PERFORMANCE EVALUATION OF RECYCLED PET FILAMENTS PLASTICIZED WITH WASTE COOKING OIL FOR FUSED DEPOSITION MODELING APPLICATIONS

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ABSTRACT: This study investigates the mechanical and microstructural properties of recycled polyethylene terephthalate (rPET) filaments plasticized with refined waste cooking oil (rWCO) for Fused Deposition Modeling (FDM) applications. rWCO was physically refined using cornstarch treatment and blended with rPET at 5%, 7.5%, and 10% concentrations. Filaments were extruded and printed using a Creality K1C printer, followed by tensile testing, XRD, and SEM analysis. The 7.5% rWCO blend showed improved morphology and crystallinity, but tensile strength remained lower than pure rPET. Statistical analysis revealed a moderate negative correlation ($r = -0.650$) between rWCO content and tensile strength, with ANOVA confirming significance ($p = 0.022$). Regression modeling indicated that rWCO concentration accounts for 42.29% of the variability in tensile strength. Despite mechanical limitations, rWCO enhanced print consistency and surface quality. The 7.5% blend emerged as the most balanced formulation, supporting its potential for sustainable filament development. Future work should explore lower rWCO ratios and compatibilizers to improve mechanical resilience.

KEYWORDS: *FDM, rPET, Waste Cooking Oil, Plasticizer, Tensile Strength, ANOVA,* *Regression, SEM, XRD*

1.0 INTRODUCTION

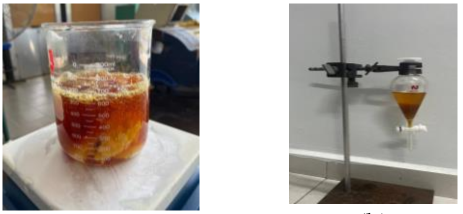
Additive manufacturing (AM), enables fast, precise fabrication of complex structures while reducing waste and improving efficiency. Its versatility has expanded applications in aerospace, healthcare, and education, driving interest in using recycled polymers like rPET for sustainable filaments. However, rPET is less durable and flexible than virgin PET [1] due to chain scission during recycling, which lowers molecular weight, viscosity [2], tensile strength, impact resistance, and fatigue performance [3]. Increased crystallinity adds brittleness [4], and impurities from recycling can cause yellowing and reduced optical quality [5]. Blending with impact modifiers like SEBS-g-MA or E-EA-GMA can improve thermal and mechanical properties [6].

The performance of rPET can be improved through reactive extrusion with chain extenders or copolymer blends, which enhance elasticity, mechanical strength, and thermal resistance [7], and similarly, incorporating additives such as nano silica into chitosan films has been shown to enhance mechanical strength and stability, illustrating how modifiers can generally improve polymer-based materials [8]. For applications such as concrete reinforcement or geotextiles, additional chemical treatments or conversion into nanofibers are often required to increase durability and compatibility with the matrix [9]. Nevertheless, rPET still exhibits inferior strength, ductility, and property consistency compared to virgin PET. This study investigates the use of recycled waste cooking oil (rWCO) as a renewable, low-toxicity bio-plasticizer to improve interlayer bonding and reduce brittleness [10], [11]. In this study, rPET was blended with 5%, 7.5%, and 10% rWCO, and the resulting filaments were tested for tensile strength to assess the effect of rWCO concentration on mechanical performance and identify the optimal blend for sustainable 3D printing.

2.0 METHODOLOGY

2.1 Physical Refining of Waste Cooking Oil (rWCO)

Figure 1(a) shows the slurry added to hot rWCO and stirred for 10 minutes, forming residues and clarifying the oil. This physical refining method aligns with recent polymer recycling innovations aimed at improving mechanical and chemical properties. Techniques such as chemical recycling to monomer (CRM) and catalytic upcycling have also been used to enhance polymer quality and compatibility [12].



(a) (b)

Figure 1: (a) Mixture of rWCO and cornstarch after 10 minutes of heating; (b) Filtration setup used to remove impurities and obtain refined rWCO

After settling for a week to allow phase separation, the upper layer of refined rWCO was filtered using a separatory funnel, as shown in Figure 1(b), to remove impurities. This purification step addresses common issues in recycled plastics such as brittleness and contamination. Similar to reactive mixing in polymer blends [13], refining rWCO improves its compatibility with rPET, enhancing filament flexibility and consistency for 3D printing. This approach supports the development of high-performance, eco-friendly materials through sustainable upcycling techniques.

2.2 Extrusion & Filament Preparation Process

After refining the recycled waste cooking oil (rWCO), it was sprayed onto clean PET bottle. Each PET bottle was first weighed to determine its initial mass, then the final target weight was calculated based on the desired rWCO ratio (5%, 7.5%, or 10%). The rWCO was sprayed gradually while monitoring the weight with a digital balance until the PET bottle reached the calculated target. This ensured a consistent and accurate rWCO-to-PET ratio for each blend. Once the oil application was complete, the treated PET bottles were extruded using a PET Extruder Machine to produce filament for 3D printing. The extruded filament was then collected and weighed. Any excess oil spilled during extrusion or left on the bottle was also gathered and measured. This helped confirm how much rWCO was actually absorbed by the PET, which is important for analyzing its impact on the material's mechanical performance.

2.3 3D Printing Parameters

Table 1 shows the 3d printing parameters used. Tensile samples were prepared according to ASTM D638 Type IV and tested on a Shimadzu UTM (20 kN load cell, 5 mm/min). Fractured surfaces were sputtercoated with a 10 nm palladium and gold layer before microstructural observation using a Carl Zeiss Evo 50 SEM at 50x, 100x, and 150x with a 10-kV acceleration voltage, while interlayer gaps were measured using ImageJ.

Table 1: 3D Printing parameter for rPET [14]

Parameter	
Nozzle Temperature	220–230 °C
Bed Temperature	100 °C
Nozzle Temp (Pellet)	250–270 °C
Bed Temp (Pellet)	90–110 °C
Infill Density	70%
Layer Thickness	1.1 mm

3.0 RESULTS AND DISCUSSION

3.1 Tensile Test

Tensile tests were conducted to evaluate the effect of rWCO on the mechanical performance of rPET with rWCO concentrations of 0%, 5%, 7.5%, and 10%. This analysis aimed to determine whether rWCO improves flexibility or compromises structural integrity. The results, shown in Table 2 and Figure 2, respectively, provide insights into how rWCO content influences the strength and consistency of 3D-printed rPET filaments.

Based on Figure 2, pure rPET showed the highest and most consistent tensile strength at 14.10 MPa. The addition of 5% rWCO reduced strength to 10.45 MPa with greater variation, likely due to poor dispersion in the polymer matrix [15]. This aligns with findings in [10], [11] showing that WCO increases flexibility but decreases mechanical strength. At 7.5%, the strength increased to 11.52 MPa with more uniform curves, indicating improved compatibility and flexibility, which is the same as reported in studies using EBA-GMA and TPU where the strength reduction is present but more controlled [15], [16]. However, at 10%, strength slightly dropped to 11.41 MPa, indicating possible over-plasticization or phase instability [18].

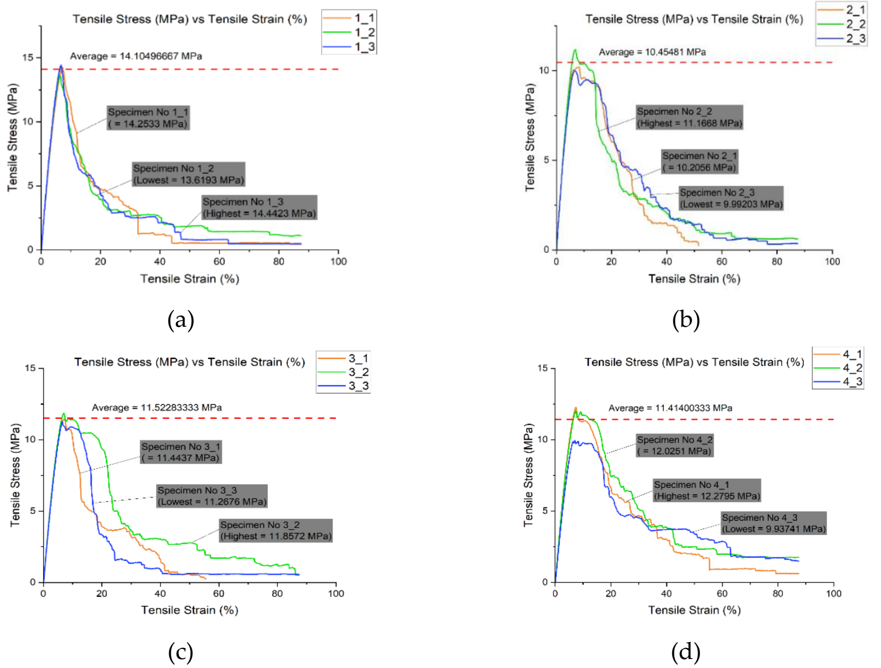


Figure 2: Stress strain curve for tensile test under parameter set (a) 0% rWCO (Pure rPET); (b) 5% rWCO; (c) 7.5% rWCO; (d) 10% rWCO

Table 2: Tensile test result

Set	Parameter	Tensile Force (N)		Tensile Strength (MPa)	
		Average	Std Dev	Average	Std Dev
(A)	Pure rPET	237.25	7.25	14.10	0.43
(B)	5% rWCO	175.85	10.53	10.45	0.63
(C)	7.5% rWCO	193.81	5.09	11.52	0.30
(D)	10% rWCO	191.98	21.61	11.41	1.28

All rWCO blends showed an 18–26% reduction in tensile strength compared to pure rPET, with the steepest drop at 5% (25.9%). Similar trends have been reported in rPET blends with flexible polymers like TPU and PLA, where increased flexibility compromises strength due to reduced intermolecular interactions [18]. In this case, the unexpected drop in tensile strength may be attributed to poor miscibility between the rWCO and rPET matrix, which can lead to uneven dispersion of the plasticizer and the formation of microphase separation or voids. These imperfections can act as localized stress points under mechanical loading, weakening the overall structural integrity of the material [19],

[20]. Additionally, the presence of rWCO may interfere with the crystallization behavior of rPET during cooling, reducing the formation of well-ordered crystalline regions that are essential for mechanical strength [21]. Well-ordered crystalline domains play a critical role in ensuring toughness and stability, and disruptions in this structure can significantly reduce mechanical performance [22], [23]. Together, these factors counteract the intended plasticizing effect and contribute to the observed decline in tensile performance.

3.2 Microstructural Analysis

To evaluate the structural impact of rWCO, X-ray diffraction (XRD) analysis was conducted. This technique identifies changes in crystallinity and reveals whether rWCO alters the molecular structure of rPET. Such changes may explain variations in mechanical properties. Figure 3 compares the XRD patterns of pure rPET and rPET blended with 7.5% rWCO.

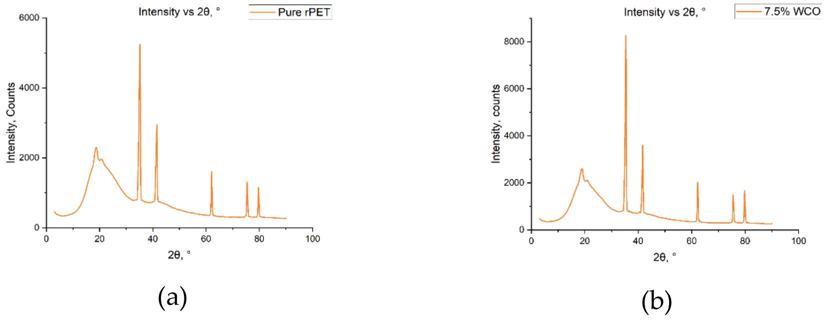


Figure 3: XRD analysis results for the rPET sample, comparing (a) pure rPET and (b) rPET with 7.5% rWCO

For the pure rPET sample shown in Figure 3(a), the X-ray diffraction (XRD) profile displays clear peaks at around 2θ = 35°, 42°, and 61°. These peaks confirm that the recycled PET retains a semi-crystalline structure, meaning that not all of the original crystal regions were lost during recycling. The sharpness and clarity of the peaks suggest a well-organized and uniform crystalline arrangement. This is important because such crystalline regions help improve mechanical strength and stability by distributing stress more evenly throughout the material. Similar findings have been reported in other studies, where untreated or lightly processed rPET maintained good crystallinity and showed consistent mechanical properties [4]. As a result, the pure rPET sample provides a reliable baseline for comparing how additives like rWCO affect the structure and performance of the material.

In contrast, the 7.5% rWCO-modified sample in Figure 3(b) exhibits slightly higher peak intensities at the same diffraction angles, pointing to a possible increase in crystallinity. This may be attributed to components in the rWCO facilitating better polymer chain alignment during the cooling stage, thus promoting the formation of more ordered regions, an effect similarly observed in plasticized or additized rPET systems [5], [16]. However, despite this apparent improvement in crystallinity, the mechanical testing results show a reduction in tensile strength. This contradiction suggests that increased crystallinity alone does not guarantee improved mechanical properties, a finding also reported in rPET composites and blends where enhanced ordering did not translate to strength gains due to weak interfacial bonding or phase incompatibility [18], [22]. Other factors such as the plasticizing effect of rWCO or the presence of microstructural defects may play a more dominant role in compromising the mechanical integrity of the blend, as similarly shown in various recycled PET formulations with increased brittleness despite crystallinity improvement [23].

To further investigate the material characteristics, Scanning Electron Microscopy (SEM) analysis was performed to examine the interfacial morphology between the rWCO and rPET phases. Figure 4 displays SEM images of the fracture surfaces for both pure rPET and the 7.5% rWCO blend. The fracture surface of pure rPET appears more uniform and denser, reflecting strong bonding and consistent stress distribution, which corresponds to its higher tensile strength, an observation consistent with prior SEM studies showing tight microstructure in unmodified rPET systems [24]. In contrast, the 5% rWCO blend likely shows more voids or rougher surfaces due to poor compatibility and phase separation, which weakens the structure, similar to what has been reported in poorly compatibilized polymer blends that exhibit stress-concentrating defects [25]. At 7.5% rWCO, the fracture appears more ductile and fibrous, suggesting improved dispersion and bonding, a trend supported by SEM studies where elastomer- or nanoclay-modified rPET systems showed smoother, fibrous morphology and improved mechanical behavior [26]. This supports the earlier finding that tensile strength increases at this ratio, before slightly dropping again at 10% due to possible over-plasticization or phase instability, an effect also seen in organoclay- or additive-loaded blends where excessive modifier content disrupted the matrix and degraded performance [27]. These structural differences observed under SEM reinforce the idea that the mechanical performance is closely linked to rWCO concentration and its interaction with the rPET matrix.

Table 3: Interlayer gap length of rPET sample

Parameter Set	Length of Interlayer gap (μm)				Angle (°)
	L1	L2	L3	Average	
(A) Pure rPET	63.47	65.89	66.21	65.19	-90
(B) 7.5% rWCO	52.48	55.12	56.73	54.77	-90

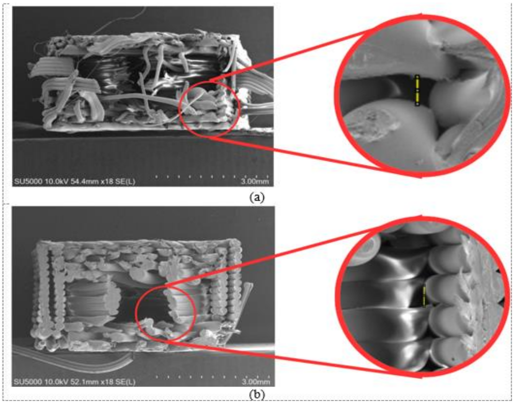


Figure 4: SEM image for rPET sample fracture interface for (a) pure rPET and (b) 7.5% rWCO

Figure 4(a) illustrates the surface of pure rPET, which shows clear signs of poor interlayer adhesion, excessive stringing, and large voids, indicating unstable extrusion and suboptimal print quality. These characteristics are consistent with previous observations where unmodified rPET exhibited weak bonding and inconsistent layer fusion during 3D printing [26]. In contrast, Figure 4(b), showing the 7.5% rWCO blend, reveals a more uniform and compact structure with improved layer definition and fewer voids, similar to findings where oil-based additives improved printability and interlayer fusion in polyester systems [5]. Table 3 compares the average interlayer gap length and angle between pure rPET and rPET with 7.5% rWCO, showing that the rWCO blend has a shorter average gap (54.77 μm vs. 65.19 μm) at a consistent -90° angle, indicating improved layer bonding. However, despite the enhanced morphological appearance, the reduction in tensile strength observed for the 7.5% rWCO sample may be attributed to factors such as the plasticizing effect of WCO, which can reduce molecular entanglement and stress transfer [18], molecular-level incompatibility between phases that can limit cohesive bonding [16], or increased brittleness due to over-crystallization, a phenomenon also observed in highly ordered rPET systems that show better morphology but reduced toughness [22].

The findings of this study show a reduction in tensile strength of 18–26% compared to pure rPET, consistent with studies who reported that WCO-based plasticizers increase flexibility but reduce mechanical strength in polymer systems [10], [11]. However, this outcome differs from previous findings which showing that higher crystallinity generally enhances strength when strong interfacial bonding is achieved [22], [23]. In this work, although crystallinity increased, the strength still decreased, suggesting that the plasticizing effect of WCO disrupted molecular entanglement and weakened interfacial interactions, thereby overshadowing the strengthening contribution normally associated with increased crystalline regions.

3.3 Correlation Analysis

Correlation analysis was conducted to examine the relationship between rWCO blend ratio and the tensile strength of the printed specimens. This analysis helps determine whether increasing the rWCO content has a consistent impact on the mechanical performance of rPET. By exploring this relationship, the study aims to assess how effectively rWCO functions as a modifier in recycled polymer systems.

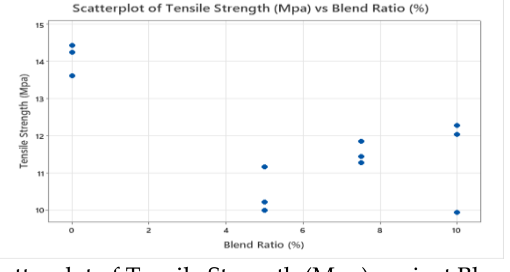


Figure 5: Scatterplot of Tensile Strength (Mpa) against Blend Ratio (%)

Figure 5 displays a scatter plot showing the distribution of tensile strength values across various rWCO blend ratios. The highest tensile strength, approximately 14.5 MPa, is observed at 0% rWCO. A noticeable drop occurs at 5%, where tensile strength declines to around 11 MPa. From 6% to 10% rWCO, the tensile strength fluctuates between 10 and 12 MPa, without a consistent upward or downward pattern.

Table 4: Analysis of Variance for Scatterplot

Source	DF	Adj SS	Adj MS	F	P-Value	F crit
Between Groups	3	21.93263	7.310878	12.59826	0.002125	4.066181
Withing Groups	8	4.642467	0.580308			
Total	11	26.5751				

Table 4 and Figure 5 show that adding recycled waste cooking oil (rWCO) clearly affects the tensile strength of rPET. The ANOVA results confirmed a significant difference between the blend groups, with a p-value of 0.002125, which is below the 0.05 threshold, and an F-value higher than the critical value. This means the changes in strength are real and not due to chance. The tensile strength dropped from 14.10 MPa for pure rPET to 10.46 MPa at 5% rWCO. There was a small increase at 7.5% and 10%, reaching 11.52 MPa and 11.42 MPa, but the values were still lower than the control. The scatter plot in Figure 5 supports this trend, showing a clear drop at 5% followed by slight improvements. These results suggest that the effect of rWCO on strength is not linear, and using too much or too little can weaken the material. This highlights the importance of finding the right rWCO ratio to keep both strength and sustainability in balance.

To better quantify this trend, Pearson correlation analysis was applied. The coefficient value, presented in Table 5, helps evaluate the strength and direction of the relationship between rWCO content and tensile strength.

Table 5: Pearson correlation coefficient

	Tensile Strength (Mpa)
Blend Ratio (%)	-0.650

A moderate negative correlation was identified between rWCO content and tensile strength, indicating that as the blend ratio increases, the tensile strength tends to decrease. This relationship is supported by the Pearson correlation coefficient (r = -0.650), suggesting an inverse trend where higher rWCO content moderately weakens the material's mechanical performance. While this trend is visible in the scatter plot, the p-value is crucial in determining whether the correlation is statistically significant, reinforcing the need to interpret both the strength of the relationship and its significance together. Using this correlation, a simple linear regression equation was developed to further describe the relationship, as follows:

$$Tensile\ Strength\ (MPa) = 13.35\ -\ 0.2617\ Blend\ Ratio\ (\%) \qquad (1)$$

Equation 1 derived from the experimental data provides a mathematical representation of the relationship between rWCO content and tensile strength. This best-fit line helps illustrate the general trend observed in the scatter plot, showing that tensile strength decreases as rWCO ratio increases. With an R^2 value of 42.29%, the model indicates that rWCO concentration accounts for just over 42% of the variability in tensile strength, suggesting a moderate predictive capability. However, this also points to the involvement of other influencing factors beyond rWCO content, such as print consistency, material compatibility, or structural uniformity.

Table 6: Regression Model

S	R-sq	R-sq(adj)
1.23846	42.29%	36.51%

Although the regression model establishes a quantifiable link between rWCO content and tensile strength, its limited explanatory power implies that the relationship is only partially linear. The relatively low R^2 value means that a significant portion of the variation in tensile strength is still unexplained by rWCO concentration alone. Therefore, while the model supports a downward trend, it underscores the need to consider additional material or processing parameters that may be contributing to the mechanical behavior of the rPET-rWCO blends.

Table 7: Analysis of Variance for Tensile Strength

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	11.2374	11.2374	7.33	0.022
Error	10	15.3377	1.5338		
Total	11	26.5751			

Table 7 demonstrates that the variation in rWCO content has a statistically significant impact on the tensile strength of the printed specimens, as evidenced by the F-value of 7.33 and a p-value of 0.022. Since the p-value is less than the standard significance level of 0.05, it confirms that the observed differences in tensile strength across the different blend ratios are not due to random chance. The result indicates that changes in rWCO ratio do play a meaningful role in altering tensile strength, thereby validating the need for further investigation into how bio-based additives interact with recycled polymers during the printing process.

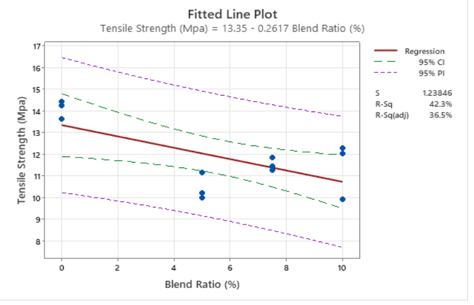


Figure 6: Fitted Line Plot

Figure 6 illustrates the Fitted Line Plot generated from the regression analysis, which uses the Pearson correlation and linear regression equation based on the relationship between rWCO content (independent variable) and tensile strength (dependent variable). From this analysis, a best-fit line is drawn through the data points to model the trend. In this case, the plot shows scattered data points around the line and a gentle negative slope, visually confirming a weak and inconsistent relationship between rWCO ratio and tensile strength.

Based on the data, the addition of recycled waste cooking oil (rWCO) affects the tensile strength of recycled polyethylene terephthalate (rPET) in a non-linear manner, with a sharp decrease at 5% rWCO followed by a slight increase at 7.5% and 10%, consistent with previous studies [6], [15], and [20] reporting non-linear additive–strength relationships. This plot helps assess the reliability of the regression model: while a strong correlation would have data points closely following the line, the observed scatter suggests that other factors may also influence mechanical performance, and the fitted plot provides a clearer interpretation of the trend.

4.0 CONCLUSION

This study confirms the feasibility of using refined waste cooking oil (rWCO) as a plasticizer in recycled PET (rPET) for 3D printing. Although tensile strength decreased by 18–26% compared to pure rPET, the 7.5% rWCO blend showed optimal balance in printability and structural consistency. Statistical analysis revealed a moderate negative correlation ($r = -0.650$), with regression indicating a 0.26 MPa drop per

1% rWCO increase. For future work, lower rWCO concentrations (1–3%) and compatibilizers should be explored to enhance mechanical properties without compromising processability. Additional tests such as impact and flexural strength, along with process optimization, are recommended to improve performance and reliability in sustainable additive manufacturing.

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AUTHOR CONTRIBUTIONS

R.A. Hamid: Writing, Editing and Supervision; A. S. Amzan: Experimental Works, Data Analysis and Original Draft Preparation; T. Ito: Proof-reading and Reviewing; A.H. Muhammad: Raw Materials Preparation

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission, and declare no conflict of interest on the manuscript.

REFERENCES

[1] Oussai, Z. Bártfai, L. Kátai and I. Szalkai, "Development of 3D printing raw materials from plastic waste", *International Scientific Conference ERAZ: Knowledge Based Sustainable Development*, pp. 177–183, 2019.

[2] Hajji and M. Colella, "Effect of mechanical recycling on structural modification and mechanical behavior of PET", *Industrial & Engineering Chemistry Research*, 2025.

[3] T.T. Nguyen, "Characterization of recycled polyethylene terephthalate (rPET) – Impact of proportion of virgin and recycled PET on mechanical strength", *Materials Research Proceedings*, 2024.

[4] E. Slezák, F. Ronkay and K. Bordácsné Bocz, "Improvement of mechanical properties of recycled PET by reactive toughening and post-crystallization," *Acta Technica Jaurinensis*, 2022.

[5] S.M. Sayed and X. Li, "Light-colored rPET obtained by nonmetallic TPA-based ionic liquids efficiently recycle waste PET," *Industrial & Engineering*

Chemistry Research, 2023.

[6] O. Rashwan, Z. Koroneos, T. Townsend, M.P. Caputo, R.J. Bylone, B. Wodrig and K. Cantor, "Extrusion and characterization of recycled PET filaments for additive manufacturing," *Scientific Reports*, vol. 13, 2023.

[7] M. Asensio, K. Núñez, J. Guerrero, M. Herrero, J. Merino and J.M. Pastor, "Rheological modification of recycled poly(ethylene terephthalate): Blending and reactive extrusion," *Polymer Degradation and Stability*, 2020.

[8] N.A.C. Imani, Y. Kusumastuti, H.T.B.M. Petrus, D. Timotius and M. Kobayashi, "Enhanced mechanical properties of organic-inorganic chitosan/nano silica composite film," *Journal of Advanced Manufacturing Technology (JAMT)*, vol. 15, no. 2, 2021.

[9] M. Chinchillas-Chinchillas, A. Gaxiola, C.G. Alvarado-Beltrán *et al.*, "Application of recycled-PET/PAN composite nanofibers in cement-based materials," *Journal of Cleaner Production*, vol. 252, p. 119827, 2020.

[10] Y. Fang, S. Chen and L. Wang, "Synthesis of bio base plasticizer using waste cooking oil and its performance testing in PVC," *Case Studies in Chemical and Environmental Engineering*, vol. 1, p. 100024, 2020.

[11] H. Liu, C. Zhang and Y. Li, "Applications of waste cooking oil as a green plasticizer in polymer processing: A review," *Polymers*, vol. 17, no. 3, p. 368, 2024.

[12] G.W. Coates and Y.D. Getzler, "Chemical recycling to monomer (CRM) approaches for polymers," *Nature Reviews Materials*, vol. 5, no. 7, pp. 501–516, 2020.

[13] V. Titone, M. Tricoli, L. Balzano, G. Malucelli and F. Carosio, "Compatibilization of polymer blends by reactive mixing: A case study on recycled PET and PE," *Polymer*, vol. 269, p. 125555, 2023.

[14] A. Pandzic *et al.*, "Optimization of 3D printer settings for recycled PET filament using hybrid techniques," *Heliyon*, vol. 10, no. 6, p. e28081, 2024.

[15] R. Tabary and H. Fayazfar, "Circular economy solutions for plastic waste: Improving the mechanical properties of recycled PET filaments for 3D printing," *Journal of Cleaner Production*, vol. 438, p. 140602, 2024.

[16] B. Tóth, E. Slezák, A. Kovács and F. Ronkay, "Progress in 3D printing of recycled PET: Mechanical performance of EBA-GMA toughened filaments," *Additive Manufacturing Letters*, vol. 5, p. 100188, 2024.

[17] E. Çava and M. Aslan, "Investigating printability and mechanical performance of 3D printed recycled PET with PLA and TPU hybrid additives," *International Journal of 3D Printing Technologies and Digital Industry*, vol. 7, no. 2, pp. 252–258, 2023.

[18] S. Abdul Haq, S. Aziz, M.F. Ghafir and M.S. Idris, "Mechanical properties of recycled PET/PC/MDI composite filaments for additive manufacturing," *Journal of Materials Research and Technology*, vol. 29, pp. 417–427, 2025.

[19] A. Zervoudakis, M. Peng and D. Lake, "Dihydroxy polyethylene additives for compatibilization in recycled PET/HDPE blends," *Journal of Applied Polymer Science*, vol. 139, no. 23, p. e52599, 2022.

[20] M. Habib, S.A. Khan and H. Fayazfar, "Compatibility and miscibility of recycled polyethylene and PET blends for additive manufacturing," *Polymer*

Testing, vol. 128, p. 108024, 2024.

[21] J.A.F. Cestari, M.G. Castro and M. Amaral, "A new strategy for upcycling marine plastic waste through melt-blending with engineering polymers," *Journal of Cleaner Production*, vol. 443, p. 140789, 2025.

[22] H. Liang, S. Qu and Y. Wang, "Super-toughness and reinforcement of recycled PET/polyamide blends via oriented crystalline microstructures," *Polymer*, vol. 277, p. 126191, 2025.

[23] L. Qin, M. Huang and X. Zhang, "Simultaneously achieving super-toughness and processability in rPET blends via crystallinity engineering," *Composites Science and Technology*, vol. 227, p. 109645, 2022.

[24] P.R. Akshaya, L. Palaniappan and N. Rasana, "Properties of blends from polypropylene and recycled PET with maleic anhydride compatibilizer," *Materials Today: Proceedings*, vol. 27, pp. 1263–1269, 2020.

[25] A. Tahmasebi, M. Jafari and M. Farnia, "Synergistic effect of a dual-functional compatibilizer in PET/PS organoclay nanocomposites: Morphology and mechanical properties," *Polymer Composites*, vol. 44, no. 1, pp. 24–33, 2023.

[26] N.E. Zander, Z.R. Boelter and M. Gillan, "Rubber-toughened recycled polyethylene terephthalate (rPET) for fused filament fabrication," *Additive Manufacturing*, vol. 32, p. 101024, 2020. doi: 10.1016/j.addma.2020.101024

[27] D. Loaeza, M. Sánchez-Soto and J. Cailloux, "Extruded/calendered sheets of fully recycled PP/opaque PET blends: Structure–property relationships," *Journal of Applied Polymer Science*, vol. 138, no. 47, p. e50967, 2021.