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Investigations of Thermal Conductivity for Palm Fronds and Egg Shell Filled Epoxy Composites

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ABSTRACT

Thermal conductivity has been improved by using epoxy reinforcement techniques extensively. Thus, combining natural materials (egg shell particles and palm fronds) to epoxy is the focus of this work's reinforcement. Different percentages of particles (4, 6, 8 and 10%) were used the effect of adding egg shell (ES) and palm fronds (PF) particles to the epoxy resin has been studied during thermal conductivity tests under natural conditions and immersion in an acid solution (HCl) for a period of (14 days) with normality (0.3 N). Thermal conductivity test results under natural conditions (N.C) showed that epoxy reinforced with palm fronds particles (EP/PF) increased with increasing weight percent (wt%), but thermal conductivity values (K) for egg shells particles (EP/ES) decreased with increasing weight percentage, while immersion in acidic solution (HCl) exceeds the (K) values after immersion more than the value in (N.C).

1. INTRODUCTION

Thin composite materials fall into the class of cutting-edge materials that arose at the close of the 20th century and proliferated in numerous industrial domains to address every issue we encounter [1]. Composite materials are starting to be a source of interest for manufacturers and investors. Its perfect qualities—high strength and stiffness, low cost, and low weight—have led to a growth in its employment in a variety of technological applications [2]. Due to the general requirements, the need to use composite materials that have extremely high mechanical characteristics has become common. A number of variables influence the characteristics of the composite, such as the distribution and size of the reinforcement particles within the substrate, the type of bond that holds the particles supported by the substrate together, and the interface area [3]. The last ten years have witnessed notable advancements in green technology due to worries about the environment and sustainability, especially in the field of materials science with the development of biocomposites. The creation of biocomposites from agricultural leftovers (such as egg shell and palm frond) is currently drawing interest among the potential substitutes, such as wood and plastics [4, 5]. It produces a lot of fiber and agricultural particles, and most of the agricultural residues are turned into fuel. More than 400 million tons of agricultural waste, including bagasse, corn cobs, peanut shells, and other wastes, are produced in India [6, 7]. Because it is readily available, agricultural waste makes an ideal potential trash alternative to plastic products. Utilizing agricultural wastes is beneficial for the economy, environment, and technology due to its low density, low manufacturing energy requirement, low CO_2 emission, and high degree of biodegradability when compared to thermoplastic, in addition to its quantity and capacity for renewal, polymeric materials strengthened with inorganic fillers [8, 9]. Researchers are using natural materials as reinforcement in composites because of the growing need for reasonably priced materials with a good strength to weight ratio. Natural materials, which are derived from plants and are called lignocelluloses in nature because they are made of lignin, cellulose, hemicelluloses, and ash, are a popular choice for use in structural applications these days.

Raju et al. [6] studied the tensile strength, impact strength and water absorption of epoxy resin filled with different sizes of peanut shell particles (0.5, 1, 2, 3 mm) with a volume fraction of (30 to 40%). The results of this research showed that the specimens (filled with peanut shell +30%), 0.5 particle size provided maximum tensile strength, impact resistance, with minimum water absorption [10]. Olaitan et al. [11] studied the tensile strength, flexural strength, impact strength and hardness of a 2.5% and 5% filled epoxy resin sample. 7.5%, 10%, 12.5% and 15% by weight of rice husk and peanut husk fractions. The results showed that the samples reinforced with peanut shell have higher tensile strength, flexural strength, impact strength and higher toughness than the samples reinforced with rice husk.

Daniel-Mkpume et al. [12] studied the effect of cylindrical luffa fibers and particles on the mechanical properties of epoxy resin. Luffa cylindrical fibers treated with 8% ((NaOH), with weight fractions 2%, 4% and 6%) were used to reinforce the epoxy resin. The manual molding method was used. The results showed that the addition of luffa cylindrical fibers and particles improves the mechanical properties of epoxy resin.

Haitham and Mohammed [13], by studying the effect of different weight fractions (4%, 8%, 12%, 16%) of eggshell particles reinforced with epoxy resin on D beach, tensile strength, impact strength, and flexural strength, and water absorption. The results indicated that samples containing 16 wt% of eggshell particles filled with epoxy resin had the highest value for shore hardness D, tensile and impact strength and flexural strength, while the same weight percentage of 16% showed a lower value for water absorption.

In the study of Fadhila [14], where the researcher compared the characteristics of the flexural test and the impact energy of the peanut shell reinforced with an epoxy resin matrix. Peanut shells are added to the matrix of epoxy resin with different weight fractions (2%, 4%, 6%, 8%). Where samples of the highest bending resistance and modulus (reinforced by 4% weight of peanut shell) were obtained, while the samples provided (Reinforced + 8% peanut shell weight) Higher impact resistance and fracture toughness.

In the study of Reddy et al. [15], an attempt was made to develop epoxy composites made of jute fibers filled with pomegranate powder. Hydrogenated pomegranate peel was used and used as a filler to prepare the compound. The hybrid composites were prepared by reinforcing jute fibers with a constant 20 wt% and filling the characteristic wt% pomegranate peel powder (2, 4, 6, 8). Mechanical properties such as impact, flexural, and tensile strength studies were performed. There was improvement in impact, flexural, and tensile strength when pomegranate peel powder filler was added to 6 wt%, But then by weight, agglomeration occurred, which led to a reduction in that mechanical loss properties.

Bargas [16] studied the possibility of using agricultural material waste (waste of pistachio shells) to strengthen each of the polymethyl methacrylate resins (PMMA) and unsaturated polyester resins (UPS) separately. Use and weigh fractions (0, 5, 10, 15, 20, 25, 30) of pistachio shells. The results of the study showed that there was a clear improvement in some mechanical properties such as (tensile, bending, hardness and shock) with increasing the weight fracture. While the study showed that the compression test was the opposite in the two groups, where there was a decrease with each increase in the weight fractures. The results of the physical tests showed the presence of Gradual decrease in (thermal conductivity) values with increasing gravimetric fraction.

The aim of the study is to characterize and compare thermal conductivity and their impact after immersion in acid (HCl) palm fronds & egg shells from agricultural products reinforced on epoxy resin composites for Manufacturing of composite polymers for obtain heat insulating material use in buildings and electrical devices.

Thermal conductivity (K) is one of heat transfer phenomena, where energy is transferred from one place to another due to temperature difference (the oscillation of particles of a substance), we can therefore define the thermal conductivity of a substance as a measure of a substance's ability to conduct heat and is usually expressed by the coefficient of thermal conductivity (K).

Thermal energy is transmitted through the material by different mechanisms, depending on the nature of the material, whether conductive or insulating, and on the movement of the molecules. In conductive solids, heat is transmitted through the material with free electrons in the crystal. In the case of insulating materials, there are no free electrons, therefore the heat is transmitted by a different mechanism, which is by elastic waves (elastic waves) resulting from the oscillations of the molecules, since these oscillations are transmitted to neighboring molecules. Due to its association with bonds, heat is transferred from the hot end to the cold end in the form of flexible quantum waves called phonons, and the phenomenon of heat conduction is subject to Fourier's law of conductivity thermal and is explained in the following relationship [17].

$$Q = -K A \frac{dT}{dx} \quad (1)$$

These two formulas can be used to determine the thermal conductivity [18].

$$K (T_B - T_A) / d_s = e [T_A + 2 /r (d_A + l / 4d_s) T_A + l / 2r\, ds\, T_B] \quad (2)$$

(e) which represents the value of thermal energy transferred per unit area of disk per second (W/m^2 K) is calculated from the following Eq. (3):

$$IV = \pi\, r2e (T_A+T_B) +2\, \pi\, re [\, d_A T_A + d_S\, l / 2(T_A+T_B) + d_B T_B + d_C T_C] \quad (3)$$

where, (T_A, T_B, and T_C) represent the temperatures of the three disks (A, B, and C), respectively.

I: current(amps), r: disc radius (cm), d: thickness of disc (cm) V: voltage (volts).

Place the sample between the two discs (A, B) and pass the electrical energy on the circuit and leave it until the temperature of the two discs (A, B) reaches a state of thermal equilibrium, then the values (T_A, T_B, T_C) are recorded. And let it (the discs) cool down gradually for a period of (40 minutes) and the experiment was repeated for all discs, as shown in Figure 1.

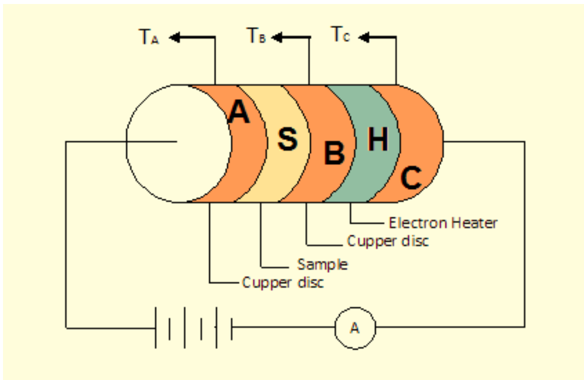


Figure 1. The electrical circuit used in the heat conduction device

2. EXPERIMENTAL PART

2.1 Materials

Epoxy resin (Polyprime EP from Hankl business), which has a low viscosity and a density of 1.03 g/cm^3, is used as a matrix in the fabrication of composite products. The particle base and epoxy resin in liquid state are easy to mix, as it has high chemical resistance, high adhesion properties and low creep rate. Polymerization and solidification can occur by adding a solid of the same type of resin as the hardener which is a light, low viscosity, low density, transparent amber liquid. Resin hardeners have a long life (1:2). The time is 48 hours at room temperature, 2 weeks left to complete the curing (Full Curing) then the samples are cut according to the model used for evidence search. The following statement of the epoxy resin shown in Figure 2, and the chemical statement of Epoxy resin preparation is show in Figure 3.

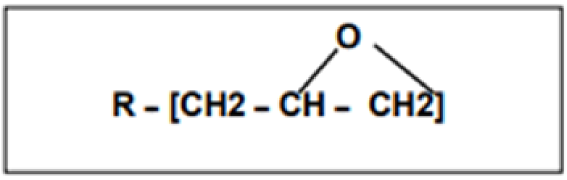


Figure 2. The chemical statement of epoxy resin preparation

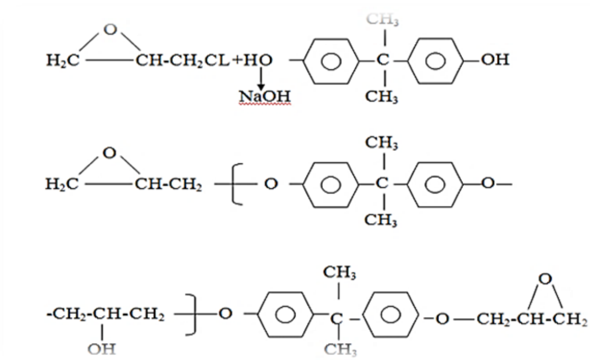


Figure 3. The chemical equation for the preparation of epoxy resin [19]

2.2 Reinforcement material

In this work two types of particles were used (ES and PF). The reinforcing materials were cleaned, exposed to the sun, and then ground in a high-quality technical way to obtain particles with a particle size of approximately (40-50 microns) with weight ratios of (0.04, 0.06, 0.08, 0.1%). A vibrating sieve was used to obtain the appropriate particle size for the materials used.

2.2.1 Palm fronds

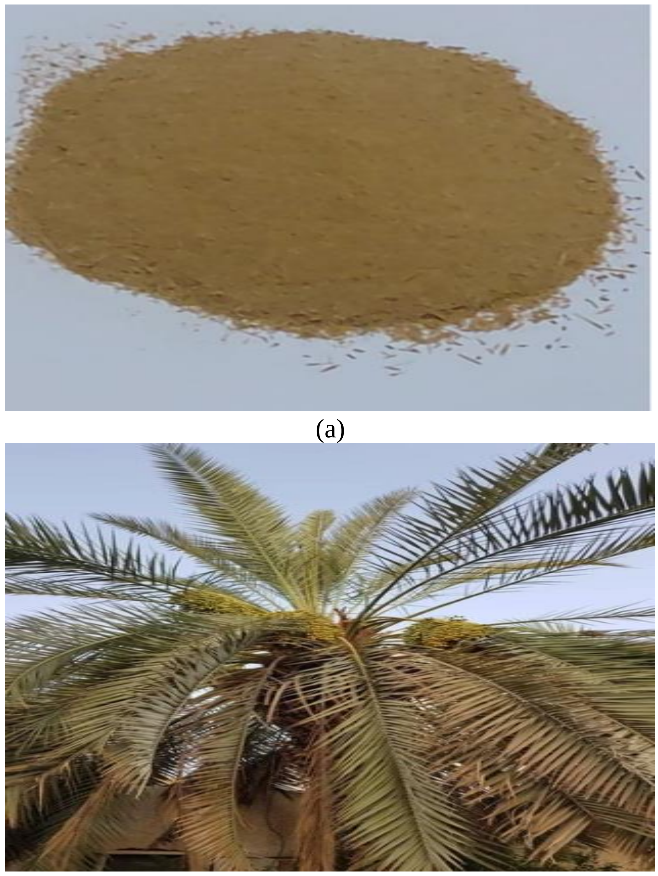
The date palm tree, which belongs to the phoenix Dactylifera family of palm trees, is typically found in California, the Canary Islands, Northern Africa, India, and Pakistan in addition to our own country, Iraq. Over 16 million date palms grow in Iraq. Every year, it generates about 630,000 tons of date palm leftovers [20]. Table 1 lists the chemical components of the various date palm tree frond sections [21].

The palm fronds used as fillers were obtained from the date palm tree from the annual pruning of the date palm Figure 4 (a) (Al-Khastawi variety, Iraq) and its grains size was (40) µm. As shown in Figure 4 (b).

Palm fronds after being exposed to air for three months to attain a moisture content that was balanced, pruning residues were pulverized with a shredder and a small laboratory mill. The resulting particles were then sieved through a 40 µm screen and preserved on a cloth. After being oven-dried for 24 hours at 100 ± 5°C to repel moisture, they are stored in airtight plastic bags before being installed.

Table 1. Chemical constituents of the different parts of date pam tree fronds

	Cellulose	Hemicelluloses	Lignin	Ash	Extractive
Leaflet	40.21	12.8	32.2	10.54	4.25
Rachis	38.26	28.17	22.53	5.96	5.08



(a)

(b)

Figure 4. (a) Date palm tree (Al-Khastawi variety); (b) Palm fronds powder

2.2.2 Egg shell

The tough outer coating of an egg, known as the chicken egg shell (ES), comes in brown or white hues. A chicken egg's composition by weight is composed of 60% albumen, a white substance, 30% yolk, a yellow substance, and 10%-11% shell, which includes the egg shells and membrane. It was claimed that an egg weighs between 60.0 and 60.2 g overall, and that an empty shell weighs between 6.6 and 7.3 g. The shell contains a small amount of organic materials, estimated to be between 3 and 4.5 weight percent. Several investigations have found that the density of the ES with membrane ranges from 2.50 to 2.62 g/cm^3. It was stated that the membrane's density was roughly 1.36 g/cm^3. With trace amounts of other elements like magnesium and phosphorus and 3-4% organic content, the primary constituent of ES's chemical makeup is $CaCO_3$ in the form of calcite, which ranges from 94 to 98 weight percent. Table 2 provides an overview of some of the reported $CaCO_3$

contents. The inner membrane contamination and the meal that the chicken ingested can affect the composition of ES. Research indicates that brown ES contains 96-97 weight percent $CaCO_3$ and 3-4% organic matter, whereas white ES had 94 weight percent $CaCO_3$ and 6 weight percent organic matter. Based on published research, the $CaCO_3$ content of brown and white ES was deemed to be equal [22].

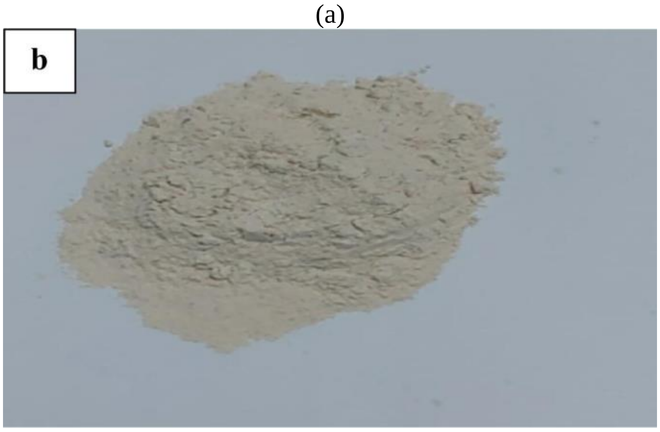
Table 2. Eggshell composition of $CaCO_3$

$CaCO_3$ Content (wt%)	Eggshell Density (g/cm^3)	References
94.00	2.53	[23]
96.41	2.59	[24]
97.30	2.62	[25]
97.80	2.50	[26]

The eggshells used as fillers were obtained from the eggs of chickens available in the social environment in which I live Figure 5 (a) shows the eggshells used. They are oven-dried at 100°C for an hour to repel moisture.

It is then ground using a grinding machine dedicated to grinding solids, followed by passing through a 50-micron sieve. Figure 5 (b) shows eggshell powder with a grains size of (50 µm) microns. Then they are placed in sealed plastic bags to keep them from moisture.

(a)



(b)

Figure 5. (a) As-received eggshells; (b) Eggshell powder

2.3 Preparation of samples

The following procedures are included in the Hand Lay-up approach, which is illustrated in Figure 6, and it was utilized to prepare the samples.

The method used to prepare the samples is the Hand lay-up method.

Step 1: Prepare the mold. The mold used in the casting process is the base of each pane of glass covered with a thermo paper mould (to prevent sticking of the resin to the pane and to enable easy machining by cutting) with a high degree of equator sealed sheets (ensuring a balance of stability by means of a flat surface) the sides of the mold by the pane of glass thick (4 mm).

Step 2: Assembling the specimen. The following steps comprise the main process for sample preparation and casting, as illustrated in Figure 7: the weighted quantity of the additives (PF and ES) micro in (4%, 6%, 8%, 10%) by weight fraction, a mixture of additives and matrix at room temperature, and the weighted amount of epoxy and hardener added in the required ratio (1:2). Blend for a maximum of ten minutes in a designated bowl.

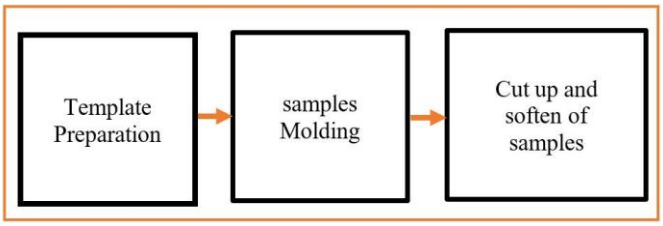


Figure 6. Samples preparation

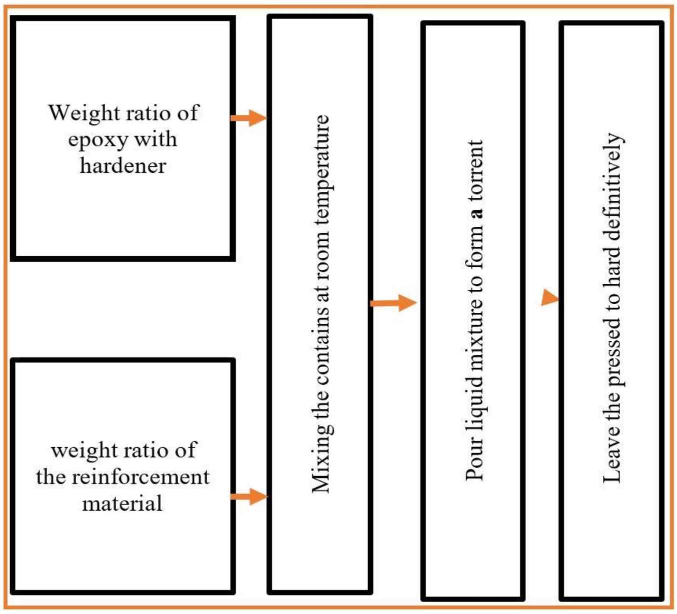
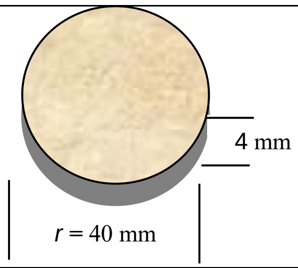


Figure 7. Modeling of samples

Table 3. Standard dimensions for thermal conductivity according to ASTM

Standard Specifications	Standard Dimensions for Test Samples	Test
Lees' Disk	 4 mm; r = 40 mm	Thermal conductivity

Pour the liquid mixture to form a flow in the middle of the mold so that the flow occurs in all areas of the mold continuously and set the mold to fill to the desired level. It takes (48) hours to cure, then bake at 50°C for 5 hours to complete formability

Step 3: Cut specimens in diameter according to ASTM schedule 5 specimen for smooth plate refining (silicon carburetors) and different grades of fineness. As shown in Table 3.

3. THERMAL CONDUCTIVITY

Here are two basic systems for determining the thermal conductivity (K) of materials:

1-Searl method: It is used to calculate the value (K) for samples of materials with good thermal conductivity such as copper (prepared in the form of rods) and whose measurement principle is an application of Fourier's law which is illustrated in relation (1).

2-Lee's disk method: It is used to measure the value (K) of materials with low thermal conductivity prepared in the shape of a circular disk, as shown in Figure 1.

The values of (K) for polymers are between (0.15 and 0.45) w/ (m.k), while for metals they are above (100 w/ (m.k)).

After activating the electrical source with a voltage of (6.3 volts), and the current in the electrical circuit is approximately (0.23 A), After the discs have reached thermal equilibrium, which takes roughly 90 minutes, the temperatures of the discs are measured.

Eqs. (1) and (2) are used to calculate thermal conductivity values.

4. RESAULTS AND DISCUTION

Thermal conductivity is the passage of energy from one place to another due to the irritation of the atoms or molecules of the material as a result of the change in temperature. The tested samples' thermal conductivity is determined using the Lee's disc apparatus.

Eqs. (1) and (2) are used to calculate the thermal conductivity values of the samples, both in their native state and after a 14-day immersion in an acidic normalcy solution (0.3N).

From Figure 8, the composite material's thermal conductivity values drop as the weight percentage of egg shell particles (ES) in (NC) increases, while increase the thermal conductivity values with an increase in the weight percentage of palm fronds (PF).

This was characterized by a gradual decrease in thermal conductivity, and it was the lowest value at the weight ratio (0.1) and amounted to (0.2363) for egg shell (ES). While the lowest value was for palm fronds (PF) at the weight ratio (0.1), which was (0.6053). This decrease is due to the fact that the thermal conductivity of the composite material is affected by the interface between the substrate and the supporting material and the irregular structure of the base material, which consists of heat-insulating polymer materials with low thermal conductivity in the heterogeneous random structure. This results in a random dispersion of thermal energy as it is transmitted through the random structure of the polymer composite. Besides, there are also randomly dispersed particles in the structure of the core material, which in turn leads to the random diffusion of thermal energy as it travels through the random structure of the polymeric composite material, which leads to a decrease in the thermal conductivity of the composite. This agrees with the study [27].

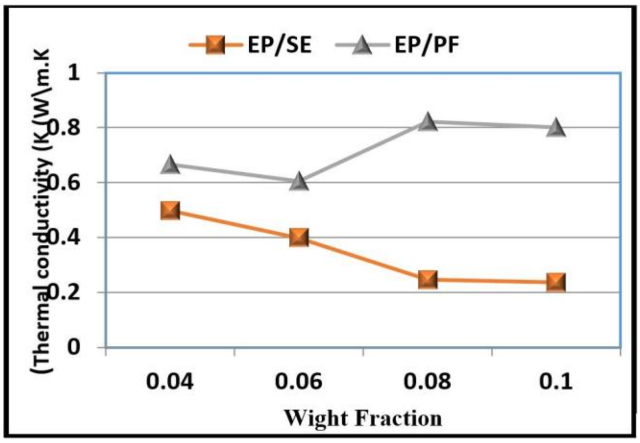


Figure 8. Thermal conductivity value at natural condition (N.C) with weight fraction for (EP/PF & EP/ES) composites

Figure 9 shows the relationship of thermal conductivity with the percentage weight of (EP/PF & EP / ES) compounds after immersion in HCl We noticed that the values of thermal conductivity (K) in the case of immersion in the acidic solution (HCl) are greater than the values in natural condition (C.N). because acidic solution (HCl)enter through the interface and there are already cracks in the material,, acting in weak and strong molecular bond of the matrix and the relaxation bonds lead to an increase in the plasticity of the matrix where it occurs heat transfer by rotational motion and vibrations of molecular chains, Moreover, because bond relaxants increased the extensibility of molecular chains upon movement as well as the reaction of chemical solutions to decompose materials, raising thermal conductivity. This agrees with the study [28].

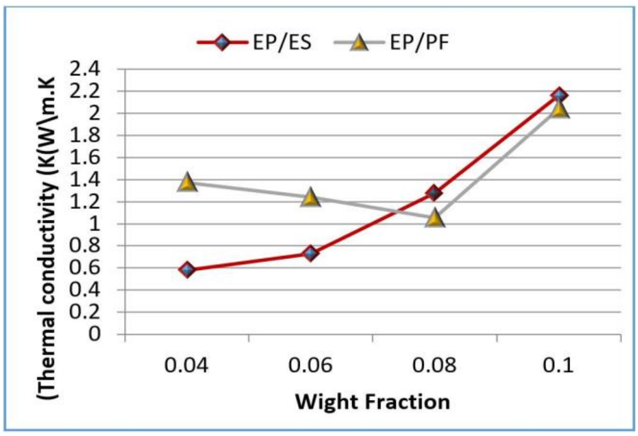


Figure 9. Thermal conductivity relation with weight Fraction for (EP/PF & EP/ES) composites in HCl

The field emission scanning electron microscopy (FESEM) carried out to investigate the morphology nature of the prepared composite materials. The field emission scanning electron microscopy type (Thermoscientific Quattro S) used to exam the prepared samples. Figure 10 shows the FESEM morphology images captured from the samples surface of treated and untreated composites materials with hydrochloric acid (HCl). The obtained FESEM images demonstrated that the samples surfaces consist of two overlapping areas; smooth and rough areas, where the smooth area attributed to the epoxy matrix and the rough area due to the added powders (ES powder, PF powder) respectively [29-31]. From Figure 10 revealed that there is no obvious effect on the surface of samples after the hydrochloric acid treatment, when comparing between the FESEM images (a and b) (c and d) of untreated and treated (Ep/ES & Ep/PF) samples observed that there is no noticeable difference on the surfaces.

The FESEM images proved that as a good homogenous distribution of the added (ES powder, PF powder) which attributed to good mixing process of the composite materials components, as a result of well-designed processing parameters [32]. As shown in Figure 10.

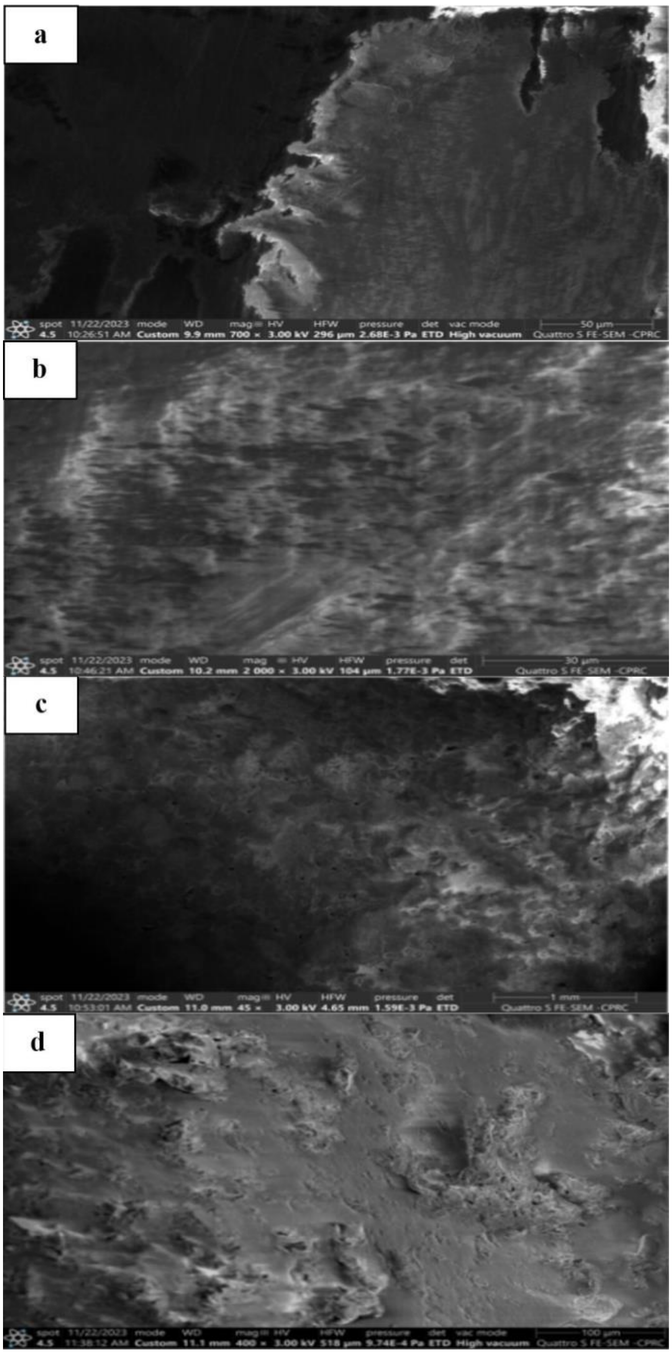
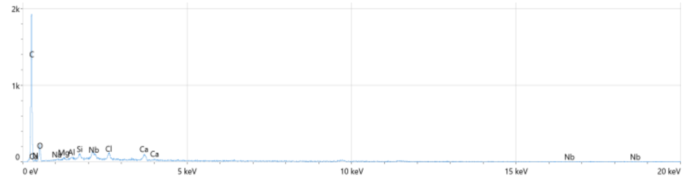
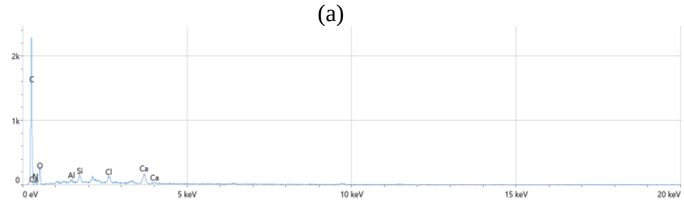


Figure 10. FESEM morphology images of prepared composites, (a) untreated Ep/ES; (b) treated Ep/ES with HCl; (c) untreated Ep/PF; (d) treated Ep/PF with HCl

Figure 11(a) Ep/PF and Figure 11 (b) Ep/ES show the EDX spectra including the elements peaks of (EP/PF and EP/ES) composites, the ratios of the chemical compositions for prepared composite materials were presented in Tables 4 and 5. From the EDX results, demonstrated that there are many metals within the structure of epoxy composites. The main detected elements are carbon, nitrogen and oxygen, which are attributed to the epoxy matrix, while other metallic elements detected within the epoxy composite's structure depend on each filler's component [33].



(a)



(b)

Figure 11. EDX spectra of (a)EP/PF and (b) EP/ES composite material

Table 4. Element ratios of prepared (Ep/EF) composites

Element	Atomic %	Atomic % Error	Weight %	Weight % Error
C	60.2	0.3	53.0	0.3
N	13.4	1.7	13.8	1.8
O	24.5	0.7	28.7	0.8
Na	0.2	0.0	0.4	0.1
Mg	0.2	0.0	0.4	0.0
Al	0.2	0.0	0.3	0.0
Si	0.4	0.0	0.8	0.0
Cl	0.4	0.0	1.0	0.0
Ca	0.4	0.0	1.2	0.0
Nb	0.1	0.0	0.4	0.0

Table 5. Element ratios of prepared (Ep/ES) composites

Element	Atomic %	Atomic % Error	Weight %	Weight % Error
C	51.6	0.4	44.8	0.3
N	22.0	2.2	22.3	2.2
O	24.7	0.7	28.6	0.8
Al	0.2	0.0	0.4	0.0
Si	0.5	0.0	1.0	0.0
Cl	0.4	0.0	1.0	0.0
Ca	0.6	0.0	1.7	0.0

5. CONCLUSIONS

Based on the experimental findings reported in this work, a material to use in thermal electrical appliances and homes and buildings was manufacturing as a thermal insulator. (EP/ES) was the optimal thermal conductivity value.

Decrease in the thermal conductivity values of the composite material with an increase in the weight fraction of particles of egg shell While increase the thermal conductivity values(K) with an increase in the weight percentage of palm fronds (PF) in (N.C). The composite showed (EP/ES) the best thermal conductivity value in weight percent (0.1) was (0.2363W/m.k) and the lowest value was (0.6053W/m.k) in weight percent (0.06) for (EP/PF). Whereas after immersion in chemical solution (HCl), the thermal conductivity values(K) increase with an increase in the weight percentage for egg shell (ES). While decrease in the thermal conductivity values of the composite material with an increase in the weight fraction of palm fronds (PF).

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