treatment that can improve the bonding between the kenaf fibers and the matrix, resulting in better stress transfer and enhanced tensile strength in the mechanical properties of composite materials, especially for applications where tensile strength and flexibility are critical. Kenaf fibers improve the tensile properties of rPET/rPP composites. NaOH treatment further enhances the bonding between the fibers and the matrix, improving the overall tensile strength and elongation of the composite. The rPET/rPP + kenaf with NaOH composite is likely the most suitable for applications requiring both strength and deformation capacity, while the rPET/rPP

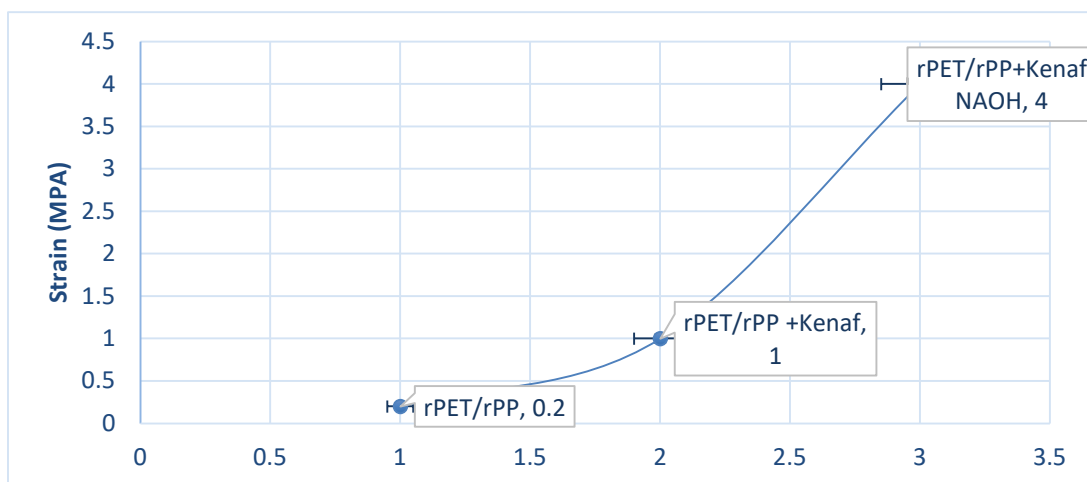
composite is more suitable for applications with low load-bearing requirements. If you need to explore more specific aspects, such as calculating the modulus of elasticity or fracture toughness.

Figure 7 illustrates the curve showing a relatively linear relationship between stress and strain, indicating elastic behavior at lower strains. However, the material appears to have a lower stress (tensile strength) than the other composites. This composite of rPET/rPP and kenaf shows a steeper stress-strain curve, indicating it can withstand higher tensile stress. The presence of kenaf fibers likely improves the strength of the composite material. This also suggests that the material exhibits some non-linear behavior as it strains beyond the elastic limit.



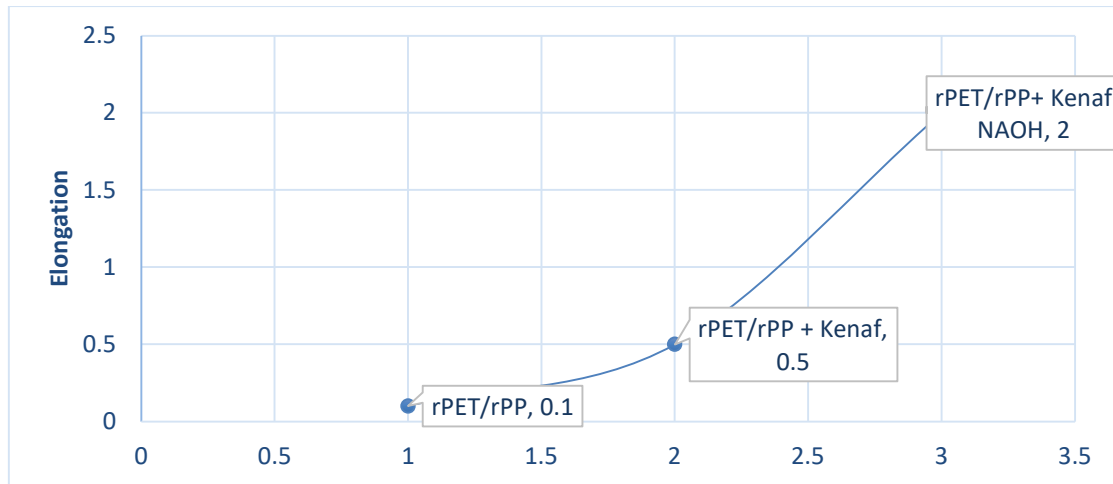
**FIGURE 7:** Linear relationship between stress and strain

Figure 8 presents the results of the flexural testing that was conducted according to the different formulations. There were three formulations: Recycled Plastic (rPET/rPP), recycled plastic with Kenaf reinforcement (rPET/rPP+Kenaf), and recycled plastic with Kenaf reinforcement that undergoes sodium hydroxide treatment (rPET/rPP + Kenaf + NAOH).



**FIGURE 8:** Flexural testing was conducted according to the different formulations

Figure 9 presents the results of the graph illustrating the elongation behavior of different recycled material composites, including recycled PET (rPET) and polypropylene (rPP) blends, as well as blends reinforced with kenaf fiber treated with NaOH. The base recycled PET and polypropylene blend shows minimal elongation, indicating low ductility and flexibility. Adding untreated kenaf fibers improves elongation slightly. This suggests that the natural fibers enhance the composite's ability to stretch under stress but are still limited in ductility. When the kenaf fibers are treated with NaOH, elongation increases significantly. This treatment likely improves the fiber-matrix bonding, making the composite more flexible and able to withstand higher deformation before breaking.



**FIGURE 9:** Elongation behavior of different recycled material composites

#### 4. CONCLUSION

The research of recycled plastic with kenaf reinforcement aims to study the properties of project materials and use recycled plastic with kenaf reinforcement to expand the use of plastics in automotive applications. The treatment of kenaf fibers with NaOH plays a critical role in improving the elongation properties of the composite. This makes the treated fiber-reinforced composite a more suitable candidate for applications requiring higher flexibility and ductility, such as automotive interiors or packaging materials. Our project also reduces waste from plastic because it is a non-biodegradable material that can save the environment from the pollution caused by this plastic waste. For further research and development of this project, we want to continue our project, some suggestions here are to improve our project by using only thermoplastics and using natural fibers with high strength to get better research results.

#### ACKNOWLEDGEMENTS

The authors wish to thank all related members from the Mechanical Engineering Department, Politeknik Sultan Azlan Shah (PSAS), Mechanical Engineering Department, Politeknik Sultan Azlan Shah (PSAS), and the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia.

#### REFERENCES

- Andreasi Bassi, S., Tonini, D., Saveyn, H., & Astrup, T. F. (2021). Environmental and socioeconomic impacts of poly (ethylene terephthalate)(PET) packaging management strategies in the EU. *Environmental Science & Technology*, 56(1), 501-511.
- Holbery, J., & Houston, D. (2006) Natural-fiber-reinforced polymer composites in automotive applications. *JOM* 58, 80–86.
- Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526), 2115-2126.

- Karayannidis, G. P., & Achilias, D. S. (2007). Chemical recycling of poly (ethylene terephthalate). *Macromolecular Materials and Engineering*, 292(2), 128-146.
- Raj, B., Rahul, J., Singh, P. K., Rao, V. V. L. K., Kumar, J., Dwivedi, N., Kumar, P., Singh, D., & Strzałkowski, K. (2023). Advancements in PET packaging: Driving sustainable solutions for today's consumer demands. *Sustainability*, 15(16), 12269.
- Saiman, M.P., Wahab, M.S., Wahit, M.U. (2014). The effect of fabric weave on the tensile strength of woven kenaf reinforced unsaturated polyester composite. In: Ahmad, M., Yahya, M. (eds) *Proceedings of the International Colloquium in Textile Engineering, Fashion, Apparel and Design 2014 (ICTEFAD 2014)*. Springer, Singapore.
- Schyns, Z. O., & Shaver, M. P. (2021). Mechanical recycling of packaging plastics: A review. *Macromolecular rapid communications*, 42(3), 2000415.