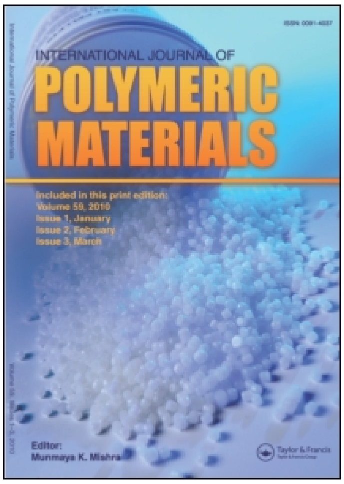

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The importance of polymer composites among industrial materials is due to their improved mechanical properties. In recent researches, mechanical and physical properties have been improved by way of making composites with fiber reinforcement. Silk and cotton fibers used in the textile industry have good physical and mechanical properties. In this study, composite structures were produced by using recycled Poly Propylene, PP, polymer with silk and cotton waste as fiber reinforcement in different ratios. The fiber dimensions of silk and cotton wastes were between 1 mm, 2.5 mm, and 5 mm. They were mixed in the ratios of PP/silk and cotton waste 97%/3 and 94%/6. The mixture of polymer composite was prepared with double screw extruder. The sample was tested for tensile strength, elongation, yield strength, elasticity modulus, izod impact strength, melt flow index (MFI), heat deflection temperature (HDT), and vicat softening temperature. Thermal transitions of the materials were determined with Differential Scanning Calorimeter (DSC) and micro-structure properties were observed with a Scanning Electron Microscope (SEM).

Keywords: cotton waste, polymer composite, polypropylene, silk waste

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INTRODUCTION

Polymers are used in many engineering applications. But sometimes their properties are not enough for all requirements. For that reason, polymer structures are reinforced by fibers to form composite structures. Polymer-based composite structures have advantages over other composite materials. The most important advantage with fiber reinforcement is that the material's tenacities are increased. Fiber-reinforced composite structures' mechanical and thermal properties depend on the fiber's amount, orientation, and length in the structure. Cotton and silk fibers are used in many fields, especially in textiles. Cotton and silk fibers have good physical and mechanical properties as textile materials. All synthetic polymers are used as a matrix component of composite structures. In staple or even filament form organic or inorganic fibers can be used as a reinforcement material. In this study, for economic, technologic, and ecological reasons, these fibers are used to improve the mechanical and physical properties of polymer composites.

Natural fibers are used as a reinforcement material besides mineral and glass fibers in composite structures. Studies were concentrated especially on Polyethylene/Wood Pulp fibers [1–3], Polyethylene/Sisal fibers [4–5], Polyethylene/Jut [6], polypropylene/Wood Pulp fibers [1,7], Polypropylene/Cotton or Ramie fibers [8–9], Polypropylene/Jut [6], Polypropylene/Sisal fibers [10], Polystyrene/Wood Pulp fibers [11–12], Polystyrene/Sisal fibers [13] and Polyester/Jute [10], Metacrylamide/Silk [15–18], and Polystyrene/Silk [19].

In this study, 3% and 6% silk and cotton waste are added to recycled and PP polymer and the mechanical, thermal, and microstructure properties of the composites are investigated.

EXPERIMENTAL

Recycled PP/Silk and Cotton waste, polymer composites' mixing ratios, and fiber dimensions are given in Table 1.

TABLE 1 Mixing Ratios and Fiber Dimensions of Waste Silk–Cotton Polymer Composites

Groups	PP/Waste silk (Fiber lengths 1 mm – 2.5 mm–5 mm mixed)	PP/Waste cotton (Fiber lengths 1 mm – 2.5 mm–5 mm mixed)
1	100% PP	100% PP
2	97% PP–3% Waste silk	97% PP–3% Waste cotton
3	94% PP–6% Waste silk	94% PP–6% Waste cotton

Mechanical, thermal and physical properties of the materials used in the composites are given in Table 2.

Silk fibers used in textile industry are called Bombyx Mori type silk worm secretion. Waste silk fibers that are obtained during the cocoon forming or the silk filaments production, are cut with guillotine in the ranges of 1 mm, 2.5 mm, and 5 mm fiber lengths. Waste cotton fibers were collected under the spilled down grids during the opening and carding process. The cotton wastes obtained from this process are gathered into fiber dimension between 1 mm, 2.5 mm, and 5 mm. The mixture of PP with silk and cotton waste were prepared at 85–190°C temperature, 24 Bar pressure, and mix rate of 335 rpm in spinning double screw extruder (Maris TM40MW–Maris America Corporation Baltimore, USA). After the mixing process test samples were prepared in the injection machine. The extrusion and injection conditions are given in Table 3. During the production of PP and silk waste fibers no binding agent was used.

Samples were prepared in an Arburg injection machine, according to ISO 294. Tensile strength tests were carried out with a Zwick 1120 machine with pulling speed 50 mm/min according to ISO 572.2. Consequently, the mechanical properties, like yield strength,

TABLE 2 Properties of the Materials Used in the Composite Product

Properties	Waste silk [20]	Waste cotton [20]	Recycled PP [21]
Place of production	Bursa/Turkey	Cukurova/Turkey	Petkim Company/ Turkey
Type	Waste silk	Waste cotton	Petoplen MH 418
Source	Filament waste	Blowroom waste up to 5 mm, Taker-in waste up to 2.5 mm, Tambour waste up to 1 mm	
Fiber thickness	1.5 (dtex)	4.2 (micronaire)	—
% Trash		45	—
Density (g/cm^3)	1.30–1.37	—	0.91
% Moisture	11	—	—
Tenacity (g/tex)	30–50	—	—
% Elongation	13–20	—	—
Melt Flow Index, g/10 min (230°C–2160 g)	—	—	4–6
Yield strength (kg/cm^2)	—	—	31
Tensile strength (kg/cm^2)	—	—	39

TABLE 3 The Extrusion and Injection Conditions Used in Preparing the Polymer Composite

Process	Extrusion	Injection
Temperature (°C)	85–190	210–230
Pressure (bar)	24	40
Waiting time in mold (s)	—	10
Screw turning rate (rpm)	355	—
Cooling temperature (water) (°C)	85	40

% elongation, and elasticity modulus were tested in the same machine. Izod impact strength tests were made with a Zwick test machine, according to ISO 180. MFI values were determined in a Zwick 4100 testing machine, as in ASTM D 1238. DSC studies and the thermal transitions were determined with a Seteram DSC 131 machine. HDT and Vicat softening point was determined with a Ceast 6505 testing machine. For micro-structure research, samples were covered with 40 Å thickness carbon with Polaron SC 502 machine and SEM photographs were taken under 10 kV current by a JSM-5410 LV JOEL SEM machine.

RESULTS

The mechanical properties of polymer composites produced with PP/Silk Waste and PP/Cotton Waste are given in Tables 4 and 5.

As can be seen in Table 4, with the addition of 3% silk waste to PP, polymer composite's elasticity modulus value decreased but elasticity modulus is increased with increasing the ratio of silk to 6% in the composite. There is no considerable change in yield and tensile strength.

TABLE 4 The Mechanical Properties of PP/Silk Waste Polymer Composite

Mechanical properties	1. Group (100% PP)	2. Group (97% PP–3% Silk)	3. Group (94% PP–6% Silk)
Elasticity modulus (MPa)	486.1	422.0	454.6
Yield strength (MPa)	38.1	39.6	38.8
Tensile strength (MPa)	39.3	39.9	38.9
% Elongation	282.0	14.6	11.2
Hardness (Shore D)	62.1	63.0	62.3
Izod impact strength (notched) kJ m^{-2}	2.8	5.0	4.6

TABLE 5 The Mechanical Properties of PP/Cotton Waste Polymer Composite

Mechanical properties	1. Group (100% PP)	2. Group (97% PP–3% Cotton)	3. Group (94% PP–6% Cotton)
Elasticity modulus (MPa)	486.1	490.5	458.3
Yield strength (MPa)	38.1	37.1	37.6
Tensile strength (MPa)	39.3	37.8	38.0
% Elongation	282.0	29.6	37.7
Hardness (Shore D)	62.1	62.2	60.5
Izod impact strength (notched) $kJ\,m^{-2}$	2.8	3.6	5.1

Addition of silk waste to PP polymer decreased the % elongation value of the composite. There is no considerable change in tenacity value. Izod impact strength of the composite increased with the addition of silk waste to PP.

As can be seen in Table 5, with the addition of 3% cotton waste to PP, the composite's elasticity value increased slightly but elasticity value decreased with increasing the ratio of silk to 6%. There is no considerable change in yield and tensile strength values but a slight decrease was observed. Addition of cotton waste to PP decrease the % elongation value. There is no considerable change in hardness value. Izod impact strenght increased with the addition of cotton waste to PP.

Table 6 shows that there is no considerable change in polymer composite's (MFI) value with the addition of silk waste in PP. HDT and Vicat softening values increased with the increase of waste silk ratio. The results of DSC studies show PP's Tm value of 161.7 to 168.2°C. However, slight increase was observed with increased silk concentration.

Table 7 shows that there is a decrease in polymer composite's (MFI) value with the addition of cotton waste in PP. HDT and Vicat softening

TABLE 6 Thermal Properties of PP/Silk Waste Polymer Composite

Thermal properties		1. Group (100% PP)	2. Group (97% PP–3% Silk)	3. Group (94% PP–6% Silk)
MFI (g/10 min–230°C 2160 g)		4.2	4.9	4.2
HDT (°C–1.80 M Pa)		125.8	130.4	135.3
Vicat Softening Point. (°C–1 kg)		153.7	159.0	155.2
DSC (°C)	Tm	161.7	169.3	168.2

Tm: Melting point.

TABLE 7 Thermal Properties of PP/Cotton Waste Polymer Composite

Thermal properties		1. Group (100% PP)	2. Group (97% PP–3% Cotton)	3. Group (94% PP–6% Cotton)
MFI (g/10 min–230°C 2160 g)		4.2	3.4	2.2
HDT (°C–1.80 M Pa)		125.8	150.3	133.3
Vicat Softening Point. (°C–1kg)		153.7	154.4	154.1
DSC (°C)	Tm	161.7	169.4	171.2

Tm: Melting point.

values increased parallel to increasing the waste cotton ratio. The results of DSC studies are similar to those of silk, which shows an increase with increased cotton fiber content in the composite.

DSC curves of recycled PP/Waste Silk and PP/Waste Cotton are given in Figures 1 and 2.

As shown in Figures 1 and 2, addition of a polymer in a fiber form shifts the melting temperature slightly. Melting temperature of 161.7°C was increased to 168–169°C in both cotton- and silk fiber–reinforced composites.

SEM photographs of PP/Waste Silk and Cotton composites are given in Figures 3 and 4.

The presence of cotton and silk fibers is obvious in the composites. However, the fibers are not fully incorporated in the polymer. This is due to the absence of compatibilizers that were not used in this study. As a result, there was no adhesion between the matrix polymer and the fiber. Another observation can be drawn from the SEM photographs; there was no orientation of fibers within the composite.

DISCUSSION AND CONCLUSION

Elongation values of composites formed by the addition to PP polymer of waste silk and waste cotton fibers that eem to have been reduced greatly. The reason for that is the waste textile fibers are already extended to their fullest capability. When the waste textile pieces are compared to each other, the elongation of the composite made up of silk fibers seems to be lower than that of the composite made up of cotton fibers. When the morphological structure of the composite in Figure 3 is examined, noncircular cotton segments can be found. It is thought that a better physical attachment to the PP is achieved in the matrix.

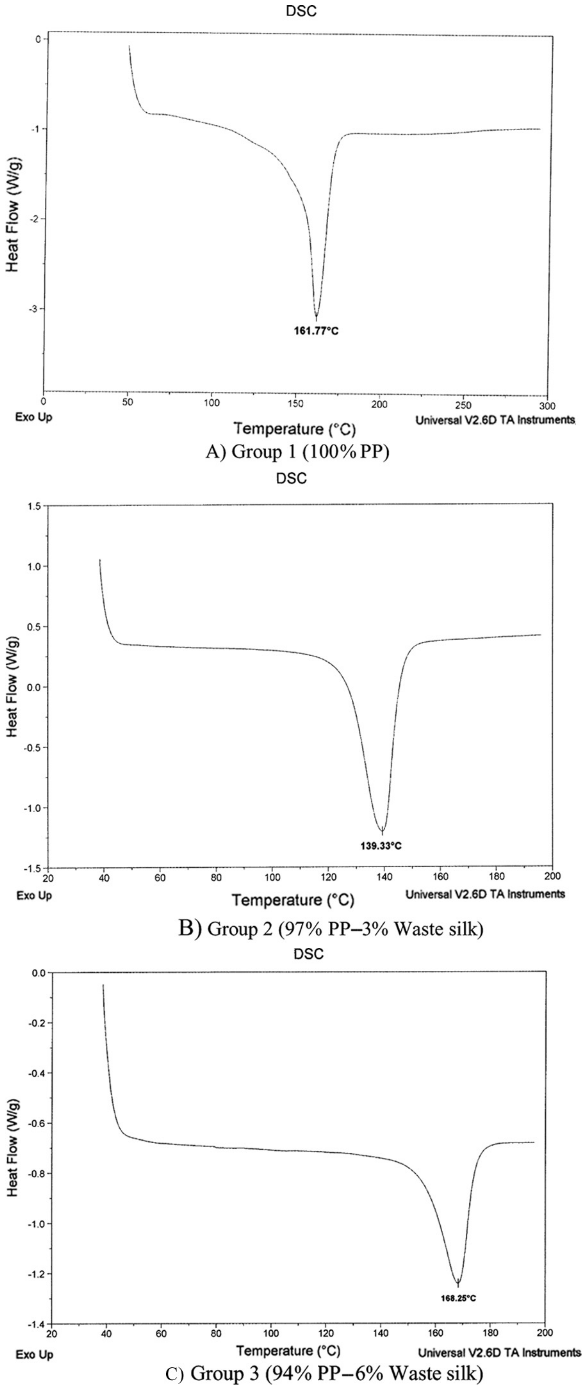
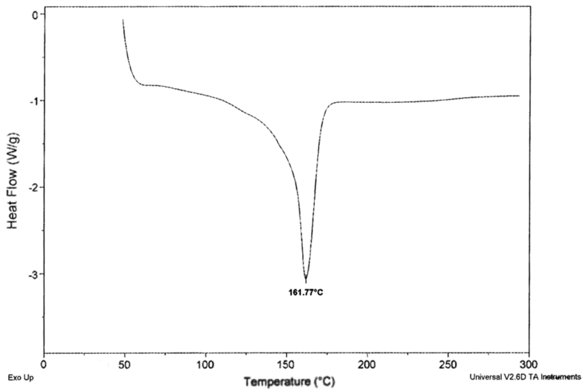
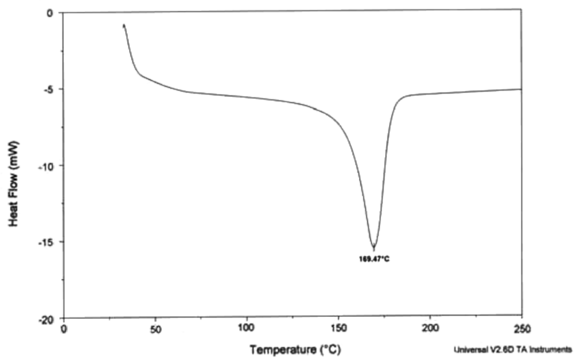


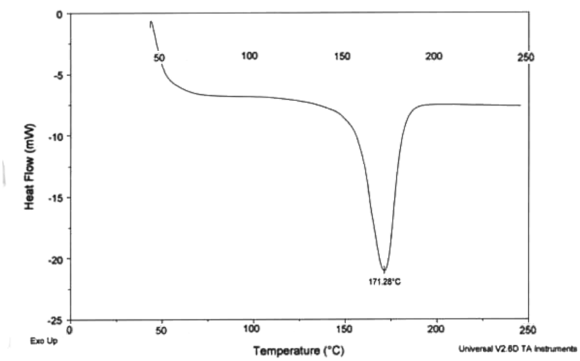
FIGURE 1 PP/Waste silk DSC curves.



A) Group 1 (100% PP)



B) Group 2 (97% PP–3% Waste cotton)



C) Group 3 (94% PP–6% Waste cotton)

FIGURE 2 PP/Waste cotton DSC curves.

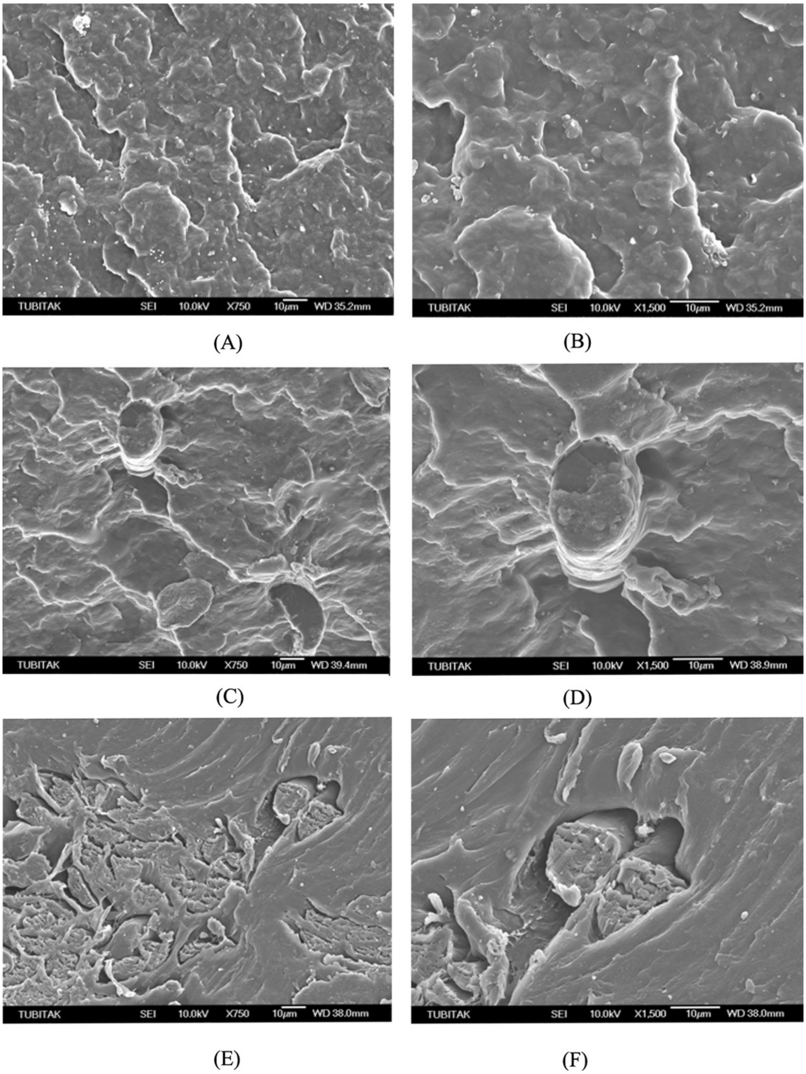


FIGURE 3 SEM photographs of PP/Waste silk composites A) PP (×750), B) PP(×1500), C) PP/Silk (97/3) (×750), D) PP/Silk (97/3) (×1500), E) PP/Silk (94/6) (×750), F) PP/Silk (94/6) (×1500).

From mechanical characteristics of the composites, flow resistance and hardening values seem stable whereas Izod impact values seem to increase. When SEM photos taken from breakage surfaces are checked, it seems that there are gaps between matrix surface and fibers.

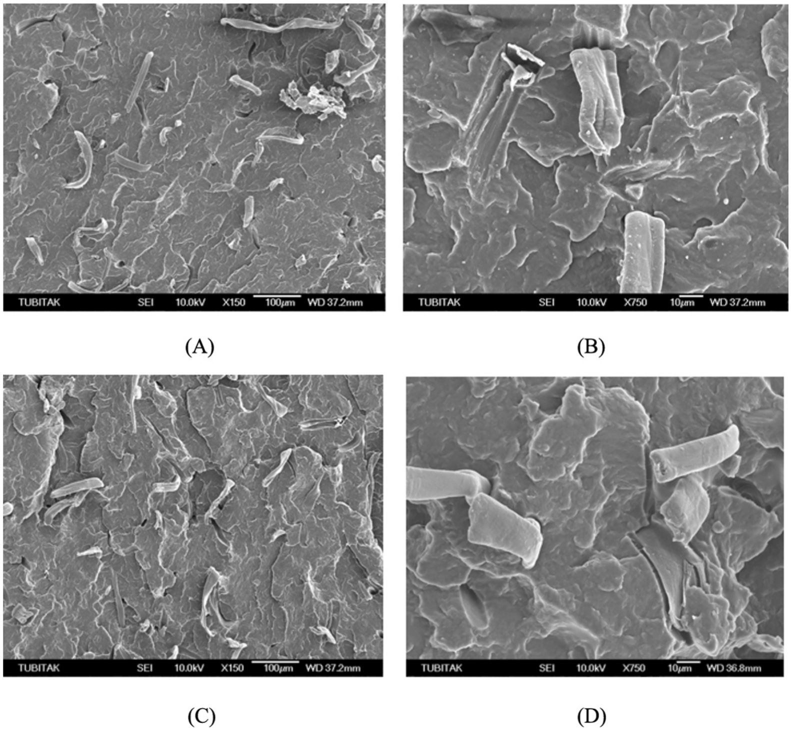


FIGURE 4 SEM photographs of PP/Waste cotton composites, A) PP/Cotton (97/3) (×150), B) PP/Cotton (97/3) (×750), C) PP/Cotton (94/6) (×150), D) PP/Cotton (94/6) (×750).

When DSC thermal analysis results are examined, the melting temperatures of the composites made up of two types of waste fibers in PP matrix increased depending on the fiber amount. The increase may be due to the immobilization of the matrix PP by both fibers.

When MFI values are examined, it is seen that there is decrease in the flow index of molten composites with the addition of waste silk and waste cotton. The decrease in the MFI values of the composite with waste silk fibers is negligible. The reason for the difference between the effects of the two fibers requires additional investigation.

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