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Preparing Composite Materials Based on Unsaturated Polyester with Natural Materials of Plant Origin and Studying Some of Their Mechanical and Physical Properties

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Abstract
The process of burning solid waste causes a serious environmental problem, leading to air and water pollution. Therefore, these agricultural wastes are added as reinforcing materials to polymers through which some mechanical and physical properties can be improved. This study included the preparation of single and hybrid polymeric composite materials from polyester resin as a base material. Powders of both sawdust and sunflower seeds were used as reinforcement materials with different weight fractions (5,10,15)% and a granule size of 75µm. Some mechanical properties were studied, including bending strength testing, bending elastic modulus, impact strength, and surface hardness testing, in addition to thermal conductivity. The obtained results showed an amelioration in some mechanical characteristics in varying proportions for both the bending test and the bending elastic modulus. As for the impact test and surface hardness, there is an increase in their values compared to their value for the pure polyester material. As for the thermal conductivity test, both single and hybrid composite materials exhibit decreased thermal conductivity values across different weight fractions.

Keywords: Bending, Thermal conductivity, Elastic modulus, Hardness.

1. Introduction
Composites are materials made up of two or more separate materials that are physically joined to form a new substance that cannot be generated by any of the components alone. Composites are made up of one or more discontinuous phases embedded in continuous phases. The discontinuous phase, also known as reinforcement, fillers, or reinforcing material, is often stronger and harder than the continuous phase, or matrix. Interfaces are the boundaries that separate the two phases of composite materials. The constituent materials' characteristics are strongly influenced by their distribution and interaction with one another. Aside from specifying the materials and their qualities, the shape of reinforcement is also significant. This geometry is defined by parameters such as the shape, size, and size distribution of the reinforcing components. concentration, distribution, and orientation of

reinforcing materials (1, 2). During this process, water is split out, and the molecular weight of the resin increases through esterification. The general purpose of polyester is to produce a product made from phthalic acid, maleic acid, and propylene glycol(3, 4). The wood plastics sector has grown rapidly and steadily over the last decade due to a variety of factors. The low cost and strengthening capability of wood fillers have opened up new possibilities for the manufacturing of composite materials. Even though wood-based fillers are not as popular as mineral or inorganic fillers, they offer several advantages over traditional fillers and reinforcing materials, such as low density, flexibility, non-damage to equipment during processing, acceptable specific strength properties, and low cost on a volume basis. Wood floor-filled composites find their primary application in the automotive and building industries, where they are used for structural applications such as decking, outdoor furniture, fencing, window parts, roofline products, door panels) etc.

Today, people are more environmentally aware, and industries are increasingly turning to natural materials as substitutes for non-renewable ones. Wood has been used as a building and engineering material since early times and offers the advantages of not just being aesthetically pleasing but also renewable, recyclable, and biodegradable (5, 6). In recent years, there have been many studies on the use of natural fillers such as coconut shells, pomegranate cores, pineapple leaves, ginger, and palm kernels as substitutes for conventional fillers. These natural fillers are used as a reinforcement material in polymer matrix composites to reduce costs, increase productivity, and improve the mechanical characteristics of the composites (7). The researchers (8) analyzed how using natural materials like Rice Husk Ash, Carrot Powder, and Sawdust as fillers for fiber glass/epoxy composites affected the mechanical properties of the composite. They found that adding these fillers increased the water absorption, hardness, flexural strength, and shear stress of the composite as the volume fraction increased.

The mechanical characteristics of polyester matrix composite reinforced with (grapes) and (dates particles) were studied, and it was found that the tensile strength and Young's modulus of unsaturated polyester increased as the percentage of grapes and dates particles increased. The modulus of elasticity for unsaturated polyester reinforced with dates particles was found to be highest at a percentage of 3.5%, while the modulus of elasticity for unsaturated polyester reinforced with grape particles was highest at a percentage of 5% (9).

Raya et al(10)She do An investigation was conducted to analyze the effects of wood and reed contents on the physical properties of (EP+W) composites, which were prepared through the casting method. The study focused on several mechanical properties, such as tensile strength, curvature, and creep. The results showed that the bending resistance and flexibility of the composite materials were significantly improved by reinforcing epoxy with wood particles. The (11) study conducted a study to investigate the mechanical properties of composite materials made using unsaturated polyester resin as a binder and two types of fillers - sawdust and chopped reeds. They measured the flexural strength and Young's modulus of these materials under normal conditions. They also immersed the commercial wood, unsaturated polyester resin, and composite samples in water for 30 days to determine the weight gain of water (Mt%) and the effect of water on their flexural strength and Young's modulus.

In comparison to the other composites, the UPE/chopped reeds composite had the highest flexural strength (24.5 MPa) and Young's modulus (5.1 GPa). The sawdust composite had the lowest weight gain (Mt%) of water (0.043%) after immersion compared to the other composites. However, there was a slight decrease in the values of Young's modulus and flexural strength for the wet samples of sawdust composite, except for the composite material formed from UPE/chopped reeds, which showed an increase in the value of flexural strength for all the samples after immersion. The wet samples of UPE/chopped reeds composite gained 29 MPa flexural strength compared to the samples at normal conditions. S. Nitin (12), The researchers conducted a study on the use of walnut shell particles reinforced polyester composites, with a weight percentage ranging from 0 to 40%, to enhance the mechanical strength and wear properties. They obtained a particle size of 1.00 mm by using two sieves of 0.5 mm and 1 mm successively. The study results indicate that the density of the composites decreases with an increase in the percentage of walnut shell particles. This decrease in density is due to the presence of porosity or voids, which occurs because no pressure was applied during the fabrication process (5). The present study utilized a thermoset polymer (polyester) as the matrix along with sunflower seed shell powder and sawdust powder as reinforcement fillers. The aim was to investigate the feasibility of using these waste materials as reinforcing fillers and to determine the mechanical properties of the composite about the reinforcing filler content concerning unsaturated polyester.

2. Materials and Methods

In this study, polyester was used Saudi saturator created by the Industrial Resins Company Ltd. as a base material in the prepared composite materials, which is It is a viscous liquid that has good characteristics as it is prepared A low molecular weight polymer known as an oligomer Accordingly, this substance can be transformed into an oligomer. The solid state, when it is solidified by adding the solidifying material (Methyl ethyl ketone peroxide) type (Hardener) It is a liquid substance with a light consistency and a transparent color (MEKP). It is added to the resin at a weight rate of (2%), noting that these solidification reactions occur at room temperature. As for the reinforcement materials used in the research, they are powders from agricultural waste, represented by sawdust wood, in addition to powder from sunflower seeds, whose particle sizes were measured using a sieving analysis, where the particle size was 75µm. Composites were prepared from polyester and agricultural waste powders by (Hand lay – up molding technique) according to the following steps:

- Preparing a special mold made of galvanized iron with dimensions $(10x10x1)cm^3$ for the casting process, which is cleaned properly with Flour after the conditioning process, then followed by a drying process to complete. Later, apply Vaseline to prevent adhesion. The resin is applied to the mold in an attempt to facilitate the extraction process. Castings after the solidification process is completed.
- Collecting wood industry waste and sunflower seeds in all their shapes and sizes, then crushing these wastes, then sifting them through a mesh sieve, passing through granules with a grain size of (75 µm). On the other hand, the coarse parts are broken into small parts. Using an electric grinding machine enables us to smooth it to the required granular size. Sawdust and sunflower seed powders are dried in an electric dryer at a temperature (50) C° to remove moisture and to ensure that a separating surface does not form between the base material and support material.
- Weigh the amount of unsaturated polyester and the material hardened with a weight percentage of (2%) per (100) gm. of unsaturated polyester, and thus mix these materials. Weighed in a plastic container using a glass rod. Gradually followed by a mechanical mixing process Electric mixer. During the mechanical mixing process, pour small amounts of the cementing material gradually to prevent clumping. Non-homogeneous, where the mixing process continues in this manner until all the powder used in it is exhausted. The mixture usually takes about three minutes. Therefore, the mixture of

polyester with the hardener the reinforcement materials resulting from the mixing process is placed in the prepared mold. Prepare slowly until it fills, then leave these castings for (24) hours at room temperature.

The next step is to remove the casting from the mold and put it in the oven at a temperature of (50°C) for 2 hours. This is done to enhance cross-linking. Once the casting is removed from the oven, it is cut according to standard specifications to prepare it for the upcoming tests.

3. Results

3.1. Experimental Test

3.1.1. Bending Test

Flexural strength refers to a material's ability to resist bending without breaking. It is a measure of the maximum bending stress a material can withstand before failing. Also, It is defined as the maximum static load that can be applied to a test sample before it breaks and is usually measured in MPa. The formula for calculating flexural strength is as follows:

$$F.S = 3PL / 2bd^2 \quad (1)$$

The distance between the two support points is denoted by 'l'. The dimensions of the sample are 'b' and 'd'. 'P' is the load that is applied(14,15).

The value of Young's modulus is calculated from the relations:

$$E = MgL^3 / 48IS \quad (2)$$

$$I = bd^3 / 12 \quad (3)$$

Where: I: Moment of inertia, b is the width of the sample. t: Thickness of the sample, and (M/S): Slope of the curve obtained.

3.1.2. Impact test:

The Charpy impact test uses a standardized test piece designed to break with a single blow from a swinging hammer. The test piece is supported at both ends, and the hammer strikes it in the middle. To conduct the test, the pendulum is lifted to its maximum height and securely fixed in place. The specimen has been fixed in place, and the energy gauge has been set to zero. When the pendulum is released to hit the specimen, some of its (kinetic energy) is used to break the specimen. At the same time, the energy gauge measures the fracture energy (UC) for the sample being tested. The impact strength (I.S.) A particular formula is used to calculate the (I.S.) values (16,17)

$$I.U = \frac{UC}{A} \quad (4)$$

UC, The fracture energy (in kJ), is determined from the (Charpy impact test instrument), and A refers to the cross-sectional area of the specimen.

3.1.3. Hardness:

The capacity of a material to withstand penetration or scratching is known as hardness. There are various standards for determining the hardness of plastic materials, with the Shore D hardness being the most commonly used. During the test, Local creep and slow retrieval of the material's dimensions occur after a force is applied to the surface of the sample and then removed. The force causes the material to deform(18, 19).

3.1.4. Thermal conductivity:

When there is a temperature difference between two surfaces, heat will flow from the warmer surface to the cooler surface. This phenomenon is called thermal conductivity. Thermal conductivity can be defined as the rate at which heat flows across a unit area over time when there is a temperature gradient of one degree Celsius between two surfaces. The thermal conductivity of a material depends on whether it is a solid, liquid, or gas, and is classified as either a dielectric or a heat conductor (20).

The thermal conductivity of metallic materials depends on the transmission of free electrons, whereas in composite materials, it varies depending on the fiber orientation. The thermal conductivity of composite materials increases when the fibers are oriented perpendicular to the thickness, but remains weak in the longitudinal direction of the fiber. Generally, the thermal conductivity of resins increases when they are reinforced with fibers. This is expected since the fibers have a higher thermal conductivity coefficient than the base material. The coefficient of thermal conductivity is measured using Lee's disk (Griffin and George - England), based on the following relations(21).

$$k[T_B - T_A/d_s] = e[T_A + 2/r(d_A + 1/4d_s)T_A + 1/2rd_sT_B] \quad (5)$$

$$IV = \pi r^2 e(T_A + T_B) + 2\pi re[d_AT_A + d_s(T_A + T_B/2) + d_BT_B + d_cT_c] \quad (6)$$

When the amount of heat energy is transmitted through disc material, it is measured in units of watts per square meter per degree Celsius, while a current passes through a convector coil.

(T_A, T_B, T_C) Heat discs A, B, C. (^oC)

(d_s), The thickness of the samples in mm.

4. Discussion

4.1. Bending Test

The basic principle of bending testing is to expose the specimen to a slow strain rate where possible. This test determines the linear behavior of the material under the applied load. The bending strength test is widely used to determine the ultimate bending resistance at the breaking point of the material under a bending load, perpendicular to the horizontal plane. Then, part of the sample will fall under the influence of compressive stresses and the other part will fall under the influence of tensile stresses, and may be accompanied by transverse shear stresses(20,21).

Figures (1) and **(2)** show the bending behavior of samples of single and hybrid unsaturated polyester composites prepared and subjected to a slow strain rate, the purpose of which was the identification of the hockey behavior of specimens It is observed from the figures that the deviation is directly proportional to the increase in the applied load When the load is removed, the sample will return to its original position, which means that the prepared samples will undergo Hokey behavior is subject to Hooke's law, Through the ratio between the load and the deflection, the slope of all samples was calculated and the elastic modulus was determined from the equation (1) (18,22). From the **Figure (3**) values obtained for the bending elasticity modulus, it can be noted that the highest value of the bending elasticity modulus for the single composite material (Up + sawdust) was 15%, which reached (1.2474) Mpa, compared to the pure polyester material, which reached (1.1448) Mpa, For the hybrid composite material (Up + sawdust+ sunflower seed), the 5% percentage obtained the highest value for the elasticity modulus, which reached (1.4644) Mpa, It is noticeable Increased modulus of elasticity for the hybrid material compared to the single material. The enhanced modulus of elasticity in single and hybrid composites is due to the incorporation of powders from reinforced materials. These powders restrict the flexibility and movement of the polymer chains, making relaxation more difficult and increasing the modulus of elasticity. This increase in modulus of elasticity leads to hardness (24-26).

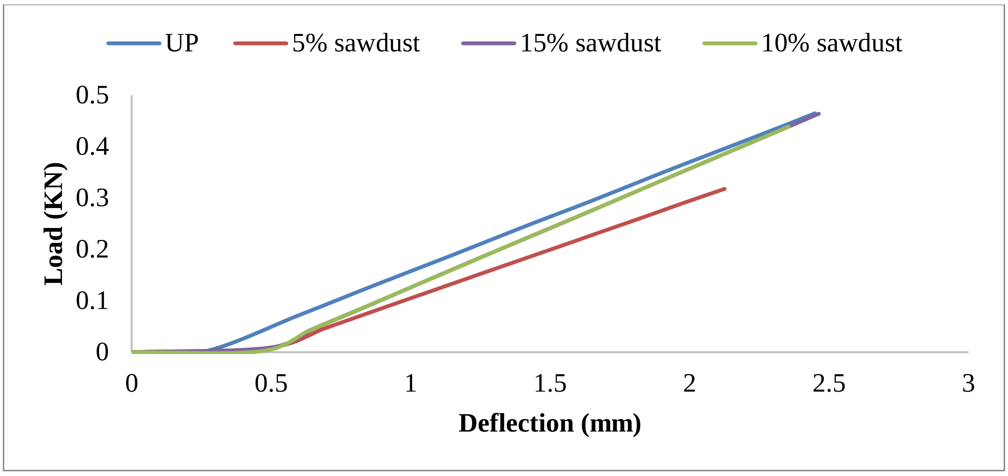

Figure 1. The relationship between the load-deflection of polyester and the single composite material.

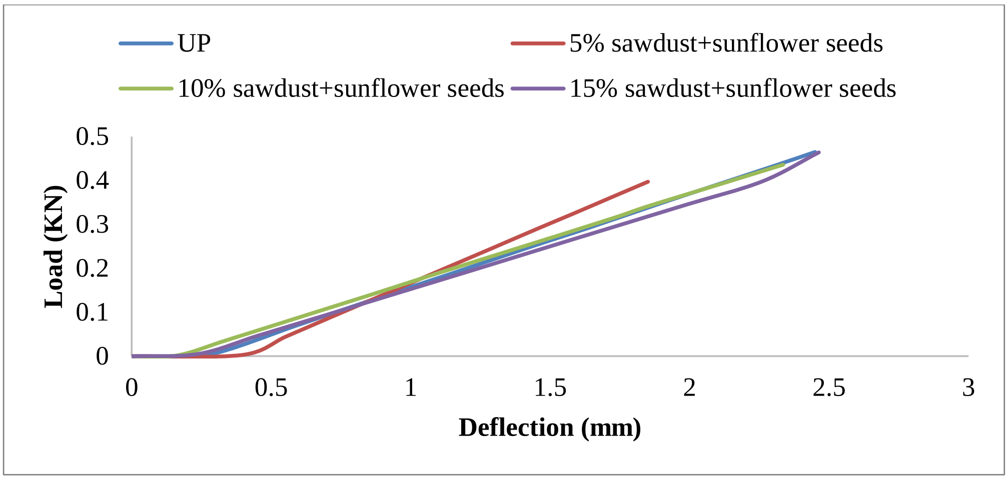

Figure 2. The relationship between the load-deflection of polyester and the hybrid composite material.

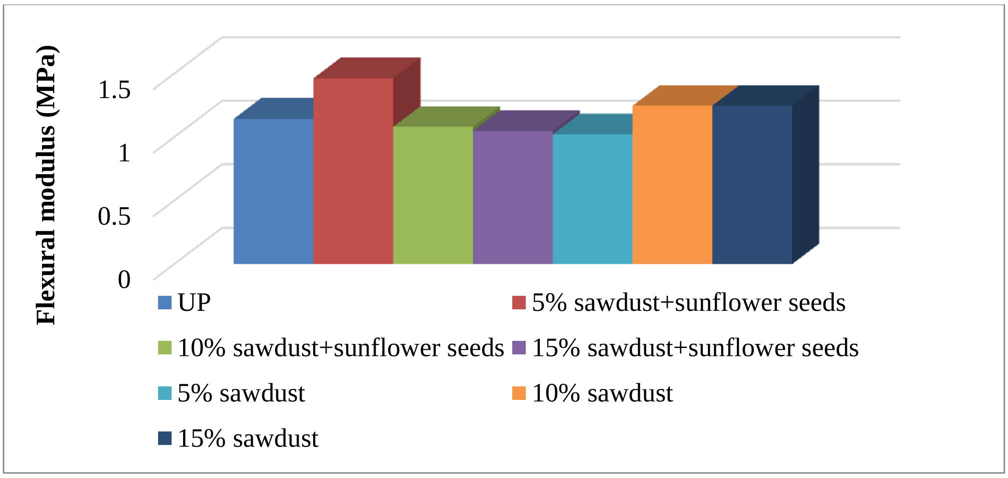

Figure 3. Flexural modulus of single and hybrid polyester composites.

From **Figures (4)** and **(5)** of the bending strength values are calculated based on Eq. (3) for both single and hybrid composite materials, the following shows an increase in the bending strength values for the single and hybrid samples, where the highest value of bending strength for the single composite material was (48.6) Mpa compared to the pure polyester material, which It is (37.8) Mpa at the ratio of(10%) and for the hybrid composite material, the highest value for bending strength reached (47.7) Mpa for the same ratio of 10%. The reason for the increased flexural strength of both the single and hybrid composite material by adding agricultural waste powders can be attributed to a better increase in the surface area of the filler in the matrix (27).

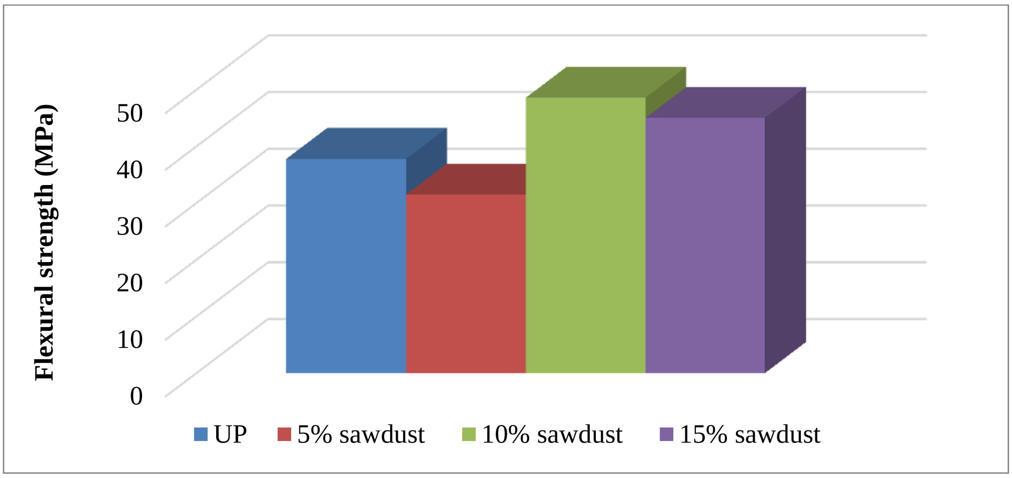

Figure 4. The relationship, between the (weight fraction) and the (flexural strength) for (polyester and the single composite material).

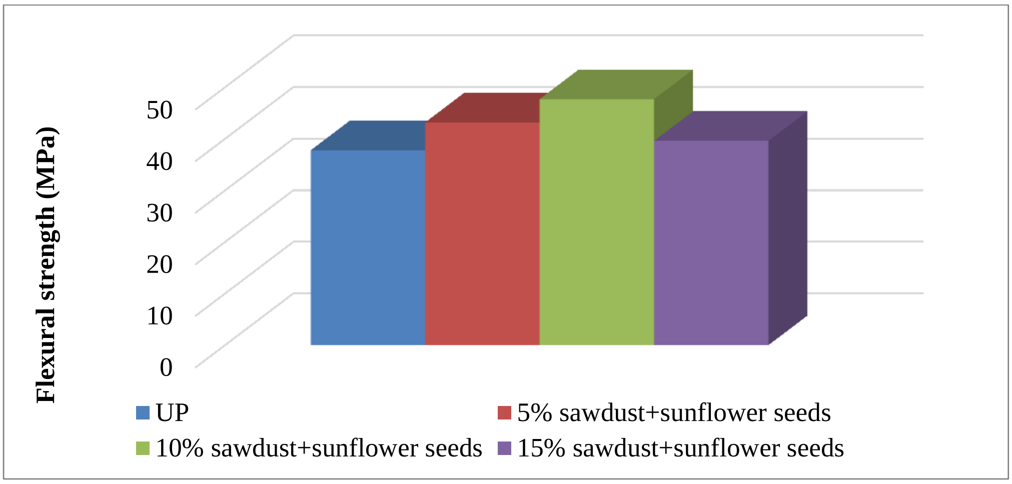

Figure 5. The relationship between the (weight fraction) and (flexural strength) for (polyester and the hybrid material).

4.2. Impact Test

The term "impact strength" refers to a material's ability to withstand sudden loads without breaking. It is a measure of the material's strength. By examining **Figures (6)** and **(7)**, which depict the relationship between impact strength and weight fracture for both single composite material and hybrid material, respectively, we can see that the value of impact strength increases with the percentage of reinforcement made up of sawdust and sunflower seeds in varying proportions. The highest value of impact strength (0.4 KJ/m^2) was achieved for single composite material at a 15% reinforcement rate, compared to pure polyester material which has a value of 0.25 KJ/m2. As for the hybrid composite material, the highest value for impact strength reached (0.5)KJ/ m^2. When natural fillers are used in a composite material, it has been found that the impact strength of the material is improved by 15%. This is due to the ability of the natural fillers to absorb energy and prevent crack propagation. Another contributing factor is the strong bonding between the natural fillers and the matrix, which creates small spaces that make it difficult for cracks to spread. However, if either of these factors is absent, cracks may appear in small dimensions at the points of impact, which can reduce the impact strength. This occurs when the reinforcements are insufficient to stop the propagation of cracks, causing a decrease in the impact strength (28).

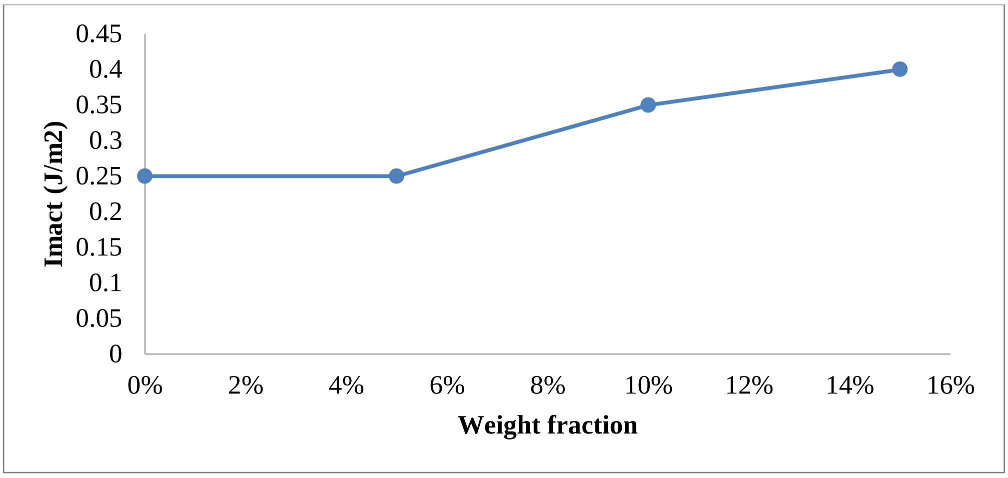

Figure 6. The relationship between (weight fraction) and (impact strength) for (polyester and the single composite material).

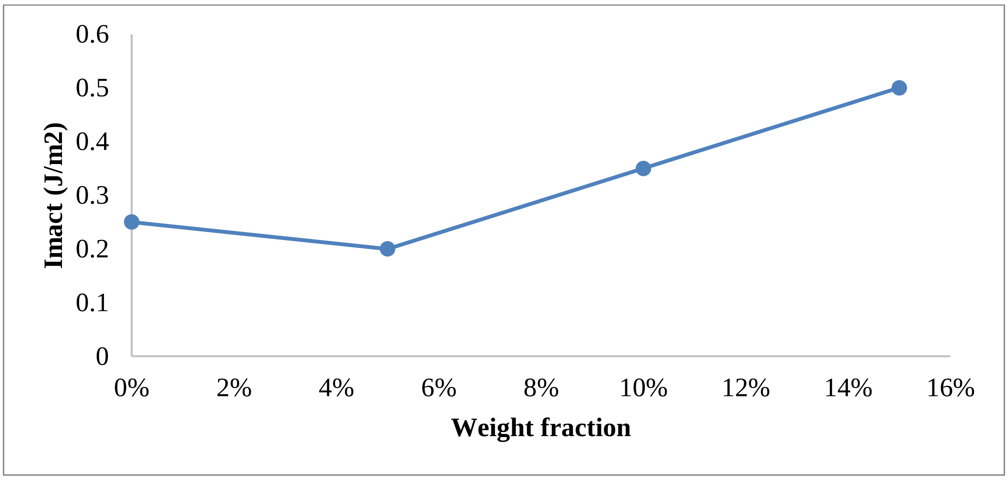

Figure 7. The relationship between (weight fraction) and (impact strength) for (polyester and the hybrid material).

4.3. Hardness

Hardness is a material's ability to resist wear, corrosion, and external penetration. The property of hardness is not one of the basic properties of the material and can be defined in more than one way. For example, it is known as the material's resistance to abrasion or the material's resistance to deformation. The material has high hardness, when it difficult to make stitches or scratches on the surface of the material (29).

From the **Figures (8)** and **(9)** after analyzing the data from the study that examines the correlation between hardness and weight fraction for single and hybrid unsaturated polyester composites, it has been observed that as the weight fraction of reinforcement with sawdust and sunflower seed powders increases, the hardness value also increases. This trend is observed for both single and hybrid materials and all weight ratios. The increased values varied according to the weight percentages, as the highest hardness value for the single composite material reached (83) for the 10% percentage compared to the pure polyester material, which had a hardness value of (72). As for the hybrid composite material, the highest hardness value was reached at the 10% percentage, which also reached (84.2). "The increase in hardness value is attributed to the bond's increase and cross-linking, which reduces the movement of polymer molecules. This leads to an increase in the material's strength against scratches and plastic deformation." (24).

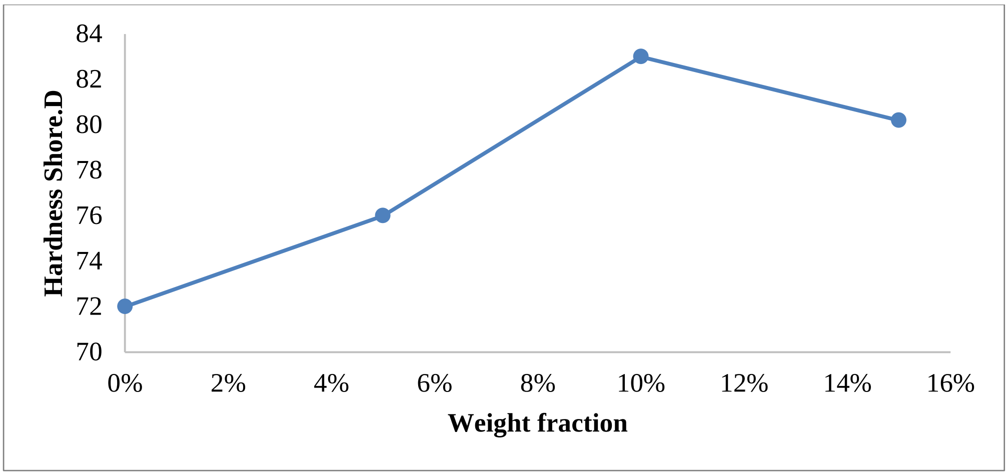

Figure 8. The relationship between (weight fraction) and (hardness) for the (polyester and the single composite material).

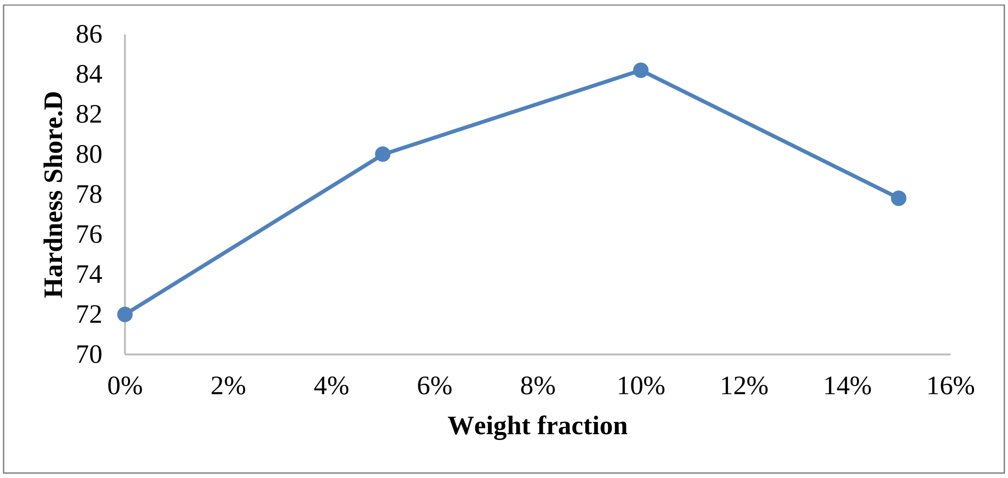

Figure 9. The relationship between (weight fraction) and (hardness) for polyester and the (hybrid material).

4.4. Thermal conductivity

Heat is a form of transferred energy, as it moves from one area with high temperatures to another. An area of low temperatures in several forms (conduction, convection, radiation), Heat can be transferred in one of these forms. From **Figures (10)** and **(11**) explain the relationship between (thermal conductivity) and the (weight fraction) of the reinforcement powders, sawdust, and sunflower seeds.

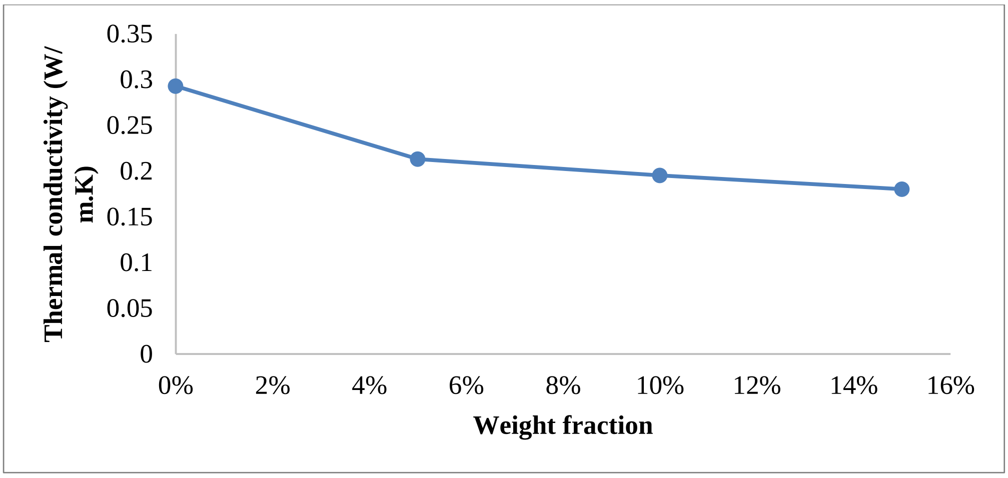

Figure 10. The relationship between (weight fraction) and (thermal conductivity) of polyester and the single composite material.

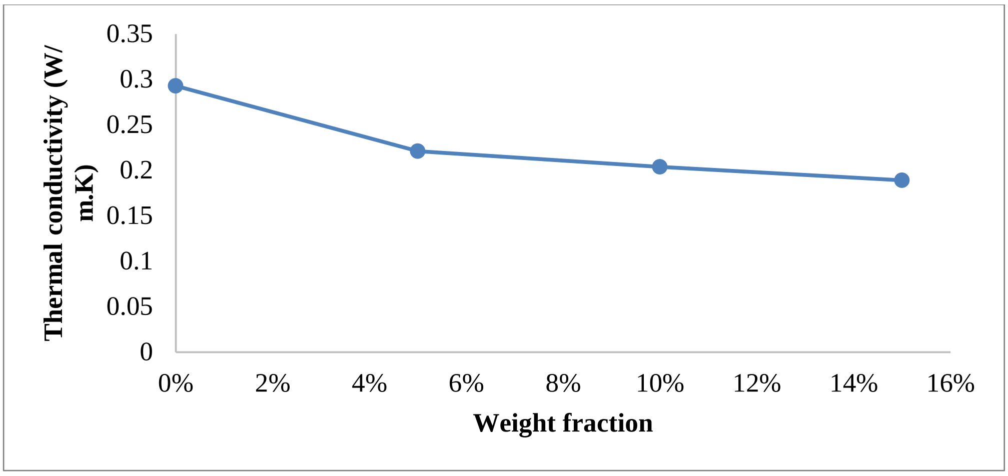

Figure 11. The relationship between (weight fraction) and (thermal conductivity) of polyester and the hybrid material.

From observing the shapes, it is clear that there is a decrease in the value of thermal conductivity for each (single and hybrid) composite materials compared to the pure unsaturated polyester material because polymers do not contain free electrons to transfer heat, whereas the internal structure of a material's vibrations determine its thermal conductivity. These vibrations are reduced when adding agricultural waste powders, sawdust, and sunflower seeds to the polyester base material, which hinders vibration and thus reduces thermal conductivity (30).

5. Conclusion

From the results obtained in the research, the following was concluded from the results of the bending test, it was noted that the single composite material (UP + sawdust) had the highest value of bending strength, while the highest value of the modulus of elasticity was possessed by the hybrid composite material (UP + sawdust + sunflower seeds). As for the impact strength test and the hardness test, the single composite sample(UP + sawdust) also had the highest values for both the hybrid composite material(UP + sawdust + sunflower seeds). and the pure polyester sample (Up). As for thermal conductivity, it is noted that there is a decrease in the value of thermal conductivity for both single and hybrid materials and for all weight fractions, which can be attributed to the nature of the insulating reinforced materials.

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Conflict of Interests

The authors declare that they have no conflicts of interest.

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