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Investigation Physico-Mechanical and Thermal Behavior of (Epoxy/Polyurethane)/Apple Waste Activated Carbon Bio Composites for the Removal of Methylene Blue from Wastewater

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Abstract
A series of (Epoxy/Polyurethane)/Apple Waste Activated Carbon (EP/PU)/(AWAC) bio composites have been prepared with varying amounts of apple waste activated carbon (AWAC) viz., 0, 2.5, 5, 7.5 and 10 wt %. The prepared bio composites have been characterized for physico-mechanical behaviors and chemical resistance. The obtained biocomposites have characterized via thermogravimetric analysis (TGA), Differential Scanning Calorimetry (DSC), and Scanning electron microscopy (SEM) to reveal the effect of the presence of the apple waste activated carbon (AWAC) on the properties of the obtained adsorbent. The thermal degradation behaviors of bio composites have been established using TGA thermograms. These results indicate that it is possible with increase the apple waste activated carbon content adsorption of (EP/PU)/(AWAC) is increased. Developed biocomposites from apple waste materials will help to reduce the overall cost of the materials for its demanding applications as insulating material. The as-prepared (EP/PU)/(AWAC) bio-adsorbent removes the cationic dyes from the waste water.

Keywords
(Epoxy/Polyurethane); Apple waste activated carbon; Biocomposites; Thermal behavior; Methylene blue.

1. Introduction

The demand for water, food, agricultural products, and other natural resources has expanded dramatically as a result of industrial development, urbanization, and population growth. Various concerns about delivering clean and useable water have been raised across the world due to climate change, misuse and depletion of water supplies, and human caused water pollution. Water contamination has become a public concern, posing a threat to ecosystems and human life security. Water pollution from different dyes has become a serious concern to human and marine life in recent years [1]. There are various types of dyes used in the pulp, textile, clothing, fabrics, food, and pharmaceutical cosmetics sectors can pose major problems by impeding sunlight penetration into the water and harming aquatic life [2]. Complex aromatic molecules are more stable and difficult to biodegrade than many artificial dyes [3]. Some dyes have been linked to allergies, skin irritation, and even cancer in humans [4]. Therefore, environmental scientists and engineers must still determine how to remove dyes effectively and comprehensively from water sources [5]. Epoxy resins are a class of thermosetting polymers that has gained industrial importance as well as academic interest because of the tunable properties of final products and the complicated set of side reactions occurring in any particular network-forming chemistry. Epoxy (EP) resins are a family of oligomeric materials that can be further reacted to form thermoset polymers. The cured epoxies exhibit an attractive performance of stiffness, strength, thermal stability, creep resistance, flexibility, impact resistance, good electrical properties, a high degree of chemical and solvent resistance, outstanding adhesion to a broad range of substrates, and a low order of shrinkage on cure, and it is widely applied as matrix of coatings, adhesives, and composites. However, because of its high crosslink density, epoxy (EP) has low

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toughness and poor crack resistance at room temperature. This is the basic reason; large body of literature has been on the subject of toughening of epoxy. The toughening of epoxy resin networks has raised much attention in recent years because epoxy resins possess desirable properties and are ideal candidates for important applications. The aim, when attempting to toughen brittle polymers, is to increase their toughness without any significant reduction in other important properties such as modulus and heat distortion temperature (HDT). The first approach to modify epoxy resins is by addition of rigid particles, which generally leads to a significant reduction in cost and a considerable improvement in the resin's mechanical, thermal, and electrical properties, namely, the elastic modulus, heat distortion temperature, and dielectric strength. Considerable work relating to the effect of particulate fillers on the mechanical properties of thermoplastic and thermosetting polymers has been reported in literature [6]. Parameters such as the volume fraction of the filler, particle size, modulus and strength of the filler and resin, filler adhesion on the toughness of the epoxy matrix have been extensively studied. The variation of some of these parameters leads to improved toughness of the filled material while increasing its strength and modulus [7]. The second method used to improve the toughness of epoxy resins involves an addition of suitable rubbers that are copolymers with varying amounts of acrylonitrile contents to the uncured epoxy resin. The effects of the acrylonitrile content of the copolymer type, the molecular weight, the concentration, and the solubility parameter of the rubber and its functional end groups on the fracture toughness or on the impact strength of the epoxy resin have been studied. In these studies, epoxy resins were modified with carboxyl terminated butadiene rubber (CTBN) [8], hydroxyl terminated butadiene rubber (HTBN) [9], or epoxy-terminated [10] copolymers of butadiene and acrylonitrile. The degree to which a highly cross-linked epoxy resin can be toughened by incorporating rubber particles is very limited because its ability to deform by shear yielding is reduced with increasing cross-link density; therefore, a third technique has emerged. Recently, a highly crosslinked thermosetting system has been toughened by tough, ductile, and chemically and thermally stable engineering thermoplastics such as polyethersulphones (PES), polyetherimides (PEI), phenolic hydroxyl-terminated bisphenol-A polysulphone (PES), and polyphenylene oxide (PPO) [11]. Because its structural formation can be easily controlled and it has good mechanical properties, PU has been widely investigated and utilized in the laboratory and industry. Therefore, the IPNs of PU with different kinds of polymers have been widely studied and used as industrial materials [12]. So far, Epoxy/Polyurethane IPNs have been developed with different approaches. In one of the earliest studies, Hsieh et al. [13] prepared thermoset polyurethane prepolymers and fabricated epoxy/polyurethane IPNs. They investigated the effect of the prepolymer percentage on the mechanical properties of the IPNs. The results demonstrated that an increase in polyurethane content initially led to higher tensile strength and crosslink density. However, beyond a certain point, further increases in polyurethane content resulted in phase separation, which caused a decline in mechanical properties. Harani et al. [14] investigated the effect of polyurethane percentage on the impact resistance of epoxy/polyurethane IPNs. The results showed that the presence of polyurethane increased the impact resistance of the epoxy resin. Liu et al. [15] fabricated Epoxy/Polyurethane IPNs using the melt method to achieve shape memory properties. They observed shape recovery ratios between 80 and 90 %. According to their results, the shape recovery speed increased with a higher polyurethane percentage. Yao et al. [16] developed a type of epoxy/polyurethane IPN using polyurethane foam raw materials to achieve shape memory properties. They reported 99 % shape recovery ratio and 95 % shape fixity ratio, which were improved up to 98 % by increasing the epoxy resin percentage. Czifrák et al. [17] fabricated epoxy/polyurethane IPNs using polycaprolactone diol with different molecular weights. In the present research, (Epoxy/Polyurethane) (EP/PU)/Apple Waste Activated Carbon (AWAC) bio composites have been prepared with varying amounts of apple waste activated carbon (AWAC). The obtained bio composites were characterized using mechanical analysis, Thermal analyses and scanning electron microscopy. Absorption of bio composites was analyzed.

2. Experimental

2.1. Materials

Methylene blue Sigma Aldrich (St. Louis, MO, USA), dye was used as the dyeing agent (adsorbate).The diglycidyl ether bisphenol A (DGEBA) based epoxy resin Araldite A 31, is a clear liquid with a viscosity of 30000 to 50000 mPa at 25 °C and Hardener K 31 (aromatic) amine type, is a clear liquid with a viscosity of 30000 to 50000 mPa at 25 °C, Tetrahydrofuran (THF), and KOH were purchased from Jahan e shimi Orumiya Chemical Reagent Co., Ltd. Toluene diisocyanate (TDI) was purchased was obtained from Sigma, Jahan e shimiOrumiya (Iran). The Jagropol oil (115) was obtained from Jahan e shimi Orumiya.

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Dibutyltindilaurate (DBTL) (C32H64O4Sn), was purchased sigma Alderich.

2.2. Synthesis of apple waste activated carbon (AWAC)

For preparation (AWAC), at first apple waste was collected, washed and was dried at room temperature. Then it put at 110 °C for 12 h in a Hot Air Oven, after made powder by a mixer and sieved using a 30 mm mesh size (50 µm). It was carbonized at 500 °C during 1h under a nitrogen atmosphere. It was mixed with activating agent potassium hydroxide (KOH) (4 M) in the during 4h at room temperature, and dried at 110 °C for one day. The mixture set a tubular furnace at 500 °C for 4 h. In the end, activated carbon washed with concentrated hydrochloric acid and deionized water.

2.3. Synthesis of (EP/PU)/(AWAC) bio composites

A calculated amount of castor oil was placed in a round bottomed flask, and raised the temperature to 60 °C, and thoroughly mixed with a predetermined amount of TDI. The reaction system was stirred vigorously with a teflon-coated magnetic stirrer, under a dry nitrogen atmosphere for about 45 min to form a urethane prepolymer and by adding 1 to 2 drops of DBTL as catalyst. The epoxy precursor (A 31, DGEBA) was then added to the system, which was stirred for a while before adding 50 wt% of K 31 (based on the amount of DGEBA) and percent weight of (AWAC). The mixture was degassed under vacuum and then poured and pressed into the preheated teflon moulds and cured at room temperature. Then the mould temperature was slowly raised to 120 °C and then the biocomposites samples were post cured at that temperature for 6 h to complete the polymerization of both phases.

2.4 Technical

Densities of blend biocomposites are measured using Mettler electronic balance, Toledo, Switzerland, model AG 204 with a weighing accuracy of ± 0.0001 g according to ASTM 792-86.

The tensile behaviors of (EP/PU) blend polymer and their composites were carried-out as per ASTM D 638 using 4302 model universal testing machine (UTM), H 50 KM, 50KN, Hounsfield, UK with an accuracy of ± 2 MPa. A minimum of five samples were tested at room temperature for each (EP/PU) based biocomposites and an average values are reported. The microprocessor controlled UTM machine is used with all the attachments for the measurement of tensile behavior of biocomposites. Hand operated durometer was used to measure the surface hardness of the prepared (EP/PU) and their biocomposites. There are two types of surface hardness tester. The relative hardness value scale lies in the range 0-100 shore A (for elastomers). Values of more than 90 shore A are however, considered unreliable and hence, beyond this range shore D (for plastics) tester is used. All calorimetric measurements were made by differential scanning calorimetry (DSC) Universal V4.3A (Q2000), TA Instrument, USA. This instrument has advanced Tzero, modulated DSC technologies and a reliable 50-position auto sampler. The DSC instrument consists of sample and reference pan with facilities for a controlled rate of heating/cooling temperature and a continuous heat-flow measuring arrangement. The test can be carried out at a temperature range from -180 to 725^{0}C with an accuracy of ± 0.01^{0}C. The thermal stability of all (PE/PU) and their composites were analyzed by using thermogravimetric analyzer (TGA) Universal V4.3A, TA Instrument, USA. The TGA instrument consists of an analytical balance supporting a platinum crucible for the specimen, the crucible situated in an electric furnace and a microprocessor controlled system. The kinetic data of blend (EP/PU) and its biocomposites were calculated by using Coats–Redfern [18] and Broido's[19] methods. Coats–Redfern (CR) [18] is respected as follows;

$$\log(-\log(1-\alpha)/T^2)=(\log(AR/\beta E_a))-(E_a/2.303RT) \quad (1)$$

where, T, α, β, A, R and Ea are the derivative peak temperature, the fraction of sample decomposed at time T, the heating rate, the frequency factor, gas constant and the activation energy, respectively. The slope of activation energy is obtained by plotting of $\log\{-\log(1-\alpha)/T^2\}$ versus 1/T. Broido's (BR)[19] method express as follows;

$$\text{Log}\,(-\log(1-\alpha)) = -\,(E_a/2.303R)\,((1/T)+K) \quad (2)$$

where, T, (1-α), E_a and R are the peak temperature of derivative curve of TG, the fraction of number of initial molecules not yet decomposed, the activation energy and the gas constant, respectively. The morphology of the (PE/PU) and its biocomposites were analyzed using scanning electron microscopy (SEM) on a JEOL equipment model JSM-5300 with 10 kV of voltage acceleration.

3. Results And Discussion

3.1. Physico-mechanical behavior

Densities of the prepared (EP/PU)/(AWAC) bio composites were measured according to ASTM D 792-86 (displacement) method and the obtained values are tabulated in Table 1. From the table it can be seen that, the density of (EP/PU) is 1.097 g/cc. and that of (EP/PU)/(AWAC) bio composites is 1.232 g/cc. Density of (EP/PU)/(AWAC) bio composites varied from 1.099 – 1.215 g/cc which lies in between their individuals. The (EP/PU) and

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(EP/PU)/(AWAC) bio composites are subjected to tensile test to understand the effect of (AWAC) in (EP/PU) matrix. The Young's modulus (E), elongation at break and tensile strength (σ) of the (EP/PU)/(AWAC) bio composites were obtained from their stress verses strain curves (Table 1). From the table it can be observed that the tensile strength and modulus of elasticity increased whereas, the elongation at break decreases with increase in (AWAC) content. The tensile strength of blend (EP/PU) is 73 MPa whereas, (EP/PU)/(AWAC) bio composites with 10 wt % (AWAC) content possess tensile strength of about 75.3 MPa. From the table, one can observe that the shore D hardness of (EP/PU)/(AWAC) bio composites increased with increase in (AWAC) content, and notched izo impact strength increased with increase in (AWAC) content. The notched izod impact strength increased to 63 J/m (at 10% AWAC content) from 62 J/m (for EP/PU). The ductility of the matrix plays a very important role in toughening at high shear rate fracturing (that is, notched izod impact strength). This is because of the hard particle of (AWAC) appeared to have higher strength and modulus properties [20].

Table 1. Physico –mechanical properties of (EP/PU)/(AWAC) bio composites

(EP/PU)/(AWAC)	Density (g/cc)	Hardness (Shore D)	Tensile strength (MPa)	Tensile Modulus (MPa)	Elongation at break (%)	Impact strength (J/m)
0	1.097	73	55.8	15.4	15	52
2.5	1.156	79	58.7	16.7	13	58
5	1.198	85	65.5	17.9	12	60
7.5	1.223	93	74.5	19.4	11	62
10	1.232	92	75.3	19.5	11	62

3.2. Swelling studies

The swelling behavior of biocomposites has been measured by exposing them to different organic solvents such as carbon tetrachloride, p-xylene, toluene, chlorobenzene diethyl ether, chloroform, ethylacetate, tetrahydrofuron, and water at room temperature till it reaches equilibrium. The measured percentage solvent uptake of biocomposites after immersing in the solvents for 4 days is given in Table 2. From the result it was noticed that (EP/PU) exhibits less swelling as compared to (EP/PU)/(AWAC) biocomposites. Furthermore, as the (AWAC) content increases, swelling resistance of biocomposites decreases. Biocomposites shows highest percentage uptake in polar, chlorinated solvents such as chlorobenzene. From the results it can also be noticed that, samples show least swelling in diethyl ether. The increasing order of degree of swelling is as follows; diethyl ether < ethylacetate < p-xylene < carbon tetrachloride < toluene < chlorobenzene. The samples exposed in chloroform and tetrahydrofuron were disintegrated into several pieces. It was also found that, the swelling of biocomposites increase by increasing contact of (AWAC).

Table 2. Swelling behavior of (EP/PU)/(AWAC) biocomposites in organic solvents

Solvents	Percentage solvent uptake				
	0	2.5	5	7.5	10
Carbon tetrachloride	45.0	65.5	70.5	85.5	120.5
P-xylene	35.5	55.4	65.6	75.7	78.8
Toluene	45.5	75.5	85.5	90.5	92.5
Chlorobenzene	92.5	110.8	120.5	145.6	145.8
Diethyl ether	18.5	25.5	35.8	45.7	49.5
Chloroform	*	*	*	*	*
Ethyl acetate	33.5	45.5	55.3	64.8	68.5
THF	*	*	*	*	*
Water	20	34	39	45	46

*disintegrated into several pieces

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3.3 Differential Scanning Calorimetry

The glass transition temperature (T_g) is one index of thermal resistance of a cured resin and can be obtained from the DSC measurement. Figure 1 shows the DSC temperature spectrum of all (EP/PU)/(AWAC) biocomposites. The T_g of (EP/PU) and (EP/PU)/(AWAC) is around 24 ˚C and 26 ˚C. It can be seen that the glass transition temperature of the (EP/PU)/(AWAC) significantly increased as increase in the amounts of (AWAC).

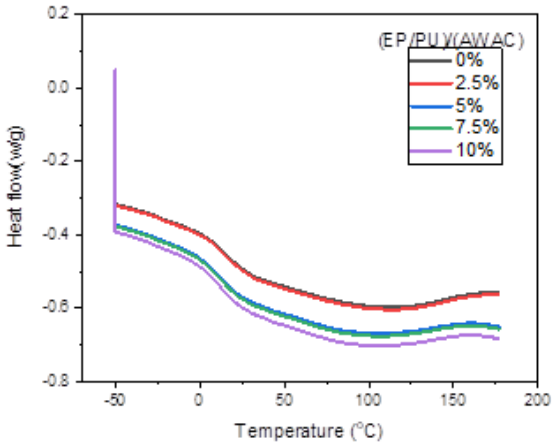


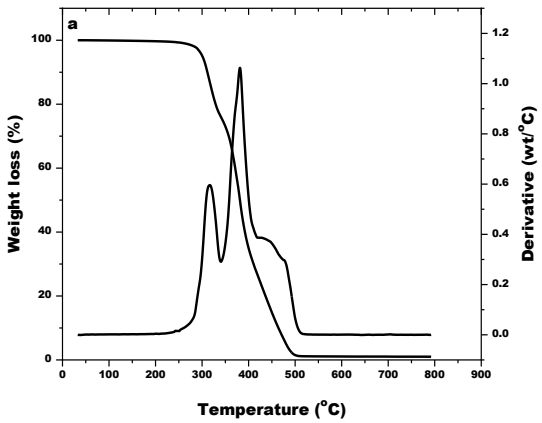
Fig. 1. DSC thermograms of (EP/PU)/(AWAC) biocomposites

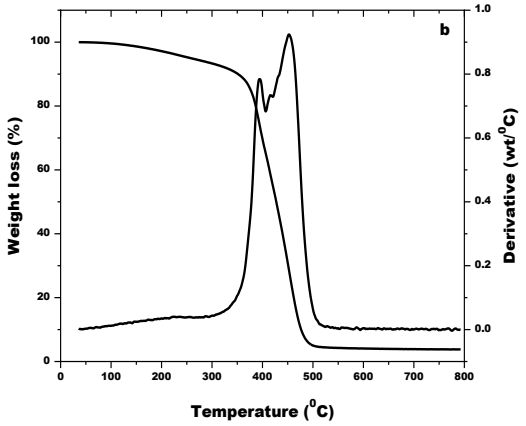
3.4 Thermo gravimetric analysis

The TGA thermograms of (EP/PU) and all (EP/PU)/AWAC) biocomposites are shown in Figures 2 (a) - (e) along with derivative thermograms. The different stages of thermal degradation were analyzed from the TGA thermograms and are given in Table 3. The effect of (AWAC) on thermal degradation process of (EP/PU) and all (EP/PU)/(AWAC) biocomposites are shown in Figure 3. From the figure it can be clearly observed that the weight loss markedly increased with increase in (AWAC) content. The ash content of (EP/PU)/(AWAC) biocomposites are slightly higher as compared to (EP/PU). From the TGA thermograms it can be noticed that, all the samples exhibit two step degradation processes.

From Figures 2 (a)-(e), a two steps thermal degradation processes for (EP/PU) and (EP/PU)/(AWAC) biocomposites was noticed. This can be attributed to the presence of both soft and hard segments. The first stage degradation occurs in the temperature range 318-399 ºC with the weight loss of 38 %. The weight loss in this step was due to soft segment of (EP/PU) and the main pyrolysis product may be carbon dioxide [21]. The second stage degradation occurred in the temperature range 339-517ºC with the major weight loss 59.2 %. This could be due to thermal decomposition of hard segment of (EP/PU). In this step weight loss may be due to liberation of HCN, nitriles of aromatic carbon and ethers. Pashaei et al [22] noticed a similar trend for the thermal degradation of PU obtained from TDI and different polyols. Ash content of (EP/PU)/(AWAC) biocomposites lies in the range 2.6-5.6 % (Table 4). All (EP/PU)/(AWAC) biocomposites also shows two steps degradation process (Figures 2 (b) – (e)). The first stage thermal degradation occurred in the temperature range 322-408 ºC with the weight loss of 37.5-39.2 %. The second stage thermal degradation process occurred in the temperature range 401-517 ºC with a weight loss of 55.7–59.2 %. This could be due to de-cross linking or unzipping and carbonization of biocomposites.

Some characteristics TGA data related to the temperature corresponding to weight loss of 0% (T_i), 10 % (T_{10}), 20 % (T_{20}), 30 % (T_{30}), 50 % (T_{50}), complete degradation (T_c) as well as oxidation index (OI) are tabulated in Table 4. Higher the values of T_{10}, T_{20}, T_{30}, T_{50} and T_c higher will be the thermal stability of the composites [23].





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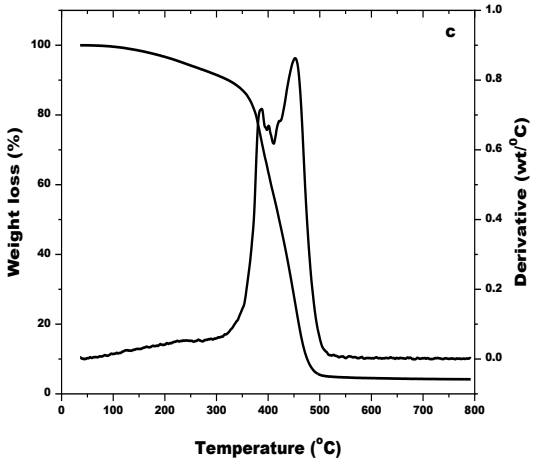

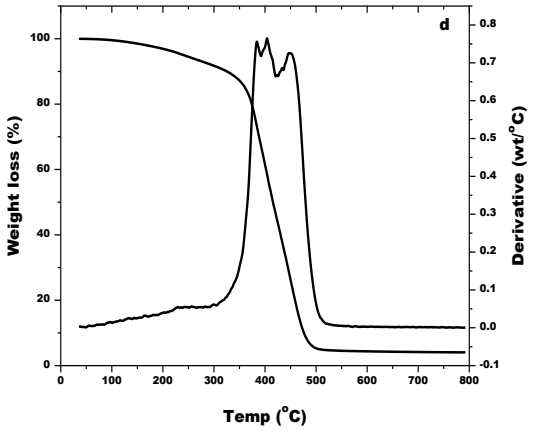

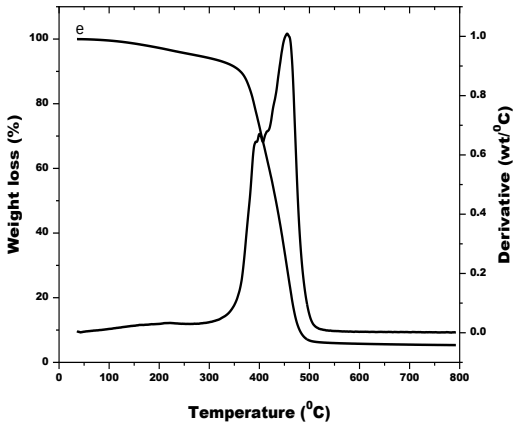

Fig.2. TGA thermograms of (a) 0%, (b) 2.5%, (c) %%, (d) 7.5% and (e) 10% of (AWAC) in biocomposites

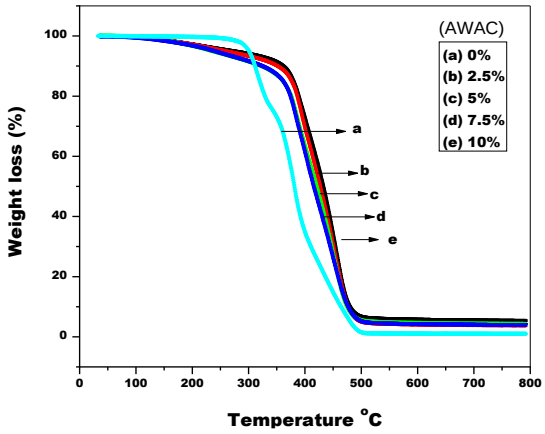

Fig. 3. TGA thermograms of all (EP/PU)/AWAC) biocomposites

Table 3. Thermal data obtained from TGA thermograms for (EP/PU)/AWAC) biocomposites

(AWAC) in (EP/PU)/(AWAC) (wt/wt, %)	Degradation stages	Temperature (°C) ± 2			Weight loss (%)
		T_i	T_{max}	T_f	
0%	1	318	387	399	38.2
	2	399	445	517	59.2
	Ash	-	-	-	2.6
2.5%	1	328	386	401	39.2
	2	401	445	512	57.0
	Ash	-	-	-	3.8
5%	1	319	368	403	37.5
	2	403	439	513	58.6
	Ash	-	-	-	3.9
7.5%	1	322	375	414	38.8
	2	414	446	515	58.7
	Ash	-	-	-	4.5
10%	1	325	378	413	38.7
	2	413	459	517	55.7
	Ash	-	-	-	5.6

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Temperature at 10%, 20%, 30%, 50% weight loss, degradation onset temperature (T_i) and complete degradation temperature (T_c) is summarized in Table 4. It has been observed that, with the addition of (AWAC) into (EP/PU) blend polymer reduces the onset temperature as well as temperature at 10, 20, 30 and 50% weight loss. However, (EP/PU)/(AWAC) biocomposites with 10 wt% (EP/PU) content system has retained the thermal behavior similar to blend polymer. From the table it was observed that the oxidation index increases with increase in (AWAC) content which reveals that the thermal stability of (EP/PU)/(AWAC) biocomposites increased with increase in (AWAC) content. This is due to thermal stability of (EP/PU) is low as compared to (EP/PU)/(AWAC) biocomposites.

Table 4. Transition temperature data obtained from TGA curves for (EP/PU)/(AWAC) biocomposites

(AWAC) in (EP/PU) (wt/wt, %)	Temperature at different weight loss (°C) ± 2						
	T_i	T_{10}	T_{20}	T_{30}	T_{50}	T_c	OI
0%	318	346	392	401	417	517	0.45
2.5%	328	347	395	401	427	512	0.66
5%	319	348	395	408	425	513	0.68
7.5%	322	352	398	409	428	515	0.78
10%	325	353	398	411	433	517	0.97

3.5. Kinetic Analysis of thermal degradation process

The thermal degradation kinetic parameters were determined for (EP/PU)/(AWAC) bio composites using Broido (BR) [19], and Coats Redfern (CR) [18] methods which provide overall kinetic data. For the sake of calculations and to know the nature of the decomposition, the complete thermogram was divided into distinct sections according to their degradation processes.

The plots of $\ln[-\ln(1-\alpha)]$ versus 1/T (BR) and $\ln[-\ln(1-\alpha)]/T^2]$ versus 1/T (CR) for first stage degradation process of (AWAC) filled (EP/PU)/(AWAC) biocomposites are shown in Figures 4 -5 respectively. The linear plot with concurrency value (R^2) closer to one was chosen for all methods. The activation energy (E_a) was calculated by regression analysis and the results are tabulated in Table 5 to understand the mechanism of thermal degradation. From the table it can be noticed that, as the (AWAC) content increases the activation energy increased in the first stage degradation process whereas, in the second stage the activation energy increased with increase in (AWAC) content. The activation energy calculated by, Coats-Redfern and Broido methods are comparable.

Table 5. Activation energies calculated by HR, CR and BR methods with respective concurrency value (R^2) for (EP/PU)/AWAC) biocomposites

(AWAC) in (EP/PU) (wt/wt, %)	Degradation stage	Activation energy (E_a) (kJ/mol)			
		CR	R^2	BR	R^2
+0	I	180	0.9798	175	0.9925
	II	216	0.9858	204	0.9853
2.5	I	185	0.9725	170	0.9795
	II	235	0.9928	240	0.9935
5	I	190	0.9898	175	0.9996
	II	240	0.9898	244	0.9895
7.5	I	185	0.9980	178	0.9898
	II	235	0.9696	270	0.9695
10	I	189	0.9954	180	0.9890
	II	217	0.9935	225	0.9968

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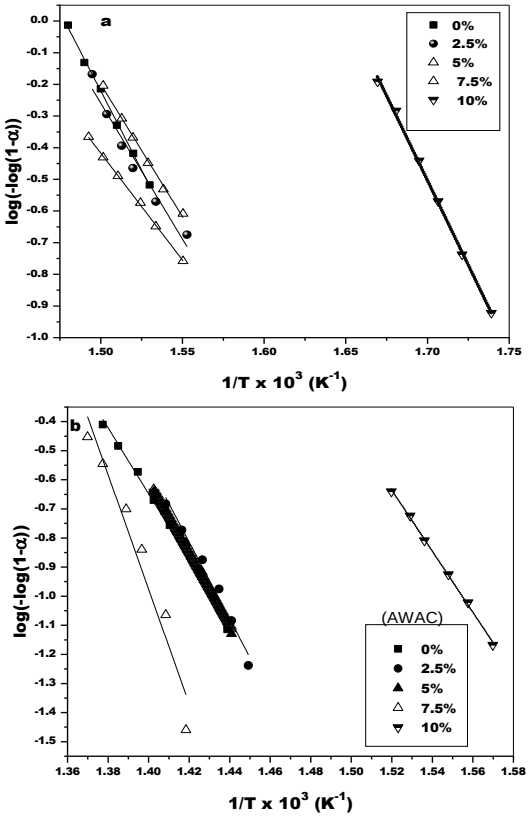

Fig.4. Broido plots for the determination of activation energies for, (a) first step and (b) second step thermal degradation process of (EP/PU)/(AWAC) biocomposites

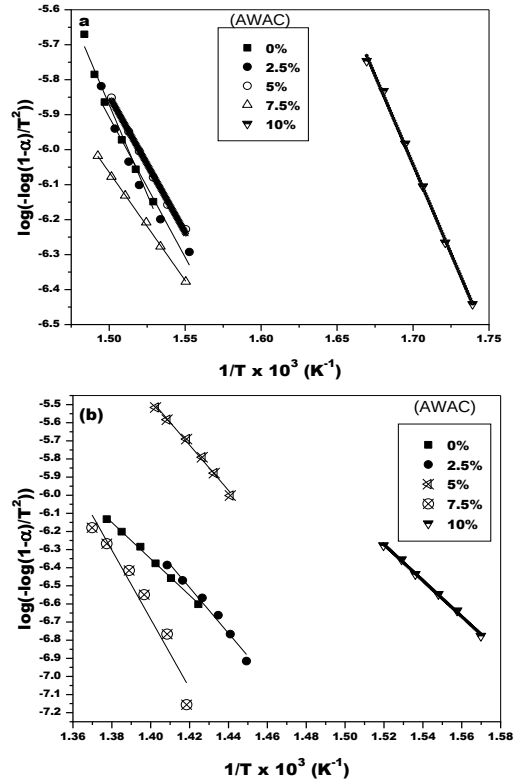

Fig.5. Plots of log[-log (1-α)/T^2] verses 1/T for, (a) first step and (b) second step thermal degradation process of (EP/PU)/(AWAC) biocomposites

3.6. Morphology

SEM has several potential advantages in morphological investigation and has been extensively used in the field of polymer, biomaterial and composite. The toughening mechanism can be explained in terms of morphological behavior. This is because the morphological examination can give interesting information on the microstructure of biocomposites. The SEM of the fractured surface of (EP/PU) and its biocomposites are shown in Figures 6 (a) - (d). The SEM photomicrographs revealed the layer like morphology for (EP/PU). A slight microphase separation is generally in (EP/PU)/(AWAC) is due to polar interaction between (EP/PU), and (AWAC). The images of SEM reveal the formation of domain phase and the layer like structure for (EP/PU). This is because biocomposites have made by three components. In the biocomposites, the polymeric chains are interaction with (AWAC). The phase segregation observed is more predominant in (EP/PU)/(AWAC) systems. scanning electron microscopy confirms better dispersion of the activated carbons in the (EP/PU) matrix at 5 % apple waste activated carbon. Figure 7 also illustrates how methylene blue adsorption occurred at 5-hour intervals for 5% of (EP/PU)/(AWAC) biocomposites.

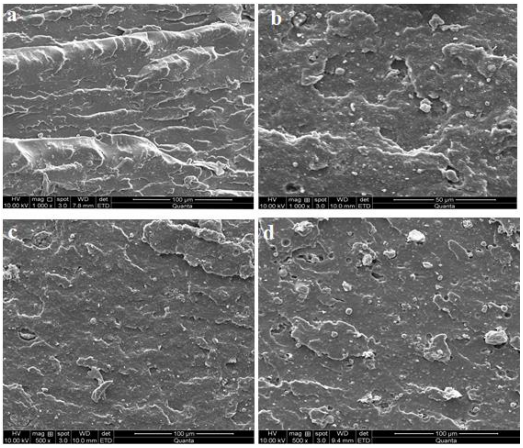

Fig. 6. SEM Photomicrographs of; (a) 0, (b) 2.5, (c) 5 and (d) 10 wt% AWAC Loaded biocomposites

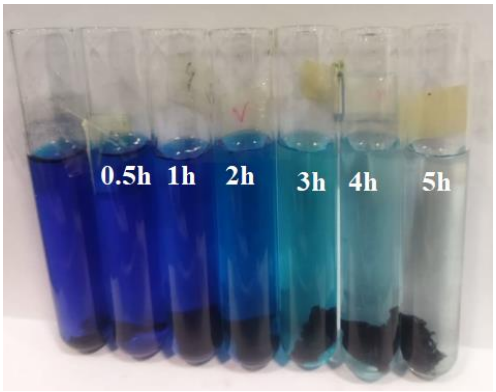

Fig. 7. The images show MB solutions approaching equilibrium at 1-h intervals 1-5 hours.

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Conclusions

(EP/PU)/(AWAC) biocomposites were synthesized with 0, 2.5%, 5%, 7.5 and 10 wt % (AWAC) content. All of the biocomposites exhibit a two-phase structure. Prepared biocomposites were characterized for their mechanical, thermal, and morphological behaviors. From the tensile behavior it was noticed that, tensile strength and modulus were

increased whereas, elongation at break and surface hardness were increased as increase in (AWAC) content. Remarkable increase in impact strength of biocomposites was observed after incorporation of (AWAC) content into (EP/PU). From DSC studies it was found that the T_g of (EP/PU) and its composites were around 24 ˚C and 26 ˚C respectively. As (AWAC) content increases the T_g of biocomposites slightly. From TGA studies it was noticed that, biocomposites having high (AWAC) content exhibit high thermal stability as compared to (EP/PU). The activation energy (E_a) calculated by regression analysis lies in the range 180 – 190 and 170 – 180 kJ/mol for Coats-Redfern and Broido method respectively. The SEM images reveal that, the formation of domain phase and the layer like structure for biocomposites and phase segregation is more predominant in 10% of (EP/PU)/(AWAC) biocomposites. The as-prepared (EP/PU)/(AWAC) bio-adsorbent removes the cationic dyes from the waste water.

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بررسی رفتار گرمایی و فیزیکی-مکانیکی بیو کامپوزیت‌های (اپوکسی/ پلی‌اورتان)/ کربن فعال شده از ضایعات سیب برای حذف متیلن بلو از فاضلاب

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چکیده

یک سری بیو کامپوزیت های (اپوکسی/پلی اورتان)/کربن فعال شده از ضایعات سیب با در صد کسرهای وزنی مختلف ۷،۵،۲.۵،۰ و ۱۰ از کربن فعال شده از ضایعات سیب سنتز شدند. وخواص فیریکی-مکانیکی و مقاومت شیمیایی بیو کامپوزیت های تهیه شده رامورد بررسی قرار دادند و بیو کامپوزیت های تهیه شده را بوسیله انالیز گرما وزن سنجی، دمانگاشت پویشی و میکروسکوپ الکترون پویشی برای نشان دادن اثر و حضور کربن فعال شده از ضایعات سیب را روی خواص جاذب حاصل شده را مشخص یابی و بررسی نمودند. خواص تخریب حرارتی بیو کامپوزیت ها را بااستفاده از آنالیز گرماوزن سنجی بررسی قراردادند . این نتایج نشان می دهد با افزایش مقدارکربن فعال شده از ضایعات سیب، جذب (اپوکسی/پلی اورتان)/کربن فعال شده از ضایعات سیب افزایش می یابد. بیو کامپوزیت های توسعه یافته از مواد ضایعات سیب کاهش هزینه تولید را برای کاربر های بالقوه از جمله مواد عایق پذیر را بهبود می دهد. وهمچنین (اپوکسی/پلی اورتان)/کربن فعال شده از ضایعات سیب تهیه شده بیو جاذب، رنگ های کاتیونی را از فاضلاب جذب می کند.

کلید واژه‌ها

(اپوکسی/پلی اورتان)؛ کربن فعال شده از ضایعات سیب؛ بیوکامپوزیت؛ رفتار گرمایی؛ متیلن بلو.

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