Waste Polyurethane Reinforced Polyester Composite, Production and Characterization

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Abstract: In this research, new composite materials were improved by reinforcing the environment-polluting waste polyurethane (WPU) to unsaturated polyester (UP). Polyester composites were produced with WPU, UP, methyl ethyl ketone peroxide (MEKP), and cobalt octoate (Co. Oc.). The effect of WPU on the changes in density, Shore D hardness, thermal conductivity coefficient, thermal stability, and porosity of the obtained composites were investigated. According to the findings, as WPU ratio increased in the composite, both the thermal conductivity coefficient and the density of the composite decreased. Shore D hardness was been found to decrease as the rate of WPU in polyester composites raised. The use of optimum WPU ratios (7 wt.%) in composite production improved some thermo-physical properties of polyester composite. The high use of WPU negatively affected both the surface morphology and thermal stability of the polyester composite. In addition, the parameters affecting the production of polyester composites were optimized according to response surface methodology (RSM).

Keywords: Polyester composite, density, Shore D hardness, thermal conductivity.

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INTRODUCTION

Studies on the hybrid use of polymers are increasingly widespread in the literature. The bond structure, hardness, brittleness, density, porosity, mechanical and thermal properties of polymers enable them to be used for different purposes according to the sectors. In this research using unsaturated polyester and polyurethane hybrid composites, it has been observed that the mechanical properties give optimum results at 5 wt.% polyurethane content (1).

Utilizing rubber waste as additives and fillers eliminates the environmental problem and ensures economic polymer composites. It has been determined that the thermal stability of the polyurethane composites obtained with 5 wt.%, 10 wt.%, and 20 wt.% waste rubber reinforcement has improved. Also, rubber reinforcement increased the density of the polyurethane and strengthened its mechanical properties. Rubber increased the surface roughness and high compressibility of the polyurethane composite while reducing its porosity (2-5).

Polyurethane's physical and chemical properties, epoxy and polyester resins are improved with polymers such as waste rubber. It has been demonstrated that the thermal stability and thermoset properties of the composite matrix obtained can be improved. It is a resin that is used with epoxy, coatings, adhesives, fibrous structures, or particle filters. Epoxy resins have been used to produce composite materials as a thermosetting polymer with high chemical, thermal, and electrical resistance. It is preferred in many applications due to its improved thermal and mechanical properties according to the purpose of use. Studies have also been conducted to improve the unsaturated polyester resin's mechanical performance and thermal stability with the isocyanate component (6,7).

Physical and chemical characterization processes have been carried out on an article that is made of sugar palm stems reinforced with epoxy, polyester, and polyurethane resin. The performance of palm stem filler varies between 2 wt.% and 10 wt.% and 90 wt.%, and 98 wt.% resin mixtures have been mixed under high pressure, and temperature, and their performances are compared. As the amount of filler by mass has been increased, the density of all three resins has decreased, and their porosity has gone up. Although the mechanical strength of composites increased, by 6 wt.% for polyurethane and up to 8 wt.% for polyester and epoxy, a negative effect on high usage rates has been observed (8).

In another study, acoustic damping flexible polyurethane foams have been synthesized using saturated aliphatic polyesters, methylene diphenyl diisocyanate, and other reagents. It has been observed that many physical properties, such as average cell size, distribution, surface roughness, and open-cell structure, are affected by microphase separation. Although the cell size decreased from 360 nm to 180 nm, it was determined that the compressive strength, open-cell structure, roughness, and cell size distribution also increased. Besides, it has been observed that polyurethanes with higher microphase separation have higher sound absorption efficiencies (9).

This study aims to use non-recyclable waste polyurethane in the polyester composite. While the density, thermal conductivity coefficient, and hardness of unsaturated polyesters decreased, their porosity and processability also increased. Thus, both environmentally problematic wastes have been used, and economical polyester composites have been obtained.

MATERIALS AND METHODS

Commercial waste polyurethane was supplied by the insulation company (İçmeli Erdem, Elazığ). The polyester components (methyl ethyl ketone peroxide (MEKP), cobalt octoate (Co. Oc.), and unsaturated polyester (UP)) were purchased from Turkuaz Polyester. For the experimental study, the factory wastes were ground into a -50/100 mesh particle size and dried at 105 °C, then added to pure unsaturated polyester and homogenized for 15 minutes at 1000 rpm at room temperature. Then, the chemical reaction was started with the help of certain amounts of MEKP and Co. Oc catalysts. At room temperature, the mixture was mixed at 1500 rpm for 2 minutes, then poured into standard molds and allowed to cure for 1 day (20-22).

The experimental study plan and chemical composition ratios are given in Table 1. Waste polyurethane and unsaturated polyester ratios were changed by keeping Co. Oc. and MEKP ratios constant (27).

Thermogravimetric analysis (TGA) of polyester composites was performed with a Q600 STD-TA device. Besides, the surface morphologies of the composites were examined with the Carl Zeiss Ultra Plus Gemini Fesem device (SEM).

RESULTS AND DISCUSSIONS

The physical and chemical properties of the polyester composite have been characterized depending on the use of waste polyurethane in different proportions by mass. In this research, properties of polyester composites such as density, Shore D hardness, thermal conductivity coefficient, and thermal stability have been determined. As seen in Figure 1, the density of the composite decreases as the waste rate goes up.

As shown in Figure 2, the Shore D hardness of polyester composite decreased as the waste polyurethane ratio increased.

Figure 3 shows how waste polyurethane improved the insulation property of the polyester composite. In other words, it reduced the thermal conductivity coefficient.

Table 1: Experimental working plan and chemical compositions.

Experiment No	WPU (wt.%)	UP (wt.%)	Co. Oc. (wt.%)	MEKP (wt.%)
1	0	98	0.5	1.5
2	2	96	0.5	1.5
3	4	94	0.5	1.5
4	7	91	0.5	1.5
5	10	88	0.5	1.5
6	15	83	0.5	1.5

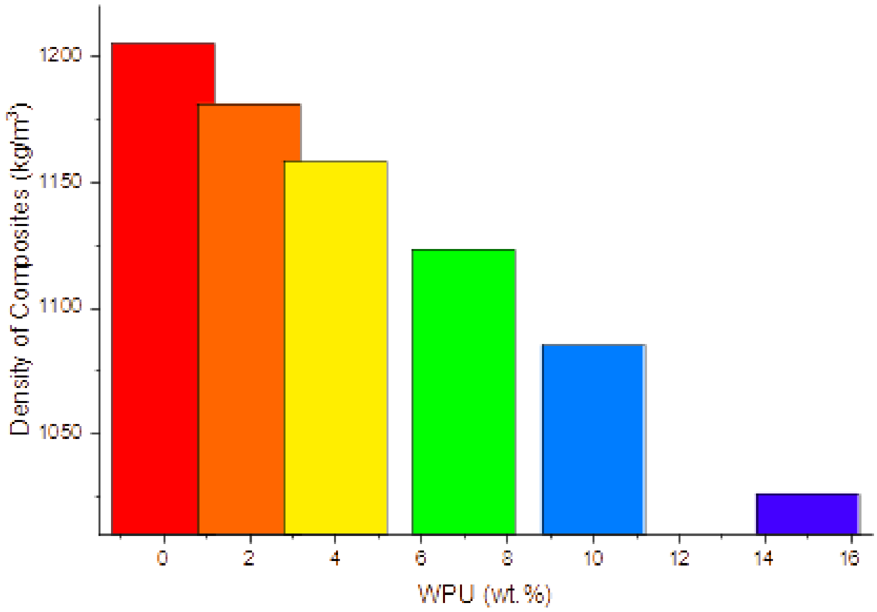

Figure 1: The change of density of the polyester composite with WPU (wt.%)

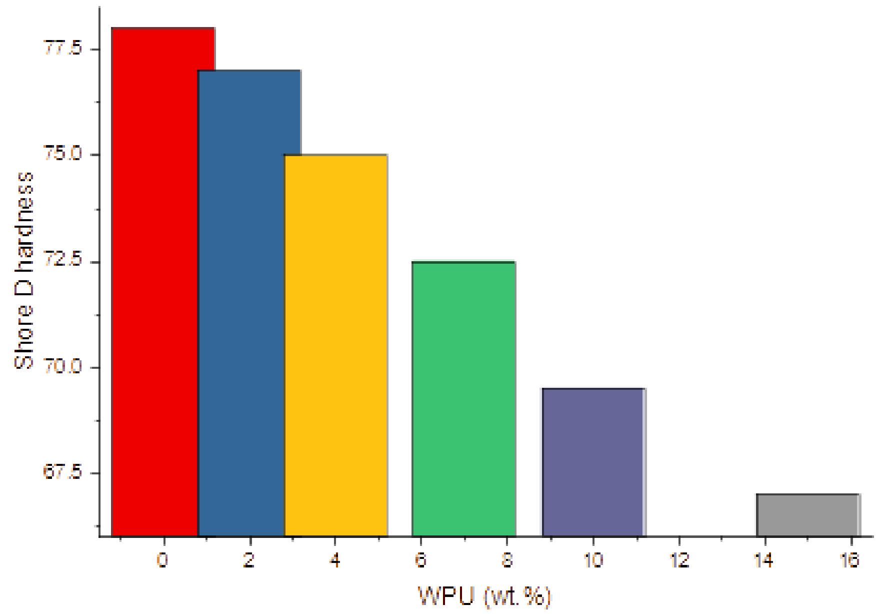

Figure 2: The variation of Shore D hardness of the polyester composite with WPU rate.

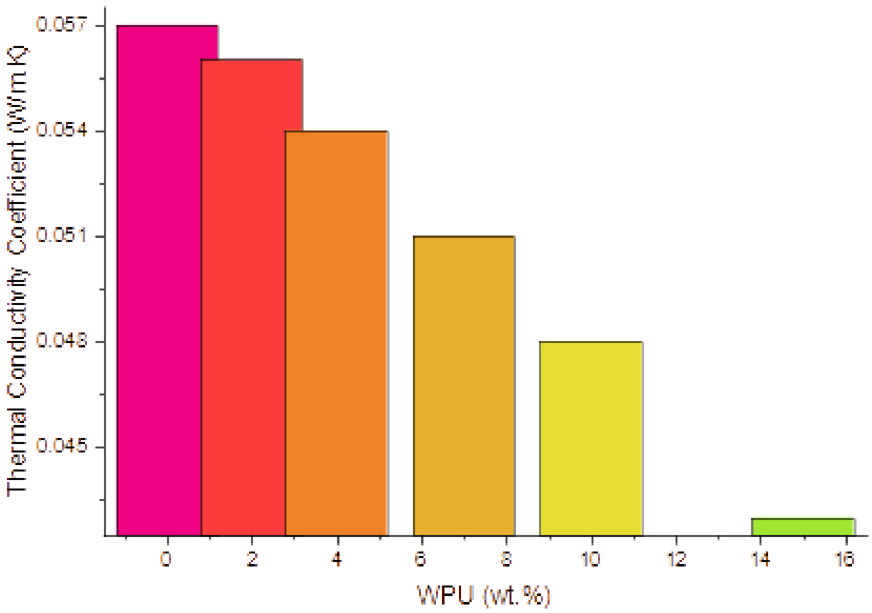

Figure 3: The change of thermal conductivity of the polyester composite with WPU (wt.%).

RSM Results for the Polyester Composites

Response surface methodology (RSM) can express the relationship between response functions and experimental data by entering the program. Optimum parameters can be determined by choosing models suitable for the data obtained in the designed experiments. It can be expressed using high-order polynomials for modeling complex systems and the most appropriate statistical approaches (10-14).

According to RSM results (Table 2), density with the natural logarithmic model, Shore D hardness with power model, and thermal conductivity coefficient with the inverse model have been preferred. The best models have been determined by statistical analysis of experimental and theoretical data (23,24).

Table 2: Evaluation of RSM results with statistical analysis.

Transform	Source	SST	F-value	P-value	R^2	Std. Dev.	Mean	C.V.%
Natural log	Quadratic	0.0465	14.64	0.0032	0.9993	0.0013	7.04	0.0108
Power	Quadratic	0.3178	177.16	0.0001	0.9994	0.0299	73.86	0.0405
Inverse	Quadratic	0.9362	5.88	0.0317	0.9833	0.2820	19.82	1.420

Figure 4 shows the effect of the waste polyurethane and unsaturated polyester rates on the composite density. The density of the composite was found to decrease as the amount of PU in the polyester mixture increased.

As it can be seen in Figure 5, Shore D hardness of the composite obtained decreased as the WPU ratio by mass increased. According to the RSM model results, polyester composite materials with the desired hardness can be produced by using WPU and UP at certain rates (15-19).

In Figure 6, the thermal conductivity coefficient went up in direct proportion to the UP rate, while it went down inversely with WPU rate. In other words, the increase in WPU ratio by mass has improved the composite's insulation feature.

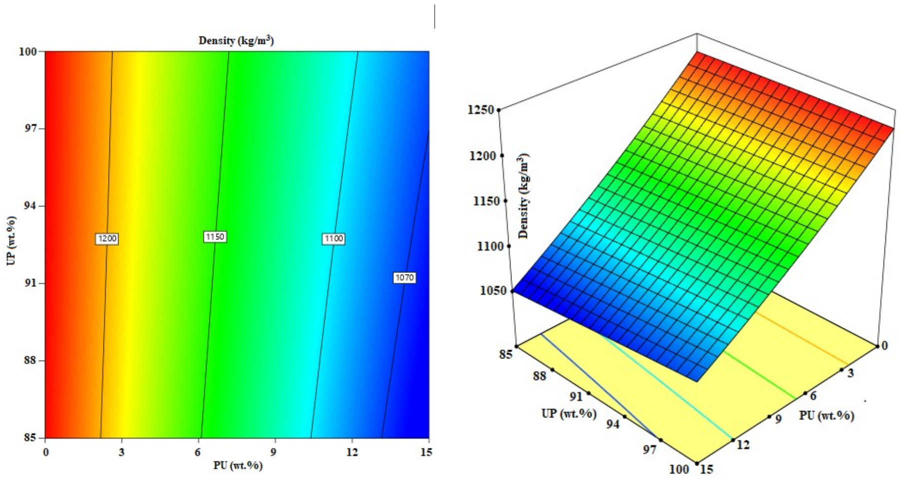

Figure 4: Variation of the density with WPU (wt.%) and UP (wt.%).

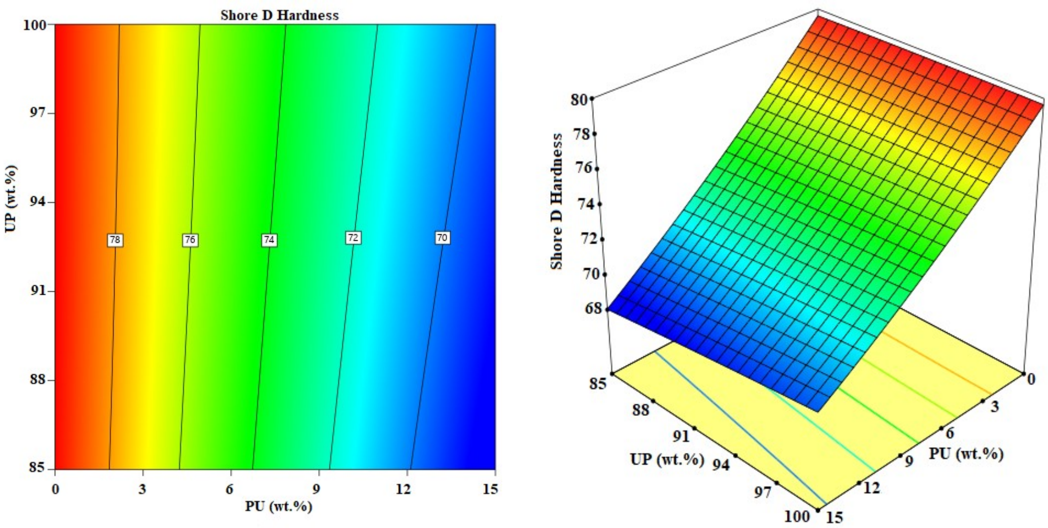

Figure 5: Change of Shore D harness with WPU (wt.%)and UP (wt.%).

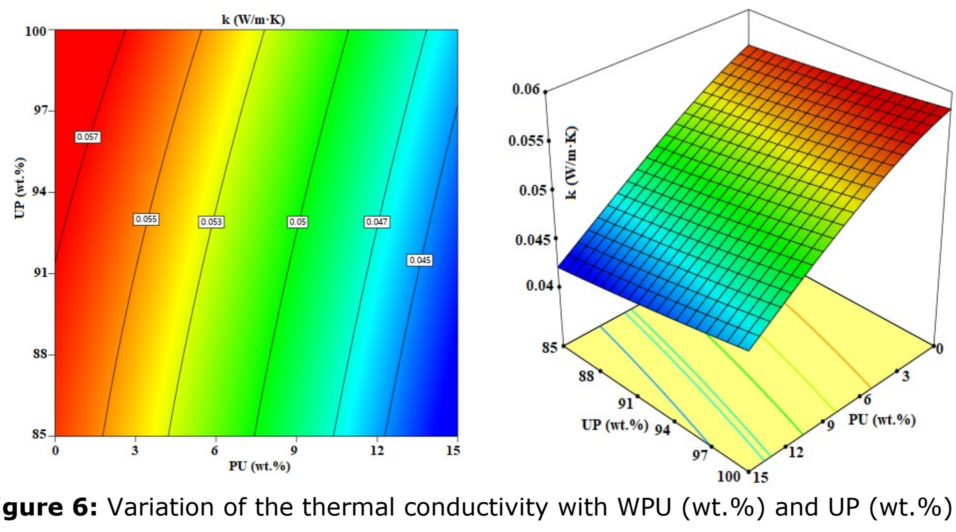

Figure 6: Variation of the thermal conductivity with WPU (wt.%) and UP (wt.%).

The equations of density, Shore D hardness, and the thermal conductivity coefficient are expressed according to the RSM results in Eq. 1, Eq. 2, and Eq. 3, respectively.

$$\ln(\rho) = +7.05331 - 0.019229 \cdot WPU + 0.001252 \cdot UP + 0.000094 \cdot WPU \cdot UP + 0.000054 \cdot WPU^2 - 6.29244 \cdot 10^{-6} \cdot UP^2 \quad \text{(Eq. 1)}$$

$$ShoreD = +73.56643 - 1.47215 \cdot WPU + 0.128089 \cdot UP + 0.006933 \cdot WPU \cdot UP + 0.007418 \cdot WPU^2 - 0.000671 \cdot UP^2 \quad \text{(Eq. 2)}$$

$$1/k = +15.25232 + 0.673490 \cdot WPU + 0.091456 \cdot UP - 0.005520 \cdot WPU \cdot UP + 0.012817 \cdot WPU^2 - 0.000726 \cdot UP^2 \quad \text{(Eq. 3)}$$

The study has been modeled by using experimental and theoretical data. A large number of variables that affect the response of the system were examined, so the response of the process to changes in process parameters could be defined by RSM (25,26). The fact that it can be applied successfully in many different processes and enables the determination of the optimum point by considering too many responses makes the response surface method stand out from other optimization methods (15-19).

Figure 7 shows the SEM image of the pure polyester composite, and Figure 8 shows that of the WPU (10 wt.%) reinforced composite. WPU reinforcement enhanced the porosity of the polyester composite, according to surface morphologies.

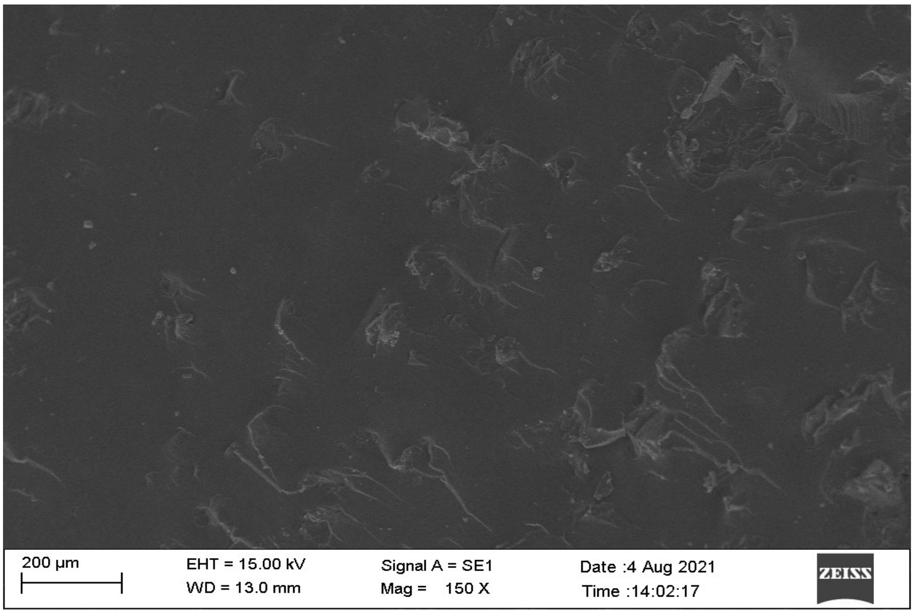

Figure 7: SEM image of the pure polyester composite (Experiment 1).

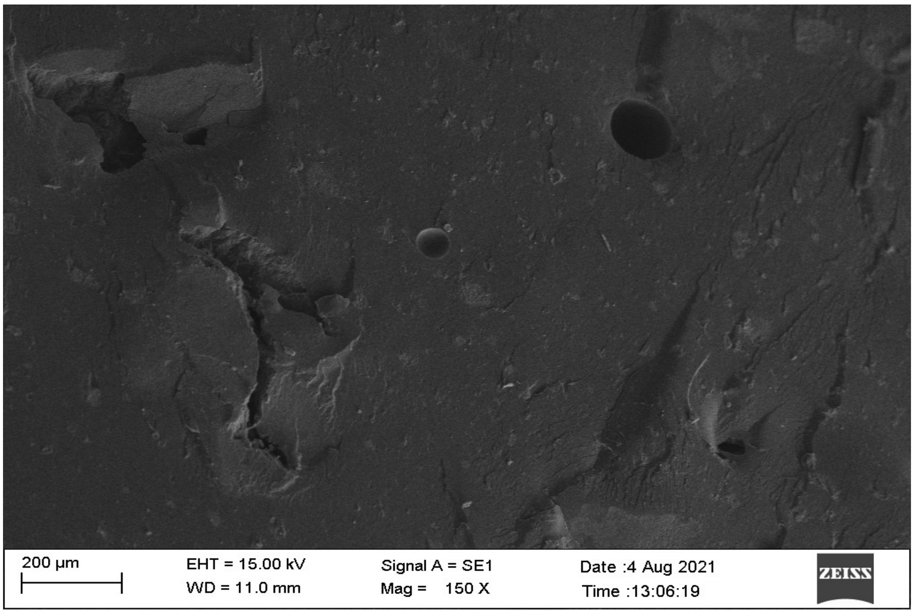

Figure 8: SEM image of the pure polyester composite (Experiment 5).

When the TGA curves (Figure 9) were studied, it was discovered that the pure polyester composite (Experiment 1) had a more stable thermal deterioration behavior than the WPU reinforced composite (Experiment 5).

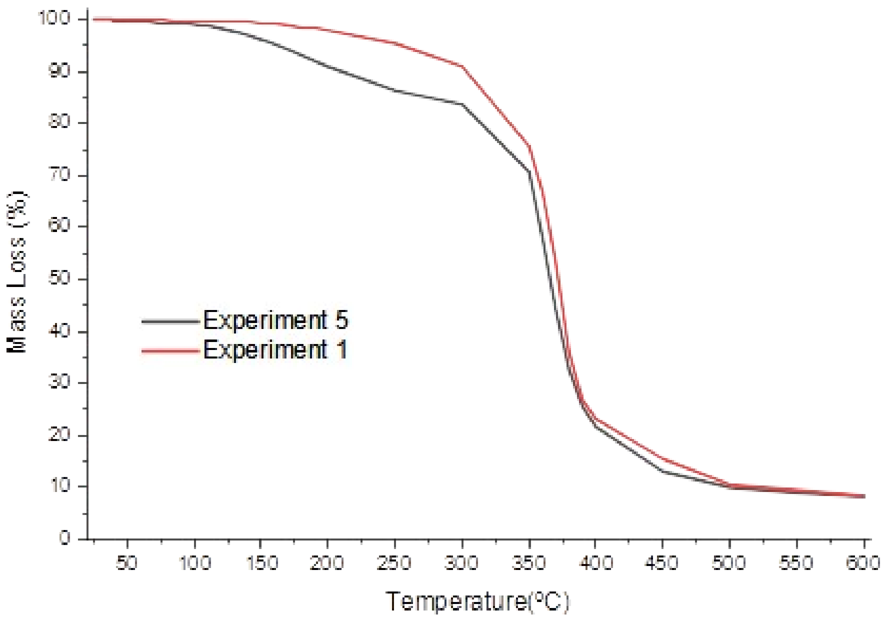

Figure 9: TGA curves of the pure polyester and 10 wt.% WPU reinforced composites.

CONCLUSIONS

This research was carried out to prevent environmental pollution from waste sponges, which are only partially recyclable, and to produce economic polyester composites. A low-density, easy to process, more flexible, and insulating composite has been produced. According to the experimental and theoretical results, both the density and thermal conductivity coefficient of polyester composites decreased as the WPU ratio by mass increased. When the SEM images were examined, the high WPU ratio by mass caused irregular porosity in the surface of the polyester composite. As seen in TGA curves, the use of high WPU by mass has reduced the thermal stability of the polyester composite. Also, the Shore D hardness of polyester composite decreased as the WPU ratio raised.

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