UTILIZATION OF RED PİNE WOD RESIDUE IN THE MANUFACTURE OF THERMOPLASTIC BASED POLYMER COMPOSITES

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Abstract

Thermoplastic-based polymer composites combine thermoplastic materials like polystyrene (PS), polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), etc. and filling/reinforcing material like glass fiber, wood fiber, agricultural based fiber, etc. In this study, the utilization of red pine wood flour in the production of thermoplastic-based composite as filling material was investigated. The effect of red pine wood waste loading on the mechanical properties of the manufactured composites was determined. High density polyethylene (HDPE) and polypropylene (PP) were used as thermoplastic polymer and the red pine sawdust were evaluated as filler. Composite samples were produced using combination of extrusion and compression molding methods. The mechanical properties (tensile, flexural and impact resistance) of the produced composites were determined in accordance with ASTM standards.

Keywords: Thermoplastic, Composite, Mechanical properties, Compression molding

1. Introduction

The composite material combines two or more physically different materials to achieve better properties than constituent materials. There is a growing interest on lignocellulosic material (wood dust, wheat straw flour, etc.) filled thermoplastic composites due to their availability, renewability, cost, eco-friendliness and ease of processing [1].

In previous studies, polystyrene (PS), polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), etc. as thermoplastic materials and wood flour, agricultural residue and industrial lignocellulosic waste as lignocellulosic filler were used in polymeric composites. The wood flours were obtained from pine, poplar, beech, eucalyptus, etc. The agricultural residues were wheat straw, rice straw, sunflower stalk, peanut shell, walnut shell, nutshell, pepper stem, etc. Industrial lignocellulosic waste was middle-density fiberboard production residues [2, 3, 4, 5, 6].

Wood processing residues has a great potential to be used in thermoplastic composites. 362 million cubic meters timber and 88 million cubic meters plywood were produced in the world between 2010 and 2011 [7]. In that time, 6,2 million cubic meters timber and 200 thousand cubic meters plywood were also produced in Turkey [7]. Timber and plywood manufacturing process produces roughly 50% and 40% residue, respectively [8]. Most of the lignocellulosic band saw residues which is substantially composed from end of production in sawmill was burned for producing energy. This great resource can be utilized in the production of lignocellulosic polymer composites as a filler material. For this purpose, the utilization of red pine sawdust collected from pallet manufactures in the city of Mersin, Turkey in high-density polyethylene-based and polypropylene-based thermoplastic composites was investigated. Mechanical properties of the produced composite were determined and compared with standards.

2. Materials and Methods

2.1 Materials

High-density polyethylene (HDPE) and polypropylene (PP) were used as thermoplastic matrix and red pine sawdust (RPS) were used as organic filler. Maleic anhydrite grafted polyethylene (Licocene PEMA 4351 by Clarient) and maleic anhydrite grafted polypropylene (Licomont AR 504 by Clariant) were utilized as coupling agents.

Paraffin wax (K.130.1000) was used as a lubricant. RPS were collected from pallet mill in the city of Mersin, Turkey. Descriptions of coupling agents were given in Table 1.

Table 1. Descriptions of the coupling agents used in this study.

Descriptions	**Licocene PEMA 4351 (MAPE)**	**Licomont AR 504 (MAPP)**
Appearance	White fine grain	Yellowish fine grain
Softening point	123°C	156°C
Acid Value	43 mg KOH/g	41 mg KOH/g
Density at 23°C	0.99 g/cm3	0.91 g/cm3
Viscosity at 140 °C	300 mPa.s	800 mPa.s

2.2 Methods

2.2.1 Composite Manufacturing

Red pine sawdust (RPS) was used as received from the plant. Particle distribution was given in Figure 1. The experimental design of the study was presented Table 2. Depending on the formulation given HDPE or PP, RPS, MAPE or MAPP and paraffin wax were dry-mixed in a high-intensity mixer to produce a homogeneous blend. These blends were compounded in a single-screw extruder (Figure 2) at 50 rpm screw speed in the temperatures (barrel to die) of 170-180-185-190-200 ^{0}C. Extruded samples were cooled in water pool and then granulated into pellets. The pellets were dried in oven at 103 ^{0}C (±2) for 24 hours. Dried pellets were compression molded (Figure 3) at 5500-6000 psi and temperatures of 175 ^{0}C for HDPE and 200 ^{0}C for PP in a hot press with cooling capabilities. Boards in the size of 250mm by 250mm by 10mm were produced and testing samples in the sizes given in corresponding ASTM standards were cut (Figure 4).

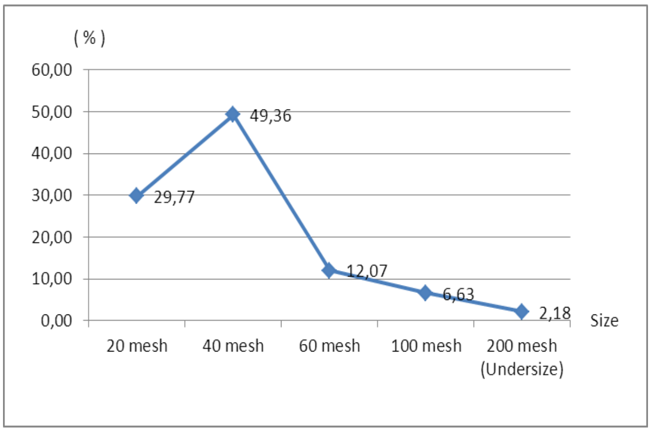


Fig 1. Particle distribution (%)

Table 2. Manufacture schedule

ID	HDPE (%)	PP (%)	Red pine wood residue (%)	MAPE (%)	MAPP (%)	WAX (% of total manufacture)
A	98	-	-	2	-	3
B	-	98	-	-	2	3
C	48	-	50	2	-	3
D	-	48	50	-	2	3

Fig 2. **S**ingle-screw extruder

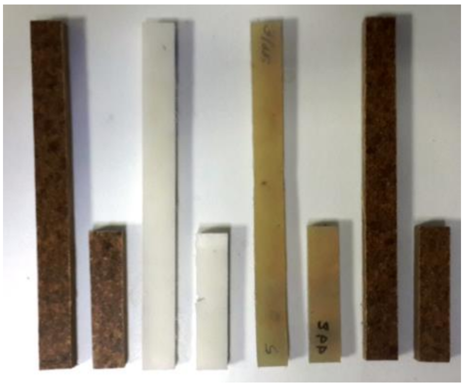


Fig 3. HDPE composite board Fig 4. Testing samples

2.2.2 Property Testing

Flexural, tensile and impact properties of all samples were determined. Five samples were tested for each test and each group. The flexural tests, tensile tests and impact tests were conducted in accordance with ASTM D 790, ASTM D 683 and ASTM D 256, respectively. Zwick/Roell 10KN Testing Machine was used for flexural tests and tensile tests. HIT5.5P impact testing machine, manufactured by Zwick™ was used while notched impact samples were being tested after the notches had been added using a Polytest notching cutter by RayRan™.

3. Results and Discussion

3.1 Mechanical Properties

In this study, flexural, tensile and impact properties of all samples were determined. The results of tests are summarized in Table 3. The graphs of mechanical properties are given in Figure 5-7.

Table 3. Summary of results

ID	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation at Break (%)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Properties (Kj/m^2)
A	22,138 **(0,445)***	284,334 **(12,438)**	54,486 **(10,3)**	38,306 **(1,523)**	972,468 **(41,348)**	9,912 **(0,638)**
B	25,236 **(3,628)**	314,66 **(23,808)**	12,664 **(2,658)**	52,482 **(3,350)**	1234,71 **(105,160)**	2,534 **(0,392)**
C	14,662 **(0,565)**	431,494 **(110,429)**	4,336 **(0,588)**	31,242 **(0,945)**	2078,068 **(55,349)**	3,868 **(0,181)**
D	16,734 **(0,542)**	572,698 **(14,244)**	3,846 **(0,203)**	32,986 **(0,928)**	2172,046 **(71,460)**	2,828 **(0,153)**

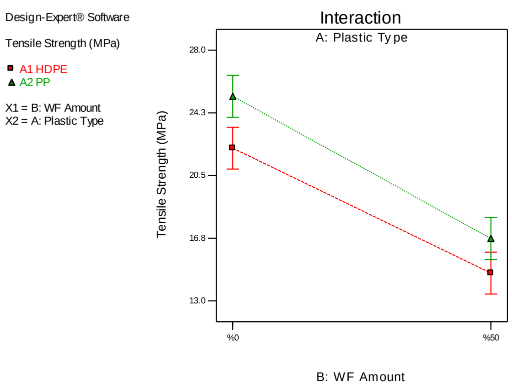
* The numerical value in the parenthesis is standard deviation.

Tensile properties include tensile strength, tensile modulus and elongation at break. The results showed that filler loading substantially affected the tensile strength ($P<0,0001$). With the rise of filler loading tensile strength was reduced in both composites. To mention of tensile modulus, rise of filler loading significantly increased the tensile modulus for both composites ($P<0.0001$). Similar results for other wood flours filled polymer composites were also reported [9, 10, 11]. Significant reduction by addition of filler in elongation at break values for HDPE was more pronounced than PP matrix.

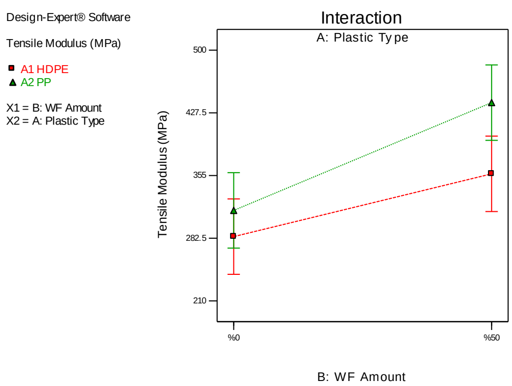
Flexural properties include flexural strength and flexural modulus. The results showed that the flexural strengths are significantly affected by filler loading ($P<0.0001$). Similar results were also reported in the flexural strength of other wood flour filled thermoplastic composites [12, 13, 14]. With filler loading flexural strength was reduced for HDPE and PP based composites.

For polyolefin-based plastic lumber decking boards, ASTM D 6662 (2001) standard requires the minimum flexural strength of 6.9 MPa (1,000 psi). Both composites produced in this study provided flexural strength values (7-50 MPa) that are over the requirement by the standard. To mention of flexural modulus, addition of filler raised the flexural modulus. ASTM D 6662 (2001) standard requires the minimum flexural modulus of 340 MPa (50,000 psi) for polyolefin-based plastic lumber decking boards. Both composites produced in this study provided flexural modulus values (363-1700 MPa) over the required standards.

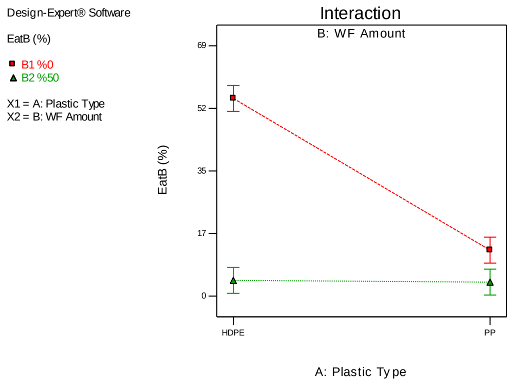
In the case of Izod impact strength, the results showed that filler loading significantly affected the impact strength (P<0.0001). Addition red pine wood residue significantly reduced the impact strength. In composite materials, improved adhesion usually changes the mode of failure from “fiber pull out” to fiber breakage, which usually requires less energy. Similar findings were reported in other studies for different wood flours or fibers [15].



(a)

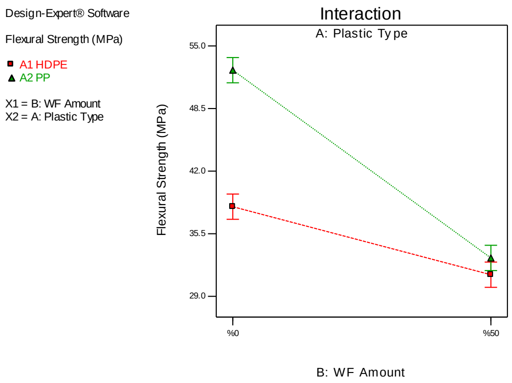


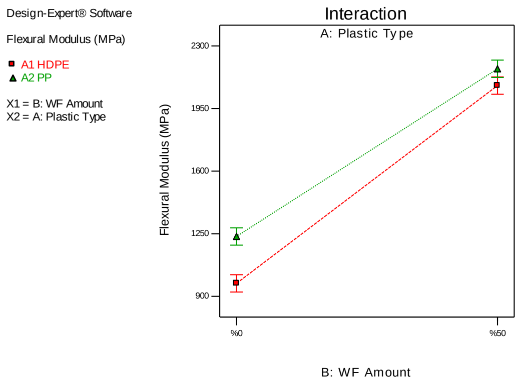
(b)



(c)

Fig 5. Tensile properties a) tensile strength, b) tensile modulus & c) elongation at break





(a) (b)

Fig 6. Flexural properties a) flexural strength, b) flexural modulus

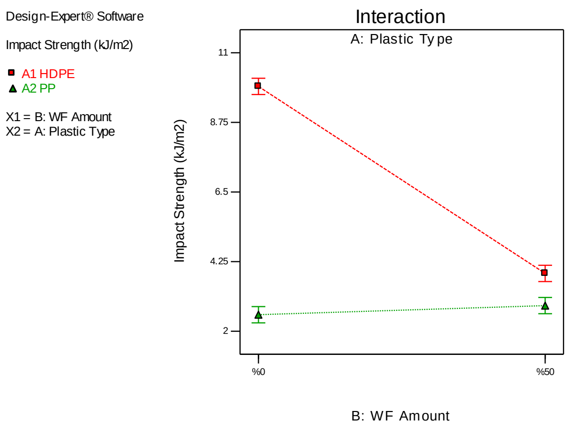


Fig 7. Impact properties

4. Conclusion

In this study, thermoplastic composites which obtain HDPE and PP as a polymer matrix and red pine wood residue as lignocellulosic filler have been produced. Mechanical properties such as tensile, flexural and impact strength is determined for the produced thermoplastic composites. Produced polymer composites have enough mechanical properties according to ASTM D 6662 (2001). Red pine wood residue can be utilized as filler for HDPE and PP based plastic composites. The utilization of the red pine wood residue flours in plastic industry could provide a new income.

5. Acknowledgements

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