MALAYSIAN JOURNAL OF INNOVATION IN ENGINEERING AND APPLIED SOCIAL SCIENCE (MyJIEAS)
e-ISSN : 2811-3780
VOLUME 04, ISSUE 01

Utilisation Of Plastic Waste To Produce Eco-Friendly Foundation Material For Household Organizer

Anis Sakinah Zainal Abidin[1]*, Nor Azrin Ahmad Kurnin[1], Suhailah Samat[1]
[1]Jabatan Kejuruteraan Petrokimia, Politeknik Tun Syed Nasir Syed Ismail, Pagoh, Johor, Malaysia.

Corresponding Author's Email: anis.sakinah@ptsn.edu.my

Article History : Received 04092024; Revised 02102024; Accepted 30102024;

ABSTRACT – Plastics are a form of synthetic organic polymers and are one of the most often used materials because they are durable, lightweight, flexible and relatively affordable to manufacture. With the global transition from reusable to single-use containers, the demand for packaging materials has surged. Thus, this have led to high contribution of plastic waste in the world. Thus, this project focused on utilizing plastic waste specifically High-Density Polyethylene (HDPE) and Polypropylene (PP) to produce eco-friendly foundation material for household organizer by using green approach. The second objective is to find the optimum mixing ratio of PP and HDPE to produce the foundation material. The product is then tested for its' mechanical property specifically tensile strength prior to constructing the final product which is organizer. PP and HDPE are obtained by collecting waste detergent bottles, supplement bottles and drinking waste bottle caps. Both materials are washed, dried and cut into small pieces before undergo heat treatment using hot press. Melted plastics are then molded into specific shape for mechanical testing. Tensile test and Young Modulus results of 7.63 MPa and 13.996 MPa respectively, indicate that a mixing ratio of 2PP: 8HDPE is sufficient to be used for constructing household organizer foundation material.

KEYWORDS : Plastic Waste Recycling, Eco-friendly Foundation Material, Poly-propylene, High Density Polyethylene.

1.0 INTRODUCTION

Plastic waste has become a pressing global concern, with staggering statistics highlighting its pervasive impact on the environment. According to recent data, the worldwide production of plastic reached an estimated 390.7 million metric tons in 2021, [1], increased to 400.3 million metric tons in 2022 [2] and this figure is projected to continue rising in the coming year. A significant portion of this plastic ends up as waste, with studies indicating that approximately 8.3 billion metric tons of plastic have been generated since the 1950s, of which only a fraction has been recycled or properly managed [3], [4]. This exponential growth in plastic production and consumption underscores the urgent need for effective waste management strategies to mitigate the detrimental effects on the environment and human health.

Among the diverse array of plastics contributing to global waste, polypropylene (PP) and high-density polyethylene (HDPE) are one of the major contributor due to their widespread use in packaging, construction, and consumer goods industries. PP and HDPE are versatile polymers valued for their durability, lightweight nature, and resistance to chemical degradation, making them present in everyday products [5], [6]. However, their persistent presence in waste streams poses significant challenges for recycling and disposal efforts. Despite advancements in recycling technologies, the complex composition and sorting challenges associated with mixed plastic waste hinder efficient recovery and reprocessing of PP and HDPE, contributing to their accumulation in landfills and marine environments [7].

The uncontrolled spread of plastic waste has significant consequences for the environment and global ecosystems, demanding immediate action to tackle this urgent concern. Plastic pollution poses a lot of threats to terrestrial and aquatic ecosystems, including habitat degradation, wildlife entanglement and ingestion, and the leaching of harmful chemicals into the environment [4]. Furthermore, the persistence of plastics in the environment escalates climate change by releasing greenhouse gases during production, incineration, and decomposition processes [8], [9]. In response to these challenges, governments, industries, and civil society stakeholders worldwide have initiated various approaches to mitigate plastic waste, including legislative measures, waste management infrastructure improvements, public awareness campaigns, and advancements in plastic recycling and alternative materials research [10]. Despite these efforts, significant barriers remain, underscoring the need for continued collaboration and innovation to achieve meaningful reductions in plastic waste and safeguard the planet for future generations.

Therefore in this research, both HDPE and PP material are chosen as raw material due to its wide usage and availability in the community and commonly disposed at landfill. Besides, their mechanical and thermal properties such as high tensile strength and melting point makes it suitable to be used to make organizer. Research indicates that PP, commonly found in plastic waste, exhibits improved flowability with increased recycling cycles, enhancing its suitability for molding organizers [11].

2.0 METHODOLOGY

2.1. Preparation of raw materials

Plastic waste made of poly-propylene and high-density poly-ethylene is collected from student residences at Kolej Kediaman UTHM, Pagoh, and community nearby Pagoh Jaya. Most of the waste collected consists of detergent, mineral water, shampoo bottle and others. All waste is sorted according to the material based on the plastic recycling symbol found under the bottles. Next, the bottles are washed, dried and cut into small pieces of 2.5cm^2 area. Equipment and materials used for molding and heat treatment are 1 mm thickness galvanised steel sheet, block base made of wood to hold the mold designed according to the testing sample size, wooden load block to compress the melted sample, silicone spray of any brand, grease-resistant/ baking paper and double hot plate, Breville BSG220 with both top and bottom non-stick flat surface.

2.2. Heat treatment and molding of sample

The samples are weighed according to predetermined ratios, as outlined in Table 1. Following this, preparations for the melting process are initiated. The melting process is facilitated by utilizing the Breville BSG220 double hot plate, which consumed approximately 2000 Watts of power. This equipment can achieve temperatures sufficiently high to melt the components of the PP/HDPE mix. Once the double hot plate is switched on, the sample is positioned between two sheets of grease-resistant paper. Pressure is applied onto the double hot plate to ensure the sample melt and mix completely. Then, the melted sample is carefully kneaded manually before placed into a mold that had been layered with silicone spray to prevent material adhesion. The mold itself is fabricated using pre-prepared galvanized steel sheet that was cut according to analysis sample size requirement. Finally, the melted sample within the mold is compressed using wooden load block to ensure even distribution.

Table 1. Ratio of PP to HDPE used.

Sample Number	Ratio PP: HDPE
1	2:8
2	5:5
3	6:4
4	7:3
5	8:2

2.3. Tensile strength analysis

The tensile test method for evaluating the mechanical properties of a polymer blend consisting of polypropylene (PP) mixed with high-density polyethylene (HDPE) is conducted following the guidelines outlined in ASTM D3039. This standard specifies the procedure for determining the tensile properties of continuous fibre-reinforced composite materials in the form of straight-sided test specimens [12]. In this method, specimens are prepared according to specific dimensions which is 250mm length, 25mm width and 3mm thickness before subjected to a controlled tensile loading until failure occurs. The test apparatus includes grips for securely holding the specimen and a load cell for measuring the applied force. It is carried out using Tinius Olsen H10KL Universal tensile testing machine with data gathered in Horizon software. During the test, the load and corresponding elongation or deformation of the specimen are continuously monitored to generate stress-strain curves, from which important mechanical properties such as tensile strength, modulus of elasticity, and elongation at break are determined.

2.4. Fabrication of household organizer

Figure 1 shows several parts of organizer prepared according to measurement finalised by using heat treatment utilizing the Breville BSG220 double hot plate. All parts are made with the same thickness of 1 cm. The measurement can be customised according to the demand. Once all parts have been molded and dried, they are assembled one by one using screws.

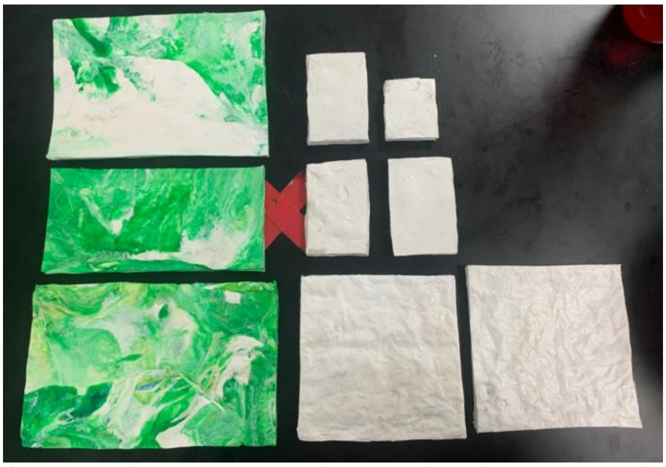

Figure 1. Different parts of the organizer before assembly

3.0 RESULT

Figure 2 depicts the sample that has been melted and molded into specific measurement before assembled into end product. The sample is molded according to measurement established in ASTM D3039 for tensile strength.

Figure 2. Molded sample of PP/HDPE composite

Figure 3 shows intriguing insights into the tensile strength characteristics of the polymer blend comprising polypropylene (PP) and high-density polyethylene (HDPE) across different ratios. The average ultimate tensile strength ranged from 7.156 MPa to 7.744 MPa, with the 6:4 PP to HDPE ratio displaying the highest strength, followed closely by the 7:3 ratio. Interestingly, as the proportion of PP in the blend increased beyond the 6:4 ratio, the average strength began to decrease, with the 8:2 ratio exhibiting the lowest strength. This trend suggests that an optimal balance between PP and HDPE content exists to achieve maximum tensile strength, with deviations from this balance potentially compromising the mechanical properties of the blend.

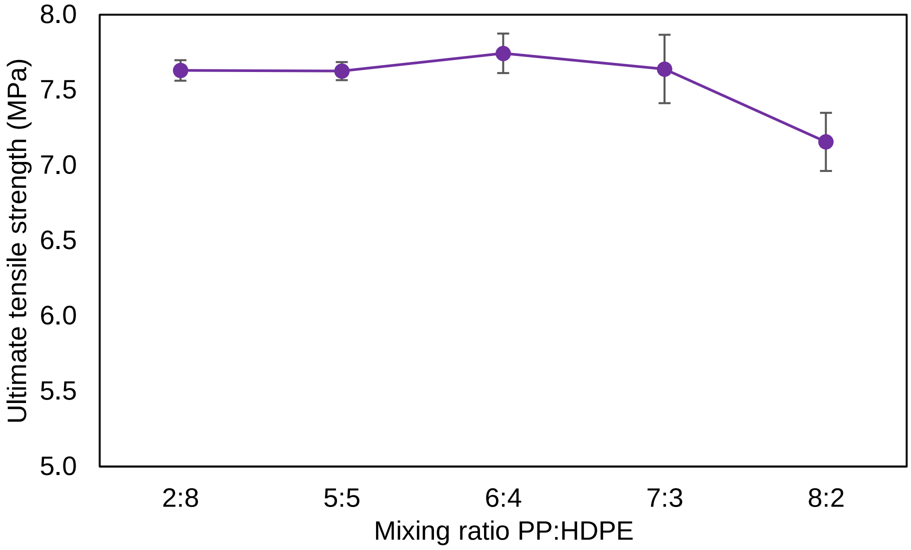

Figure 3. Effect of mixing ratio PP/HDPE on tensile strength of composite.

The variability within each ratio group, as indicated by the standard deviation (STDV) values ranging from 0.104 to 0.393 MPa, highlights the influence of factors such as material homogeneity and processing conditions on the observed strength variations [13]. Moreover, the standard error of the mean (SDE) values, ranging from 0.060 to 0.227 MPa, highlights the precision of the average strength estimates and provides confidence intervals for the reported data. Overall, these findings emphasize the importance of careful consideration of PP to HDPE ratios in polymer blend formulations to optimize tensile strength and ensure desired material performance in various applications. Though a research indicate blending PP with HDPE can potentially reduce tensile strength due to challenges in recycling [14], it is not too significant for this research as the purpose is to produce a light duty organizer.

Figure 4 shows the data analysis of Young's Modulus values for the polymer blend consisting of polypropylene (PP) and high-density polyethylene (HDPE) across various ratios which offers valuable insights into the material's mechanical behaviour. Across the tested ratios ranging from 2:8 to 8:2 of PP to HDPE, the average Young's Modulus values ranged from 13.996 MPa to 14.592 MPa. Interestingly, the highest average modulus of 14.592 MPa is observed for the 8:2 ratio, while the lowest average modulus of 13.996 MPa corresponds to the 2:8 ratio. This trend suggests a potential correlation between the ratio of PP to HDPE and the stiffness properties of the polymer blend. Studies by Redhwi et al., (2023) [15] corroborate these findings, demonstrating that variations in polymer composition can significantly impact the resulting material's mechanical properties, including Young's Modulus. Furthermore, the observed fluctuations in modulus values across different ratios align with the complexities of polymer blending, where factors such as polymer-polymer interactions, phase separation, and filler dispersion can influence material stiffness [16].

The standard deviation (STDV) values, ranging from 0.522 to 1.511 MPa, indicate notable variability within each ratio group, which is consistent with the inherent heterogeneity often encountered in polymer blends. Additionally, the standard error of the mean (SDE) values, ranging from 0.301 to 0.872 MPa, provides insights into the precision of the average modulus estimates and underscores the importance of statistical rigor in experimental analysis.

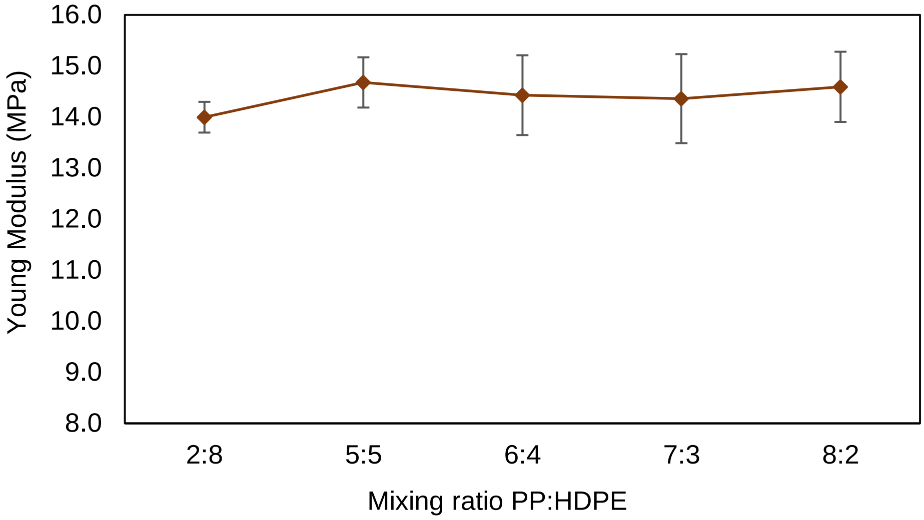

Figure 4. Effect of mixing ratio PP/HDPE on Young Modulus of composite.

Figure 5 shows the end product of stationaries organizer made of composite PP and HDPE. The development of a stationary organizer using a composite material derived from polypropylene (PP) and high-density polyethylene (HDPE) presents an innovative solution for enhancing organizational efficiency. The results from tensile strength and Young's Modulus tests indicate that while a ratio of PP to HDPE 2:8 shows a relatively lower average tensile strength, it remains sufficient for applications such as stationary organizers, which do not bear heavy loads. With average tensile strengths ranging from 7.156 MPa to 7.744 MPa and average Young's Modulus values ranging from 13.996 MPa to 14.592 MPa across various PP to HDPE ratios, the composite material offers a balance of strength and stiffness ideal for supporting stationary items effectively. Despite the lower tensile strength at the 2:8 ratio, the composite material remains durable enough to withstand typical loads encountered in stationary organization, ensuring long-term structural integrity. Moreover, the versatility of the PP-HDPE composite allows for the creation of intricate organizer designs tailored to specific organizational needs, further enhancing its utility. Thus, the stationary organizer developed from the PP-HDPE composite showcases the practical applications of polymer blend materials in providing durable and efficient organizational solutions for everyday use.

Figure 5. Stationaries organizer.

4.0 CONCLUSION

This research works on utilizing waste plastic, poly propylene and high density poly-ethylene specifically to produce foundation material for variety type of household organizer by using green approach without any usage of chemicals. Though the tensile strength and young modulus of samples differs with certain mixing ratio, organizer built from 2:8 ratio of PP and HDPE provide sufficient support for any stationaries or simple household item. For further improvement, usage of efficient molding technique with good compression factor and application of surface treatment or polishing are recommended.

ACKNOWLEDGEMENT

The authors would like to express sincere gratitude to Politeknik Tun Syed Nasir Syed Ismail, for the generous support and provision of equipment and laboratory facilities that were instrumental in the successful completion of this research project.

REFERENCES

[1] Plastics Europe, "The Plastics-the Facts 2022," Plastics Europe. Accessed: May 01, 2024. [Online]. Available: https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/

[2] Plastics Europe, "Plastics-The Fast Facts 2023," Plastics Europe. Accessed: May 04, 2024. [Online]. Available: https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/

[3] J. R. Jambeck *et al.*, "Plastic waste inputs from land into the ocean," *Science (1979)*, vol. 347, no. 6223, pp. 768–771, Feb. 2015, doi: 10.1126/science.1260352.

[4] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," *Sci Adv*, vol. 3, no. 7, 2017, doi: 10.1126/sciadv.1700782.

[5] A. L. Andrady, "Persistence of plastic litter in the oceans," in *Marine Anthropogenic Litter*, Springer International Publishing, 2015, pp. 29–56. doi: 10.1007/978-3-319-16510-3_3.

[6] PlasticsEurope, "Plastics-the Facts 2021 (An analysis of European plastics production, demand and waste data)," Plastics Europe. Accessed: Apr. 28, 2024. [Online]. Available: https://plasticseurope.org/knowledge-hub/plastics-the-facts-2021/

[7] Reifsteck. , Rafael *et al.*, "Techno-Economic Comparison of Bio-Cycling Processes for Mixed Plastic Waste Valorization," *Chemie Ingenieur Technik*, vol. 95, no. 8, pp. 1247–1258, 2023, doi: 10.1002/cite.202300021.

[8] F. L. Kakar, Frances Okoye, Victoria Onyedibe, Rania Hamza, Bipro Ranjan Dhar, and Elsayed Elbeshbishy, "Chapter 16 - Climate change interaction with microplastics and nanoplastics pollution," in *Microplastics and Nanoplastics: Occurrence, Environmental Impacts and Treatment Processes*, 2023, pp. 387–403. doi: https://doi.org/10.1016/B978-0-323-99908-3.00003-8.

[9] F. Bauer *et al.*, "Plastics and climate change breaking carbon lock-ins through three mitigation pathways," Apr. 15, 2022, *Cell Press*. doi: 10.1016/j.oneear.2022.03.007.

[10] K. K. Khoaele, O. J. Gbadeyan, V. Chunilall, and B. Sithole, "The Devastation of Waste Plastic on the Environment and Remediation Processes: A Critical Review," Mar. 01, 2023, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/su15065233.

[11] C. Budiyantoro, H. Sosiati, and J. W. Joharwan, "The influence of the number of recycling cycles on the thermal and physical properties of polypropylene," *Mechanical Engineering-Jurnal Polimesin*, vol. 21, no. 4, pp. 2023–2031, 2023, [Online]. Available: http://e-jurnal.pnl.ac.id/polimesin

[12] Tavio. , Tavio and Ardhyananta. Hosta, "Tensile Properties of Woven Plastic Straw Waste Fiber," *International journal on engineering applications*, vol. 11, no. 1, 2023, doi: https://doi.org/10.15866/irea.v11i1.22537.

[13] K. A. Kara, A. V. Dolzhenko, and I. S. Zharikov, “Influence of processing factors over concrete strength.,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Apr. 2018. doi: 10.1088/1757-899X/327/3/032027.

[14] F. Suvari and H. Gurvardar, “Revitalizing high-density polyethylene (HDPE) waste: from environmental collection to high-strength hybrid yarns,” *Polymer Bulletin*, 2024, doi: 10.1007/s00289-024-05367-x.

[15] H. H. Redhwi, M. N. Siddiqui, A. L. Andrady, S. A. Furquan, and S. Hussain, “Durability of High-Density Polyethylene (HDPE)- and Polypropylene (PP)-Based Wood-Plastic Composites—Part 1: Mechanical Properties of the Composite Materials,” *Journal of Composites Science*, vol. 7, no. 4, Apr. 2023, doi: 10.3390/jcs7040163.

[16] M. , Ramesh and M. Muthukrishnan, “25 - Biodegradable polymer blends and composites for food-packaging applications,” in *Biodegradable Polymers, Blends and Composites*, Woodhead Publishing, 2022, pp. 693–716. doi: https://doi.org/10.1016/B978-0-12-823791-5.00004-1.