

Article

Not peer-reviewed version

Sustainable Engineering of Organic Compound Polypropylene: Enhancing Mechanical and Thermal Properties with Antioxidants for Cost Efficiency

[Zahoor Ahmed Soomro](#)*, Amjad Ali, [Waqar Ahmed](#), Meher Un Nisa, Qurban Ali

Posted Date: 17 June 2025

doi: 10.20944/preprints202506.1422.v1

Keywords: Polypropylene, recycling, mechanical properties, antioxidants, melt flow index, sustainable materials, cost efficiency



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Sustainable Engineering of Organic Compound Polypropylene: Enhancing Mechanical and Thermal Properties with Antioxidants for Cost Efficiency

Ali Qurban ^{1,*}, Ali Amjad ², Ahmed Waqar ³, Meher Un Nisa ⁴ and Soomro Zahoor ⁵

¹ School of Pharmacy and biomedical science University of Central Lancashire

² Preston PR29AU, Lancashire UK

³ School of Science Lincoln University

⁴ Mersey and West Lancashire Teaching Hospitals NHS Trust Lead Employer

⁵ TUIBS, Teesside University Middlesbrough, England

* Correspondence: z.soomro@tees.ac.uk

Abstract: A challenge involving the lasting usage of organic compounds is problematic worldwide, with scientists finding ways to solve it. This study explores the effects of repeated recycling on the mechanical, thermal, and structural properties of organic material polypropylene (PP) crates with and without antioxidant additives. In the laboratory, ten batches were created: virgin PP, PP made from mechanical recycling of organic compounds and PP with Arenox A-10 as an antioxidant. Characterisation involved tensile and impact tests, Melt Flow Index (MFI), Differential Scanning Calorimetry (DSC), and FTIR spectroscopy. Results indicated that reprocessing increased MFI values (6.72 to 9.01 g/10 min) due to chain scission, while antioxidant addition mitigated degradation, preserving tensile strength (20–22 MPa) and improving impact resistance (45–58 kJ/m²). Both DSC and FTIR tests revealed that recycled PP and virgin PP have the same stability and composition. With antioxidant treatment, organic recycled PP is effective in several industrial uses and supports cost-efficiency for the environment and economy in many sectors such as construction, pipes and the automotive industry.

Keywords: polypropylene; recycling; mechanical properties; antioxidants; melt flow index; sustainable materials; cost efficiency

1. Introduction

Due to the increasing global environmental concerns and pollution, the recycling of plastic is a vital aspect for sustainability and a green environment, which is critical for life on Earth as well as for low-cost efficiency. Recent amount of waste plastic has raised an alarming concern, leading scientists to work on recycling the plastic, causing issues around the globe [1,2]. The widespread use of the plastic impacts substantially to post-consumer plastic waste, creating concerns about landfill surplus and reserve reduction [3–7].

Polypropylene is a thermoplastic obtained from petroleum, there properties such as; flexibility, recyclability, strength, chemical resistance and their mechanical properties along with low cost, make it one of the best plastics and uses for the various applications that includes recyclability, packaging, automotive and construction [7–9].

According to the latest research, the recycling of polypropylene demonstrates degraded thermal and mechanical properties as compared to the virgin PP, due to multiple recycling processing cycles and thermo-oxidative degradation [10–13]. Furthermore, another group of researchers have found that repetitive recycling and reprocessing has reduced the high-performance applications due to scission and oxidation process [14–17].

The challenge of enhancing the performance of recycled polypropylene is a considerable concern. Leading groups of scientists around the world have found that the incorporation of antioxidants during the recycling process can increase the performance of recycled polypropylene by improving the chemical and mechanical properties of the recycled plastic [18–21]. Moreover, the degradation of plastic by recycling and reusing; can be sorted by using Antioxidants, such as Arenox A-10, which can counteract this degradation [10,22]. It has been observed that Antioxidants, particularly phosphites and hindered phenols, can substantially slow down degradation, preserve the intrinsic, stabilise the polymer matrix, and improve the properties of polypropylene during reprocessing[10,18–21]. The mechanism for enhancing the properties of recycled plastic shows that antioxidants help uphold molecular weight distribution and crystallinity, which are crucial parameters affecting the mechanical and thermal behaviour of recycled polypropylene with the modifying chain scission and cross-linking phenomena.

Research suggests that the mechanical and chemical properties, cost efficiency, quality and marketability that includes tensile strength, impact resistance, and thermal stability of recycled polypropylene can be improved by using the suitable and selective antioxidant [9,10,19,21,23,24]. Due to this evidence, recycled plastics are now being used in high-performance places and the unused raw material helps keep the environment cleaner for humans and all other lives. This approach will help globally to shift towards a more sustainable and circular economy [9,10,18,19,21,23–25]. There are several types of antioxidants, but latest research has suggested that the natural antioxidants obtained from spent coffee residue can efficiently stabilise recycled PP, proposing a sustainable substitute to synthetic additives [9,10,18–21,23–26]. Recycling of polypropylene along with their improved properties by the addition of antioxidant increases its durability, reliability and extends its applications in various fields and impacts to the cost efficiency by reducing the dependence on virgin raw materials [26,27]. Each benefit and area of development are in line with major environmental goals. Therefore, recycling and re-using of the polypropylene is essential approach to overcoming the effects and progressing a circular economy [21,28,29].

This study emphases to recycle the polypropylene crates, observe the effects of antioxidants on the recycled plastic by evaluating the properties of virgin, mechanically recycled, and extruded PP with and without antioxidant additives for improving its durability, reliability mechanical and thermal properties and their applications in cost and sustainable efficiency.

The two main objectives of the study are below.

1. To observe the impact of multi-cycle reprocessing on mechanical properties of reprocessed polypropylene.
2. To identify the role of antioxidants (Arenox A-10) in modifying and improving durability and reliability by reducing the degradation of polypropylene.

2. Materials and Methods

2.1. Materials

Recycled PP crates, virgin PP, Arenox A-10 antioxidant.

2.2. Processing

Processing methods

Granulation:

The recycled polypropylene (PPr) was processed using dry granulation, without moisture or heat, in a Blackfriars granulator. Pre-cleaned, dried, and cut waste polypropylene was introduced at room temperature to form uniform granules, which were crucial for consistent feeding and melting in subsequent processes (extrusion and injection molding).

Extrusion:

The granulated PPr was processed in a Leistritz Micro 18 co-rotating twin-screw extruder. The process involved three zones: feeding, compression, and metering, with key settings like hopper end

temperature (205°C), screw speed (138–142 rpm), and mixing time (5 minutes). There was a total of three batches made as given below.

Batch B: No antioxidant

Batch C: 1 phr Arenox A-10 antioxidant

Batch D: 1.5 phr Arenox A-10 antioxidant the antioxidant was added to minimise degradation during processing and aging.

Injection Molding:

The molten polypropylene was moulded into standardised specimens using a Klockner Ferromatik F 60 injection moulding machine. The process included set temperatures (205°C across various zones) and pressures (38–69 bar), with two packing conditions tested (over-packed and normal-packed). A total of 200 specimens were produced, with some discarded due to defects. Process control strategies, including shot weight and cushion size monitoring, were key to maintaining consistent quality. The shot weight and cushion size were the most crucial parameters to maintain the basketball quality.

Sample Preparation

Ten batches (A–J) were prepared:

A: Virgin PP

B–F: Recycled/extruded PP with/without antioxidants

G–J: Recycled up to four times with 1 phr A-10

2.3. Characterisation

MFI Melt Flow Index (MFI):

The MFI measurement of the material was obtained at ASTM D1238 with 260°C temperature and a weight of 1.19 kg. It allows scientists to determine whether the polymer melt is fluid enough and how easy it will be to shape it into products.

Tensile/Impact Tests:

Both tensile and impact tests were carried out with a H10KS material testing machine from Tinius Olsen. The tensile test was carried out according to ASTM D638 and the impact test was conducted in accordance with ASTM D256. These tests assess the material's mechanical strength, elasticity, and resistance to impact forces.

Differential Scanning Calorimetry (DSC):

Thermal properties of the material were analysed using a DSC technique (ASTM E967), where the heat flow and phase transitions were monitored to evaluate melting, crystallisation, and thermal stability.

Fourier Transform Infrared Spectroscopy (FTIR):

FTIR analyses were performed using a Nicolet 380 spectrometer in the 500–4000 cm⁻¹ range at 23°C (ASTM E967). Absorption of infrared rays is used by this technique to recognise molecular groups and their arrangements.

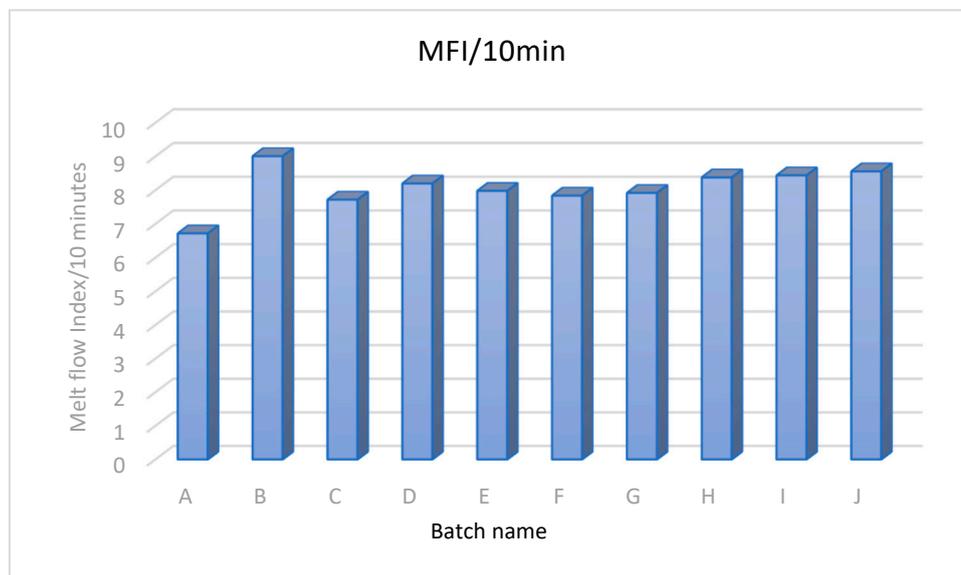
3. Results and Discussions

3.1. Melt Flow Index (MFI)

MFI was employed to cheque both the reprocessing and the viscosity of the recycled items [30]. Reprocessing increased MFI (indicating reduced viscosity) from 6.72 g/10 min (virgin PP) to 9.01 g/10 min (recycled). Antioxidant addition (1–1.5 phr) stabilised MFI values (~7.72–8.56 g/10 min), suggesting retained molecular weight (Table 1) and the comparison of all the batches is shown in Figure 1.

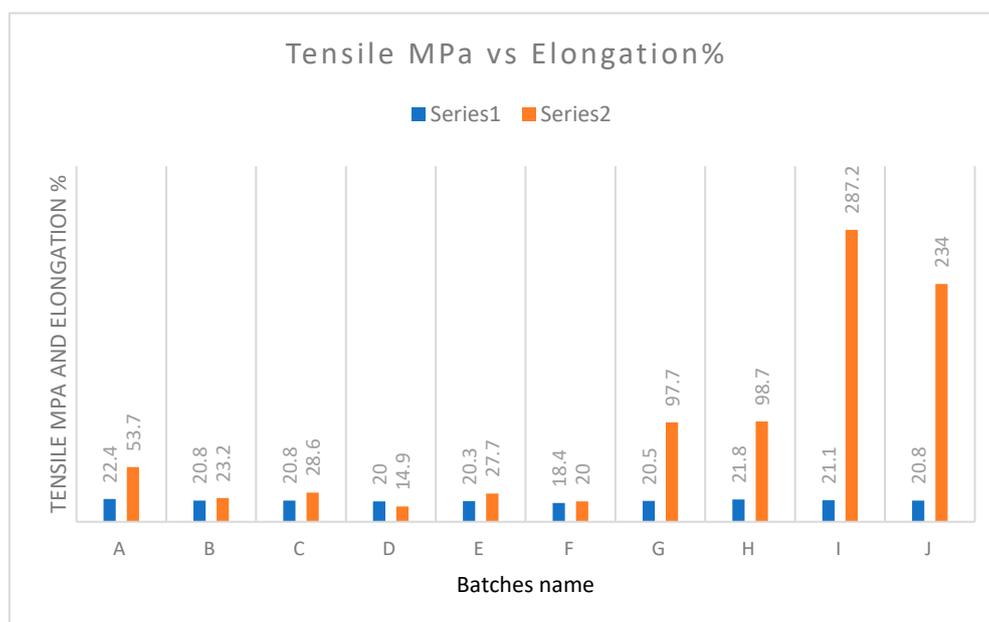
Table 1. MFI values of PP batches.

Batch	MFI (g/10 min)
A (Virgin)	6.72
B (Recycled, no AO)	9.01
C (1 phr AO)	7.72

**Figure 1.** MFI of all batches.

3.2. Tensile Properties

Recycled PP exhibited comparable tensile strength (20–22 MPa) to virgin PP (22.6 MPa) but higher elongation (up to 287% with antioxidants), enhancing ductility (Figure 2). Antioxidants reduced chain scission, preserving Young's modulus[31].

**Figure 2.** Tensile strength vs. elongation for virgin and recycled PP.

3.3. Impact Strength

Unnotched impact energy of recycled PP (45–58 kJ/m²) was lower than virgin (120.8 kJ/m²), but antioxidants improved resilience by 20% (e.g., Batch H: 54.5 kJ/m² vs. Batch B: 45.4 kJ/m²[32] (see Table 2 and Figure 3).

Table 2. Impact test of batches A, B and C.

No	Impact Test Batch A		Impact Test Batch B		Impact Test Batch C	
	Impact strength (kJ/mol)	Impact energy (kJ/m ²)	Impact strength (kJ/mol)	Impact energy (kJ/m ²)	Impact strength (kJ/mol)	Impact energy (kJ/m ²)
1	0.489	120.8	0.099	24.450	0.489	120.800
2	0.489	120.8	0.217	53.650	0.184	45.397
3	0.489	120.8	0.204	50.430	0.207	51.131
4	0.489	120.8	0.163	40.180	0.188	46.456
5	0.489	120.8	0.114	28.250	0.182	44.855
6	0.489	120.8	0.187	46.170	0.185	45.626
7	0.489	120.8	0.204	50.430	0.238	58.427
8	0.489	120.8	0.238	58.720	0.223	54.472
9	0.489	120.8	0.199	49.120	0.237	58.271
10	0.489	120.8	0.099	24.450	0.240	58.257
Average	0.489	120.8	0.184	45.397	0.237	58.369
StdDev	0	0	0.041	10.155	0.092	22.657
Error	0	0	22.408	22.369	0.028973	7.165066

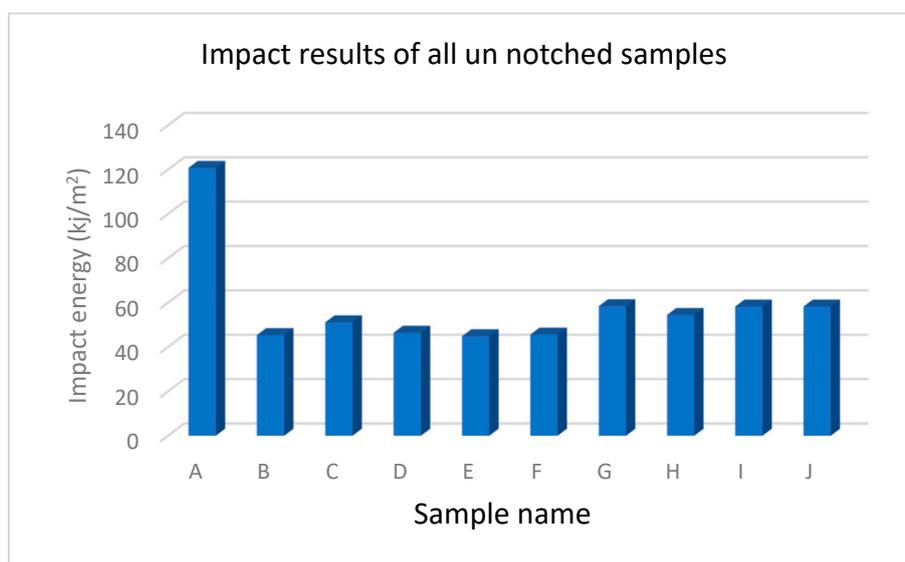


Figure 3. Impact results of all un notched samples.

3.4. DSC and FTIR Analysis:

Thermal and Chemical Stability

Differential Scanning Calorimetry (DSC) was utilised to analyse the thermal behaviour of virgin and recycled polypropylene (PP) samples, focusing primarily on melting temperature (T_m) and heat of fusion (enthalpy of melting, J/g)[33].

Melting Behaviour

As presented in Table 4, the virgin polypropylene (Batch A) exhibited the highest melting point at 166.91°C, while the recycled batches (B–J) demonstrated slightly reduced melting temperatures,

ranging between 163.77°C to 164.89°C. The little differences suggest the sample degraded a little during recycling. However, when compared with separately reported values for recycled PP (~128.06–128.42°C), a significant difference of ~38.49°C was observed, implying substantial deterioration in the crystallinity of recycled material collected from street and market waste sources.

The cause of this is chain scission, lower crystallisation and the existence of impurities or mixed polymers[10,18,20]. It is suggested by the presence of two melting peaks on the DSC graphs that the PP may have both isotactic and atactic structures or it could be that polyethylene contaminants went unnoticed during sample preparation.

Table 4. DSC Summary data of all the batches.

Batch	Melt Temperature C°	Energy of Melting J/g
A	166.91	79.46
B	164.89	39.13
C	164.50	55.58
D	164.58	38.29
E	164.83	35.94
F	164.58	39.27
G	164.89	32.74
H	164.17	30.86
I	164.17	38.00
J	163.77	39.46
Average	164.72	42.87

Enthalpy of Melting

Enthalpy readings for the recycled materials varied from 30.86 J/g to 55.58 J/g and were much lower than 79.46 J/g, the reading for virgin PP samples. The reduction shows that the crystalline nature and stability of the new material are lessened. Nevertheless, adding antioxidants increased the enthalpy somewhat which suggests they play a role in slowing thermo-oxidative damage.

While antioxidants have very little influence on melting temperatures, they make melting easier and therefore improve the material's stability and resistance to heat. It supports their key purpose in preserving polymers from disintegration and oxidation because of multiple processing stages. Therefore, DSC revealed consistent melting points (~164–167°C) across batches, confirming thermal stability.

3.5. FTIR Analysis: Chemical Stability:

Fourier Transform Infrared (FTIR) Spectroscopy was employed to evaluate the chemical integrity of virgin and recycled PP samples by identifying functional groups and possible degradation by-products [34].

Characteristic Peaks and Functional Groups

The dominant absorption peak across all samples (see Figure 4) was found at approximately 2912–2913 cm^{-1} , corresponding to symmetric and asymmetric C–H stretching in $-\text{CH}_2$ and $-\text{CH}_3$ groups—characteristic of polypropylene. Additionally, polypropylene can be confirmed by solid-state NMR since it appears at 720–726 cm^{-1} for C–C bending, 1460 cm^{-1} for CH_2 bending, 2350 cm^{-1} and 2920 cm^{-1} for CH and CH_3 stretching[35,36].

Impurity Presence

Minor shifts in wavelengths (especially in granulated samples) could be due to contaminants or copolymers such as polyethylene, as suggested by additional peaks or shoulder bands. It is possible because the feedstock came from a mix of plastic waste[41,42]. Standard FTIR tests have confirmed that PP is still the main polymer structure observed in our results.

Integrated Analysis and Conclusions

The combined results from both techniques show the overall thermal and chemical stability of virgin and recycled polypropylene.

It is found by DSC that the melting temperatures of recycled PP are almost the same as with virgin PP, but crystallinity is reduced, and the material's enthalpy is significantly lowered. Automated FTIR testing has identified polypropylene as the chemical group and demonstrated that reprocessing does not cause oxidation or the formation of additional chemical groups. While antioxidants do not change the FTIR spectrum, they make the material stronger against heat, as reflected in higher melting enthalpies. The presence of dual peaks in DSC and minor spectral variations in FTIR suggests contamination or blending with other polymers [43](e.g., PE). Overall, polypropylene that is recycled and treated with antioxidants has promising thermal and structural resistance, so it has potential for repeat use in tasks that need middle-level performance.

No variation in the quality of crystallinity was found between virgin and recycled batches as seen by DSC. No major alterations were seen for functional groups based on FTIR data, proving chemical stability. An analysis of these tests highlights moderate preservation of antioxidants.

4. Conclusions

This research confirms that using PP crates in mechanical recycling results in worsening of their properties, mainly discovered in MFI and tensile results. Despite this, including A-10 as an antioxidant allows a phone to be recycled up to four times without much impact on its performance. This research allows for using recycled PP in different applications, contributing to sustainability in the plastic field at less cost. In addition, recycled PP with 1 phr Arenox A-10 is 90% as strong as virgin PP and steadily improves ductility even during processing. Applications such as pipes, car parts and profile pieces use recycled PP instead of having to create them from scratch, all at low cost.

Future Work: Improvements can be made by optimising antioxidant levels, trying out mixed virgin/recycled blends and checking how the materials perform over a long period.

References

1. Esmizadeh E, Tzoganakis C, Mekonnen TH. Degradation behavior of polypropylene during reprocessing and its biocomposites: Thermal and oxidative degradation kinetics. 2020;12:1627.
2. Chacha JS, Ofoedu CE, Xiao K. Essential oil-based active polymer-based packaging system: A review of its effect on the antimicrobial, antioxidant, and sensory properties of beef and chicken meat. 2022;46:e16933.
3. Zhang W, Shen J, Guo X, Wang K, Jia J, Zhao J, et al. Comprehensive Investigation into the Impact of Degradation of Recycled Polyethylene and Recycled Polypropylene on the Thermo-Mechanical Characteristics and Thermal Stability of Blends. 2024;29:4499.
4. Lourmpas N, Papanikos P, Efthimiadou EK, Fillipidis A, Lekkas DF, Alexopoulos ND. Degradation assessment of high-density polyethylene (HDPE) debris after long exposure to marine conditions. 2024;954:176847.
5. Machecha AD, Mutuma B, Adalima JL, Midheme E, Lucas LH, Ochanda VK, et al. Perspectives on plastic waste management: challenges and possible solutions to ensure its sustainable use. 2024;9:77.
6. Li Z, Zhang C, Jiang Y, Bai Y, Xu M, Xu K, et al. Antimigration polypropylene antioxidants: A review. 2024;63:1713–28.
7. Raman FNA, Kamarudin K, Sun S, Shaari MF, Roslan MN, Ahmad A, et al. Preliminary Study: Characterization of UHMWPE and PP Polymer for Extrudability of PP/UHMWPE Composite to FFF Process. 2024;5:66–75.

8. Mager M, Berghofer M, Fischer J. Polyolefin recyclates for rigid packaging applications: the influence of input stream composition on recycle quality. 2023;15:2776.
9. Matthews C, Moran F, Jaiswal AK. A review on European Union's strategy for plastics in a circular economy and its impact on food safety. 2021;283:125263.
10. Lamberti FM, Román-Ramírez LA, Wood J. Recycling of bioplastics: routes and benefits. 2020;28:2551–71.
11. Hyie KM, Budin S, Martinus N, Salleh Z, Masdek NRNM. Tensile and flexural investigation on polypropylene recycling. IOP Publishing; 2019. p. 012005.
12. Sofana I, Wijayanti W, Hamidi N. Study of thermal behavior in mixed scrap tires (ST) and polypropylene (PP) plastic using thermogravimetry analysis (TGA) and differential scanning calorimetry (DSC). 2022;3:122.
13. Sanchez FAC, Boudaoud H, Camargo M, Pearce JM. Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy. 2020;264:121602.
14. Arese M, Bolliri I, Ciaccio G, Brunella V. Post-Industrial Recycled Polypropylene for Automotive Application: Mechanical Properties After Thermal Ageing. 2025;13:1–16.
15. Ranjan VP, Goel S. Recyclability of polypropylene after exposure to four different environmental conditions. 2021;169:105494.
16. Machecha AD, Mutuma B, Adalima JL, Midheme E, Lucas LH, Ochanda VK, et al. Perspectives on plastic waste management: challenges and possible solutions to ensure its sustainable use. 2024;9:77.
17. Prior L, Oliveira MS, Zhiltsova T. Assessment of the Impact of Superficial Contamination and Thermo-Oxidative Degradation on the Properties of Post-Consumer Recycled Polypropylene. 2023;16:1198.
18. Alsabri A, Tahir F, Al-Ghamdi SG. Environmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region. 2022;56:2245–51.
19. Dawoud M, Taha I. Effects of Contamination with Selected Polymers on the Mechanical Properties of Post-Industrial Recycled Polypropylene. 2024;16:2301.
20. Pfaendner R. Restabilization—30 years of research for quality improvement of recycled plastics review. 2022;203:110082.
21. Bora RR, Wang R, You F. Waste polypropylene plastic recycling toward climate change mitigation and circular economy: energy, environmental, and technoeconomic perspectives. 2020;8:16350–63.
22. Arese M, Cavallo B, Ciaccio G, Brunella V. Characterization of Morphological, Thermal, and Mechanical Performances and UV Ageing Degradation of Post-Consumer Recycled Polypropylene for Automotive Industries. 2025;18:1090.
23. Kibria MG, Masuk NI, Safayet R, Nguyen HQ, Mourshed M. Plastic waste: challenges and opportunities to mitigate pollution and effective management. 2023;17:20.
24. Yang M, Chen L, Wang J, Msigwa G, Osman AI, Fawzy S, et al. Circular economy strategies for combating climate change and other environmental issues. 2023;21:55–80.
25. Gopanna A, Mandapati RN, Thomas SP, Rajan K, Chavali M. Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy and wide-angle X-ray scattering (WAXS) of polypropylene (PP)/cyclic olefin copolymer (COC) blends for qualitative and quantitative analysis. 2019;76:4259–74.
26. Ahuja V, Singh PK, Mahata C, Jeon J-M, Kumar G, Yang Y-H, et al. A review on microbes mediated resource recovery and bioplastic (polyhydroxyalkanoates) production from wastewater. 2024;23:187.
27. Hernández-Fernández J, Rayón E, López J, Arrieta MP. Enhancing the thermal stability of polypropylene by blending with low amounts of natural antioxidants. 2019;304:1900379.
28. Gall M, Freudenthaler PJ, Fischer J, Lang RW. Characterization of composition and structure–property relationships of commercial post-consumer polyethylene and polypropylene recyclates. 2021;13:1574.
29. Graziano A, Jaffer S, Sain M. Review on modification strategies of polyethylene/polypropylene immiscible thermoplastic polymer blends for enhancing their mechanical behavior. 2019;51:291–336.
30. Oblak P, Gonzalez-Gutierrez J, Zupančič B, Aulova A, Emri I. Processability and mechanical properties of extensively recycled high density polyethylene. 2015;114:133–45.
31. Gijsman P, Fiorio R. Long term thermo-oxidative degradation and stabilization of polypropylene (PP) and the implications for its recyclability. 2023;208:110260.
32. Balu R, Dutta NK, Roy Choudhury N. Plastic waste upcycling: a sustainable solution for waste management, product development, and circular economy. 2022;14:4788.
33. Iyer KA, Zhang L, Torkelson JM. Direct use of natural antioxidant-rich agro-wastes as thermal stabilizer for polymer: Processing and recycling. 2016;4:881–9.

34. Kouranou D, Galanopoulou C, Korres DM, Tzani A, Detsi A, Vouyiouka S. Restabilization of Post-Consumer Recycled Polypropylene With Natural Antioxidants From Spent Coffee Residue. 2025;142:e56494.
35. Almeida S, Ozkan S, Gonçalves D, Paulo I, Queirós CS, Ferreira O, et al. A brief evaluation of antioxidants, antistatics, and plasticizers additives from natural sources for polymers formulation. 2022;15:6.
36. Hong M, Chen EY-X. Chemically recyclable polymers: a circular economy approach to sustainability. 2017;19:3692–706.
37. Karaagac E, Jones MP, Koch T, Archodoulaki V-M. Polypropylene contamination in post-consumer polyolefin waste: characterisation, consequences and compatibilisation. 2021;13:2618.
38. Godfrey L. Waste plastic, the challenge facing developing countries—ban it, change it, collect it? 2019;4:3.
39. Hopewell J, Dvorak R, Kosior E. Plastics recycling: challenges and opportunities. 2009;364:2115–26.
40. Li Z, Zhang C, Jiang Y, Bai Y, Xu M, Xu K, et al. Antimigration polypropylene antioxidants: A review. 2024;63:1713–28.
41. Luna CBB, da Silva WA, Araújo EM, da Silva LJMD, de Melo JB da CA, Wellen RMR. From waste to potential reuse: mixtures of polypropylene/recycled copolymer polypropylene from industrial containers: seeking sustainable materials. 2022;14:6509.
42. Kim HJ. Current Advances and Challenges in Chemical Recycling of Polymeric Materials. 2023;
43. Schyns ZO, Shaver MP. Mechanical recycling of packaging plastics: a review. 2021;42:2000415.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.