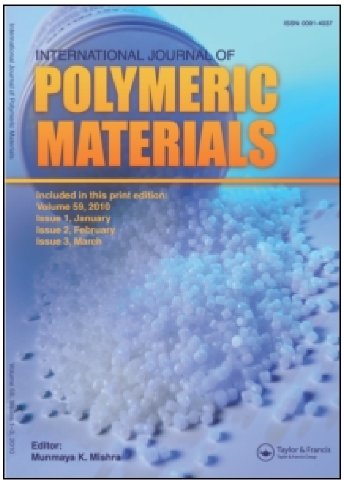

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Properties of Recycled Polycarbonate/Waste Silk and Cotton Fiber Polymer Composites

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Properties of Recycled Polycarbonate/Waste Silk and Cotton Fiber Polymer Composites

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Polymer-based composite structures have advantages over many other materials. The most important advantage is the higher mechanical properties obtained from the composites when supported by fiber reinforcement. The mechanical and thermal properties of fiber-reinforced composite structures are affected by the amount of fibers in the structures, orientation of the fibers and fiber length. Silk and cotton fibers are used in many fields but especially in clothing and textiles. However, there is not enough research on their usage as reinforcement fibers in composite structures. Silk fibers as a textile material have better physical and mechanical properties than other animal fibers. The improvement of the mechanical and physical properties of the composite structures allows them to be used in many areas. From economical, technological and environmental points of view, the improvement of mechanical and physical properties of polymeric materials are receiving much attention in recent studies.

In this study, different application areas were chosen to evaluate the waste silk and waste cotton rather than classic textile applications. Waste silk and cotton and recycled polycarbonate polymer were mixed and as a result composite structures were obtained. Silk and cotton waste fiber dimensions were in between

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1 mm, 2.5 mm and 5 mm. The recycled PC/silk and cotton wastes were mixed in the rates of 97%/3%. Mixtures were prepared by twin-screw extruder. Tensile strength, % elongation, yield strength, elasticity modulus, Izod impact strength, melt flow index (MFI), heat deflection temperature (HDT) and Vicat softening temperature properties were determined. To determine the materials' thermal transition and microstructure properties, differential scanning calorimetry (DSC) and scanning electron microscopy (SEM) were used.

Keywords: polymer composite, recycled polycarbonate, waste cotton, waste silk

INTRODUCTION

Most fibers are used in clothing and textiles rather than industrial areas. Recently, textile fibers were also used in the production of composites, because fibrous materials are cheap and improve the composites' properties. These compound materials are used in airplanes, cars, electronics and medical areas. Some of the materials used in these areas are plastics, which strengthen with fiber reinforcement.

The reason for the use of natural fibers in that kind of material is to improve mechanical properties of the resultant composites. Natural fibers are cheap, nontoxic and recoverable. In addition, they have low density which gives advantages to the fiber-reinforced composites. Waste fibers produced during the production of silk and cotton yarns were used in the composite structures in this study. This is very important in terms of economy, technology and the environment.

In the literature, it was shown that natural fibers were used as a reinforcement material, besides mineral and glass fibers, in composite structures. Studies were concentrated especially on high density polyethylene, polypropylene, polyamid 6 and polyamid 12/wood flour, cellulose flour and cellulose fiber [1], dicumyl peroxide-modified cellulose/LLDPE composites [2], low density polyethylene (LDPE)/cellulose fibers [3], wood fibers as reinforcing fillers for polyolefins [4], polypropylene/wood fiber composites [5], jute fiber-reinforced thermoplastic polymers (LDPE, HDPE, PE copolymer, and PP) [6], polypropylene (PP) and high-density polyethylene (HDPE) filled with wood and cellulose flour [7], polypropylene/flax [8], polypropylene/sisal fibers [9], short sisal fiber-reinforced polyethylene composites [10], LDPE/short sisal fiber [11], PS/short sisal fiber [12], polyester/jute fiber [13], and methacrylamide/silk [14–16].

Beside these, many natural fibers used as reinforcement materials in the composite structures have advantages such as high specific tensile modulus values and lower breaking extension.

EXPERIMENTAL

Materials and Compositions

Recycled PC/waste silk and cotton polymer composites were prepared and the amounts and fiber lengths of the samples are given in Table 1.

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

Silk fibers used in the textile industry are, in fact Bombyx Mori silk. Waste silk fibers which are obtained during the cocoon forming or the silk filaments production are cut with guillotine in between 1, 2.5 and 5 mm fiber lengths. Waste cotton fibers are spilled down from grids during the opening, carding and combing process. The waste cotton obtained from this process is gathered into fiber dimensions in between 1, 2.5 and 5 mm. The mixing of PC with the silk and cotton

TABLE 1 Recycled PC/waste Silk and Cotton Polymer Composite Mixtures and Fiber Lengths

Groups	PC (%)	Silk (%)	Cotton (%)
1	100	–	–
2	97	3 (Silk length: 1 mm)	3 (Cotton length: 1 mm)
3	97	3 (Silk length: 2.5 mm)	3 (Cotton length: 2.5 mm)
4	97	3 (Silk length: 5 mm)	3 (Cotton length: 5 mm)

TABLE 2 Mechanical, Thermal and Physical Properties of the Materials

Properties	Silk [17]	Cotton [17]	PC [18]
Place of production	Bursa/Turkey	Çukurova/Turkey	General electric U.S.A
Type	Waste silk	Waste cotton	Lexan-144 R
Source	Filament waste	Blow room 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 content	–	45	–
Density (g/cm^3)	1.3–1.37	–	1.20
% Moisture absorption	11	–	0.10
Thermal conductivity	poor	–	–
Strength, g/tex	30–50	–	–
% Elongation	13–20	–	–
Izod impact strength (23°C-J/m^2)	–	–	25
Breaking module (MPa)	–	–	2350

(–) means not available or not applicable.

TABLE 3 Extrusion and Injection Conditions to the Polymer Composites

Process	Extrusion	Injection
Temperature (°C)	85–230	230–260
Pressure (bar)	9	40
Waiting time in mold (s)	–	10
Screw turning rate (rpm)	249	–
Cooling temperature (°C)	85	40

waste was carried out at 85–230°C temperature, 9 bar pressure and mix rate of 249 rpm, using a double-screw extruder produced by Maris (Maris TM40MW–Maris America Corporation Baltimore, USA). After the mixing process, test samples were prepared in an Arburg (Arburg GmbH Co., Lossburg-Germany) injection machine, according to ISO 294. The extrusion and injection conditions are given in Table 3.

Tensile tests were carried out using a Zwick 1120 (Zwick GmbH, Ulm-Germany) machine with head speed of 50 mm/min according to ISO 572.2. Consequently, the mechanical properties like tensile strength, elasticity modulus, yield strength and % elongation were tested in the same machine. Impact tests were made with a Zwick brand impact test machine, according to ISO 180. MFI values were measured in a Zwick 4100 brand testing machine, according to ASTM D 1238. DSC studies and the thermal transitions were determined with a Seteram DSC 131 machine (Scientex Pty., Ltd., Victoria, Australia). The HDT and Vicat softening point were determined with Ceast 6505 testing machine (Ceast SPA, Pianezza, Italy). To investigate their microstructure, samples were covered with 40 Å thickness carbon with Polaron SC 502 machine (Gala Instrument GmbH, Bad Schwalbach, Germany) and SEM photographs were taken under 10 kV current with a JSM-5410 LV JOEL SEM (Jeol, Peabody, MA) machine.

RESULTS AND DISCUSSION

Mechanical properties of PC/waste silk and PC/waste cotton polymer composites are given in Figure 1.

As seen in Figure 1, the addition of 1 mm length silk waste to recycled PC polymer decreases the composites' elasticity modulus value, while increasing the length of silk increases the elasticity modulus. Yield strength and tensile strength values are decreased but increasing the length of silk fiber increases these values. There

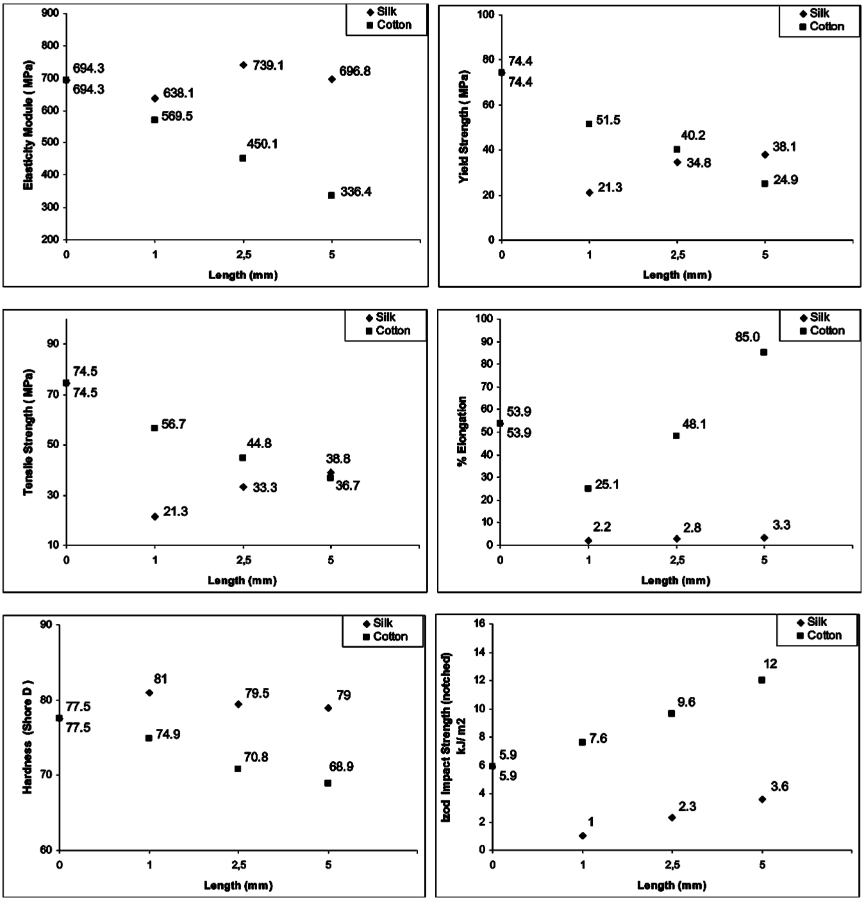

FIGURE 1 Mechanical property of PC/waste silk and PC/waste cotton polymer composites.

is a considerable decrease with the addition of waste silk in % elongation value. There is a little increase in hardness value. With the addition of waste silk, the Izod impact strength decreases but increasing the length of silk fiber increases this value.

The addition of waste cotton to recycled PC polymer decreases the elasticity modulus of the resultant composite increasing the length of cotton fibers further decreased the modulus. Yield strength and tensile strength values do decrease with increasing length of cotton fibers. But both increase in the case of silk fibers. There is a considerable decrease in % elongation value, but increasing the fiber length

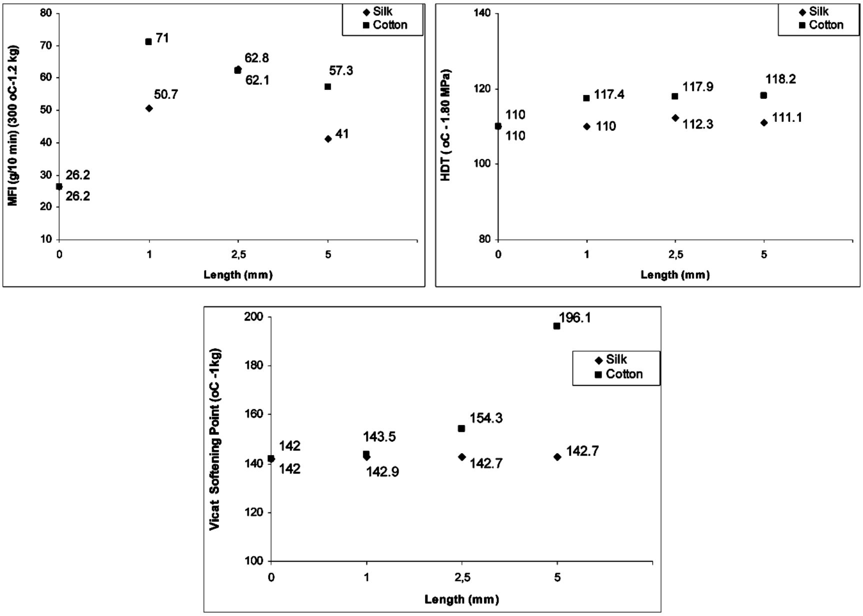

FIGURE 2 Thermal properties of PC/waste silk and PC/waste cotton polymer composites.

increases this value. Izod impact strength increased, and increasing the length of cotton fiber increases this value gradually.

The thermal values of polymer composites produced in this study with recycled PC/waste silk and recycled PC/waste cotton polymer composite are given in Figure 2.

As seen in this figure, the addition of waste silk to recycled PC polymer increases the MFI value. There is no considerable change in heat deflection temperature and Vicat softening point. The addition of cotton waste to recycled PC polymer increases the MFI value, heat deflection temperature and Vicat softening point of the composite.

The DSC curves of polymer composites produced with recycled PC/waste silk and recycled PC/waste cotton are given in Figure 3.

The addition of waste silk to PC decreases the Tg value. But, in the case of waste silk fiber length of 2.5 mm, there is an increase in Tg value of the composite. On the other hand, the addition of cotton waste to PC decreases the Tg value of the composite.

Figure 4 shows the SEM photographs of the recycled PC/waste silk and recycled PC/waste cotton polymer composites. In the case of

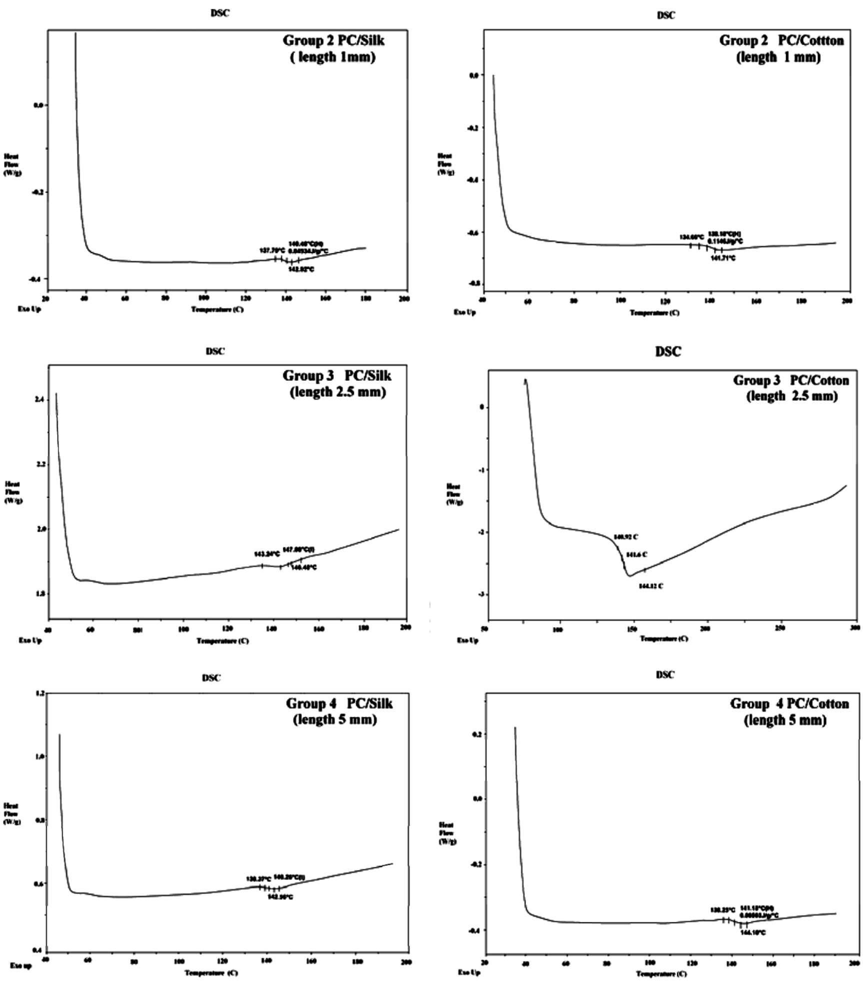

FIGURE 3 DSC curves of recycled PC/waste silk and PC/waste cotton polymer composites.

cotton fibers, there appears to be much better adhesion to the PC matrix than in the case of silk fibers.

CONCLUSIONS

Upon increasing the length of silk in PC, yield strength, tensile strength, % elongation and Izod impact strength decrease, while hardness, elasticity modulus and MFI increase. HDT and Vicat softening

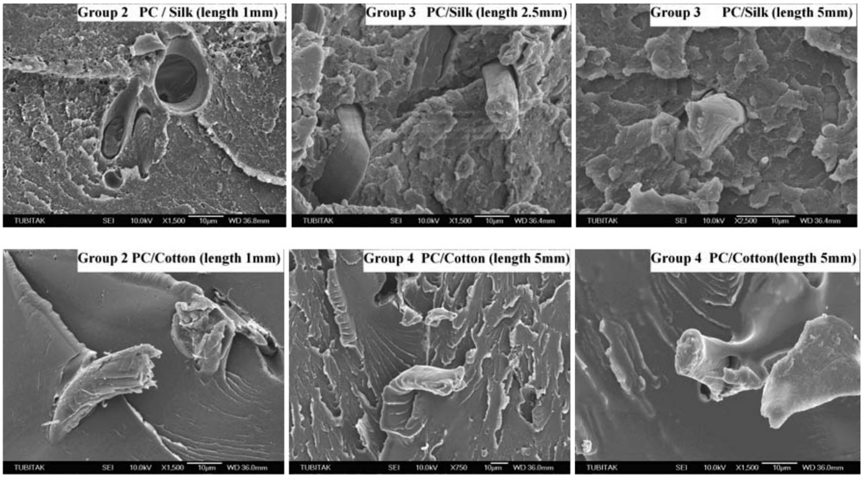

FIGURE 4 SEM photographs of recycled PC/waste silk and cotton polymer composites.

values are not changed. On the other hand, with increasing the length of cotton in PC, yield strength, tensile strength, elasticity modulus, and hardness decrease, while % elongation, Izod impact strength, MFI, HDT and Vicat softening values increase. When the PC/silk and PC/cotton polymer composites' micro-structure are examined it is observed that silk and cotton fibers did not orientate in a clear direction but there was a better adhesion of the cotton to the matrix. This may be due to the absence of compatibilizers or to differences in surface energy of the two kinds of fibers.

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