Characterization of polypropylene waste and its potential valorisation

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The amount of plastic waste is increasing daily due to its production from petrochemical oil sources and its non-biodegradable nature, which takes hundreds of years to decompose.

Polypropylene (PP) is one of the most commonly used petrochemical polymers in scientific, industrial, and household products, resulting in significant waste after its useful life. In Europe, PP waste (PPW) is typically recycled using mechanical or pyrolysis methods (Sakthipriya, 2022). The purpose of PP recycling is to reduce the consumption of raw materials such as oil and propylene, lower energy requirements for manufacturing new products, reintroduce raw materials into the economic cycle, and decrease the amount of plastic waste in landfills or incinerators (Rapa et al., 2022). However, the fragmentation of PPW into micro and nanoplastics has created environmental and potential health risks (Meides et al., 2022).

The process of recycling PPW generally involves consecutive phases such as collection, selection, shredding, cleaning, regranulation, and valorization (Figure 1).

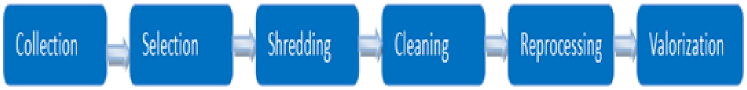


Figure 1: Scheme of mechanical recycling steps for PP wastes.

The purpose of this paper is to characterize six types of post-consumer plastic waste (PPW) obtained from auto parts (PPW1), textile cones (PPW2), cloths (PPW3), bags (PPW4), boxes (PPW5), and casseroles (PPW6) (Figure 2). These wastes were processed using a laboratory roller (type W 110 E COLLIN) and a laboratory press (type P 200P COLLIN 164) to obtain plates with dimensions of 150 x 150 x 4 mm (as shown in Figure 3). The technological conditions for rolling and pressing are presented in Table 1.

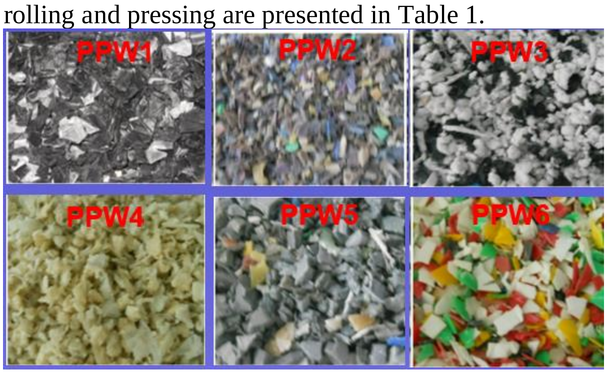


Figura 2: Post-consumer PP waste used in thus study.

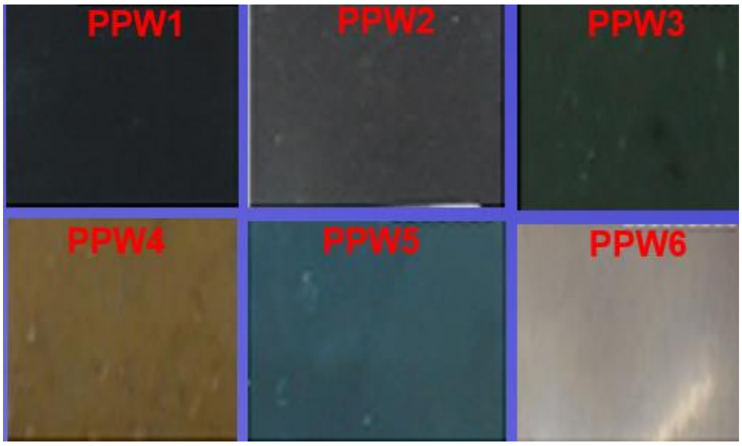


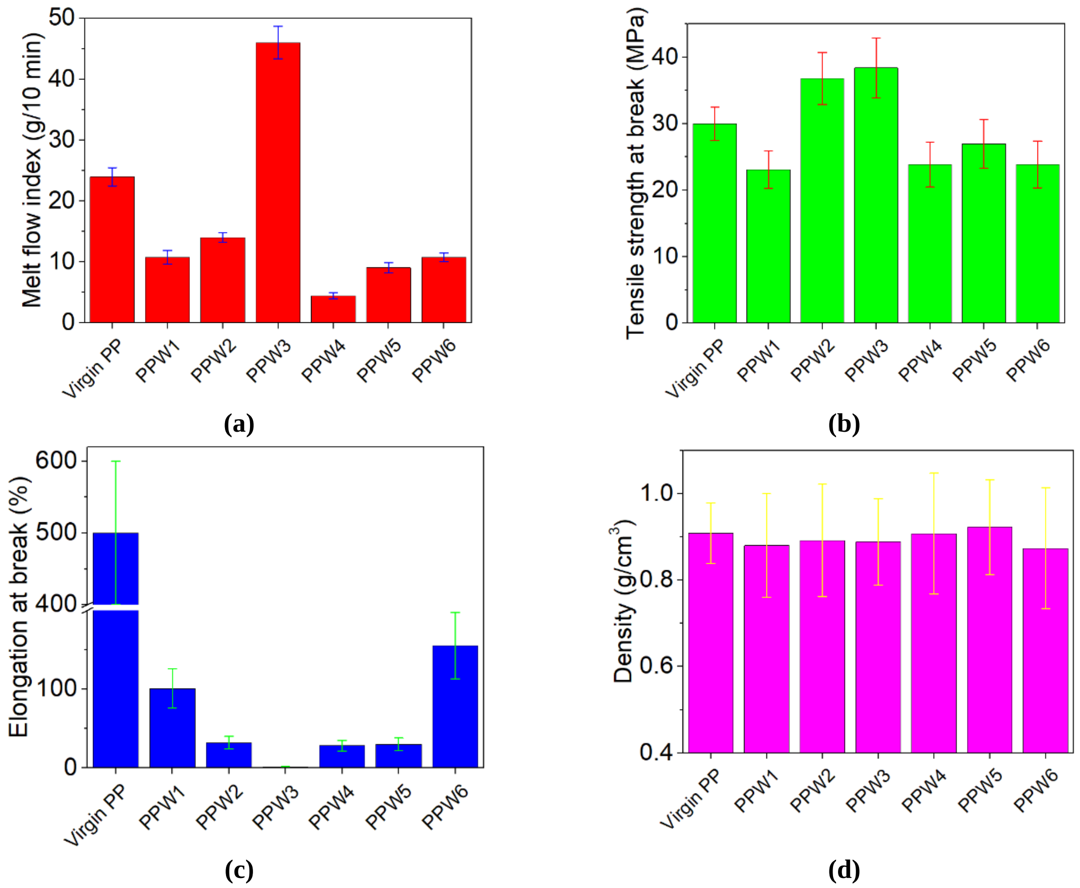
Figura 3: PPW sheets with dimension of (150x150x4) mm.

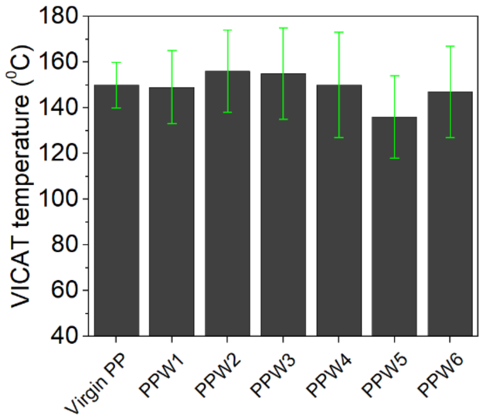
Table 1. Technological parameters for obtaining of PPW sheets.

Parameters	U.M.	Value
	Rolling	
Rolling temperature	°C	165 – 170
Rolling time	minute	10
Friction ratio		1/1.2
	Pressing	
Preheating time	minute	4
Pressing time	minute	2
Pressing temperature	°C	175
Pressure	atm.	164
Cooling time	minute	45

The characterization of PPW was performed to determine the main physical, mechanical and thermal parameters such as: melt flow index, density, tensile properties, hardness Shore, Izod impact, VICAT softening temperature, heat deflection temperature, melting and crystallinity, thermal stability. A virgin PP was used for comparison purpose.

Figure 4 shows the main physico-thermal properties achieved for the investigated samples.





(e)

Figure 4: Melt flow index (a); Tensile strength at break (b); Elongation at break (c); Density (d); Vicat softening temperature (e) for PPW compared with these properties for a virgin PP.

Table 2. DSC parameters for the PPW.

Sample	ΔH_m, J/g	T_m, ◦C	X_c, %	$T_{oxidation}$, ◦C
Virgin PP	108.9	165.5	57.0	219.7
PPW1	104.3	146.1	54.0	231.1
PPW2	106.4	164.6	54.9	214.6
PPW3	53.9	165.5	28.1	223.8
PPW3	97.0	163.5	55.4	221.8
PPW4	100.4	164.5	52.1	218.1
PPW5	94.6	130.3; 163.5	51.9	210.7
PPW6	93.1	129.5; 167.0	56.0	221.4

The analyzed samples exhibit some similar physico-mechanical and thermal values, while other properties differ. Typically, the tensile strength of PPW decreases compared to PP virgin, while the elongation at break increases. The DSC data indicates that PPW1, PPW2, PPW3, and PPW4 contain only PP homopolymer, whereas PPW5 and PPW6 samples are a mixture of PP homopolymer and C2-C3 copolymer. This is due to the degradation by chain scission undergone during successive processing, decreasing the molecular weight and the quantity of entanglements which give strength and elasticity to the sample. The DSC data show that PPW1, PPW2, PPW3, PPW4 contain only PP homopolymer, while PPW5 and PPW6 samples are a mixture of PP homopolymer and C2-C3 copolymer.

Based on the obtained results, PPW from boxes was selected for modification with 10 wt% elastomer to create products for specific applications using injection molding and extrusion technologies.

By optimizing the technical parameters in the laboratory, wheels, cable channels, flexible tubes, and sealing gaskets were successfully produced by modifying of PPW5 with elastomer (Figure 5). The data acquired emphasizes the importance of exploring various technological approaches and appropriate processing additives to utilize PPW in various environmentally beneficial applications as a valuable source of raw materials.

(a)

(b)

(c)

(d)

Figure 5: Some products obtained by injection molding technology, wheels (a) and automobile cable channel (b), and extrusion and pressing technologies, flexible tube (c) and sealing gasket (d).

The data acquired emphasizes the importance of exploring various technological approaches and appropriate processing additives to utilize PPW in various environmentally beneficial applications as a valuable source of raw materials.

References

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