Exploiting the Waste of Pistachio Shells to Reinforce the Unsaturated Polyester

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Abstract

The exploitation of waste from pistachio shell particles (PS) and recycling them to reinforce unsaturated polyester (UPS); it is possible to produce structural sections at an inexpensive price and reduce the risk of environmental pollution resulting from these wastes (PS), instead of the usual incineration and landfill operations with such waste. The samples were prepared by manual casting method according to the weight fractions (0, 5, 10, 15, 20, 25, 30) from the pistachio shell particles (PS) with a fixed granular size of (45 μm) of (PS). Some mechanical tests (the tensile elastic modulus, the bending test, and the hardness test) were carried out. Through testing, these values were increased with the increase in the reinforcement ratios of particles (PS).

Key Words: Mechanical Properties, Unsaturated Polyester, Pistachio, Environmental Pollution.

DOI Number: 10.14704/nq.2022.20.2.NQ22076 **NeuroQuantology 2022; 20(2):107-112**

Introduction

Many researchers pay a great attention to the environmental waste in order to preserve the environment and reduce reliance on raw sources and their exhaustion. Consequently, the role of compound materials became very wide and attracted the attention of engineers and manufacturers. Due to the high strength and rigidity of these materials in addition to their low cost and light weight, their use occupied a large scope in many engineering, technological and other industries fields. (Al-Ameen, Abdulhameed, Abdulla, Ogaili, & Al-Sabbagh, 2020) In general, the entry of polymers is to meet the needs of the modern era, which witnessed a clear development and a great demand for such materials. As a result of this great development and the increasing demand for polymeric composite materials, the world cannot be imagined without polymers. Whereas, these materials were distinguished (metallic, ceramic) by simplicity of manufacturing, resistance against oxidation and non-corrosion when exposed to alkaline and acidic solutions, as well as being easy to color (Mohsoun, Ahmed, & Sciences, 2019). The rise in the prices of raw materials has increased the demand for biodegradable materials which depend on renewable natural resources (VO, 2014).

Many studies have been conducted on natural fibers for several years, as for edible nuts shells, such as hazelnut shells, walnut shells, pistachio shells, and ground pistachio shells in the form of particles or powder which had received a remarkable attention in the past few years. In particular, the shells of pistachio (PS) are among these nuts which can be utilized as a preservative for some polymeric resins.

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 29 December 2021 **Accepted:** 24 January 2022

It was found that the shells (PS) were less used in the reinforcement of polymeric materials; the shell of pistachio is an agricultural waste that is abundant in countries according to its consumption. It can be collected, cleaned and grinded to strength the resins to obtain polymeric materials which can be utilized in different applications as these (PS) shells have high solidity and hardness in addition of being cheap and biodegradable (Reports, 2012).

The materials that are strengthened by particles are one of the most important materials used in engineering purposes because of their large molecular structures due to the process of binding and building the small molecules. One of the factors that affect the composite materials supported by the particles is the shape and size of these particles in addition to the mechanism of their distribution in a regular and random manner within the base material. Furthermore, the strength of the bonding among the base material, the supporting materials and the area of the interface which formed amidst the two phases has an efficient role in effecting the composite materials. (Bacarreza, Abe, Aliabadi, & Kopula Ragavan, 2012).

The Aim of the Research

1. Manufacturing structural sections from waste pistachio shells with unsaturated polyester (UPS).
2. Reducing environmental pollution resulting from throwing these wastes.

Materials and Experimental Work

Supported Materials

The waste of (PS) shells were cleaned with water, dried under the sunlight, and then grinded to obtain the required size.

Adhesive

Unsaturated polyester (UPS) was used as an adhesive material. It is one of the resins that harden by heat. It has the form of a transparent viscous liquid at room temperature and a density of approximately (1.2 g/cm3).

Preparation of Samples

All samples were prepared by using manual molding method according to the required samples and fractions' weight (0, 5, 10, 15, 20, 25, 30) of (PS) and with a particle size of 45μm. The (PS) particles were mixed with (UPS) slowly and gradually in order to obtain an acceptable homogeneity between (PS) and the base material (UPS) to avoid the occurrence of bubbles produced by the rapid mixing which affect the two materials. Furthermore, the process of mixing the two materials took place in all directions from (2-3 minutes) to ensure that no lumps occur within the base material, which greatly affects the prepared mixture. The material was poured regularly into the mold. When the samples solidify inside the molds, they are placed in an electric oven for (1 h) at a temperature of (50 °C), after that the samples remain inside the oven for (4 h) until the temperature of the samples gradually decreases at the laboratory temperature to ensure a distinctive interlocking of these polymeric chains to give the best stiffness and reduce the effective stresses formed during casting and solidification processes. We repeat this process with the same steps on all the samples prepared according to the weight ratios particles of (PS).

Mechanical Tests

Tensile Test: Tensile samples were prepared as shown in Figure (1) which gives an accurate description of those standard dimensions according to the certified American Standard (ASTM-D-638) (standard, 1985). By using the mechanical testing of tensile samples at laboratory temperature and tensile device (LAREE Yaur Tasting Solution) and applying a load (stress) to the sample and through the (stress-strain) curves, the properties of the tensile elastic modulus are calculated. Figure (2) represents the tensile test samples before and after the examination and Figure (3) represents the device used in examination.

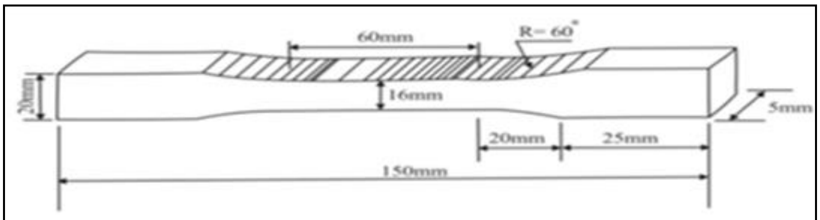

Figure 1. The International Standard (ASTM-D-638) for Tensile Samples [6]

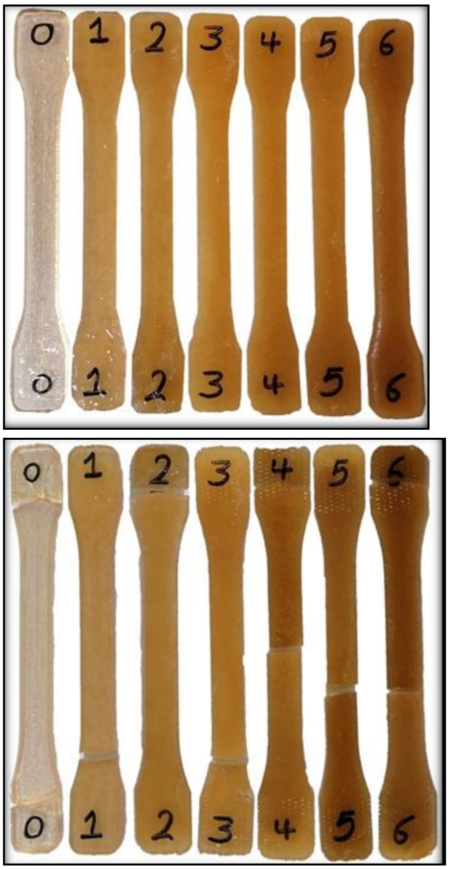

Figure 2. Explains the Samples before and after Examination

Figure 3. The Device of Testing Tensile Samples

Bending Test: The bending test samples are prepared according to American Standard (D-790 ASTM) for testing (Murali, Ramnath, & Chandramohan, 2019) as explained in Figure (4) which gives the standard dimensions for the bending test samples. The tests were carried out by using a (Three Pending test) device. The device (LAREE) was used in bending tests as shown in Figure (5) (Stress- Strain) curves are obtained through the graph of the bending samples. The bending resistance of the sample is calculated by the using of the curves, Figure (6) shows the bending test samples before and after mechanical tests.

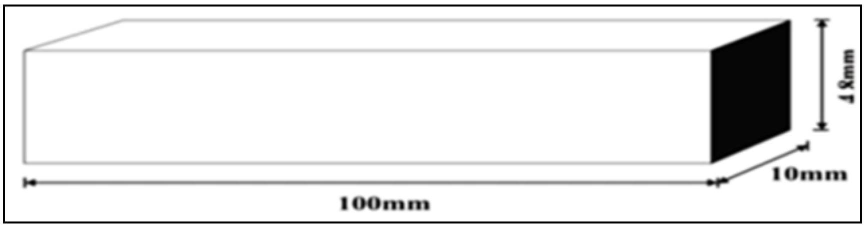

Figure 4. Standard Dimensions of Bending Samples [7]

Figure 5. Bending Test Device

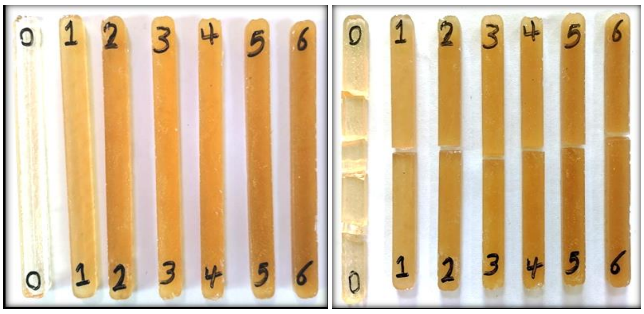

Figure 6. Bending Samples before and after Mechanical Tests

Hardness Test: The (Shore-D) method was used to calculate the hardness of the samples by utilizing the device shown in Figure (7) which is made in Germany and manufactured by Electrometer Company. This device contains a needle which penetrates the surface of the sample under the impact of a certain load. The hardness of the sample is calculated by reading the counter pointer in the device. Five values were taken from one sample; these values were taken from the middle and the edges. After that, the average of the readings was calculated for each sample. Figure (8) gives a schematic diagram for the hardness test sample (Hardness) according to the American Standard Testing Measurements (ASTM) [8], whereas, Figure (9) shows the hardness test samples.

Figure 7. Hardness Test Device Type (Shore-D)

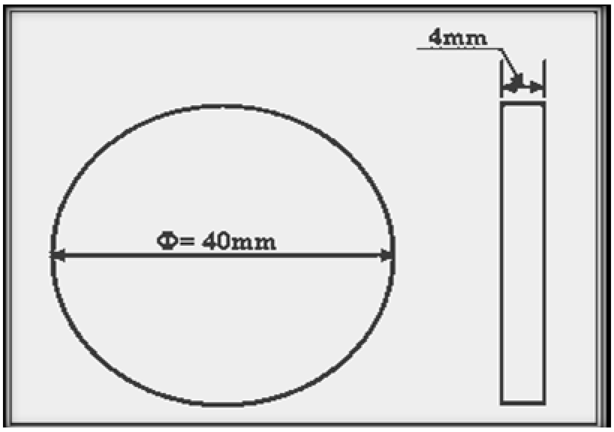

Figure 8. Gives a Schematic Diagram of the Hardness Test Sample according to the American Standard Testing Measurements ASTM D-2240 [8]

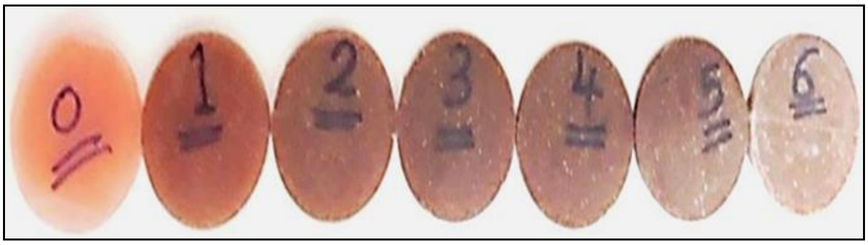

Figure 9. Shows the Hardness Test Samples

Results

1. Tensile Elasticity Modulus

Figure (10) shows the relationship between the tensile elastic modulus of the composite material and the value of the weight fractions for the pistachio shell particles (PS). According to the results, the value of the tensile elastic modulus of the pure sample of unsaturated polyester was (19 MPa), then the values were gradually increased till the highest value of (52 MPa) at the weight fraction (30%), this indicates that the (PS) particles have contributed to the increase in the tensile elastic modulus, and this growth is attributed to the particles distribution with the adhesive (UPS) thus forming interfaces that have the ability to increase the cohesion of the polymeric material.

Furthermore, the absence of agglomerates within the polymeric liquid increased the possibility of the tensile strength of the composite material and lack of stress concentration in these agglomerates which played an essential role in increasing the bonding strength of the adhesive material (UPS) with the particles of (PS) with a noticeable increase in the values of the tensile elastic modulus of the composite material and reinforcement ratios. (Sahai, Mahanwar, & Sciences, 2015).

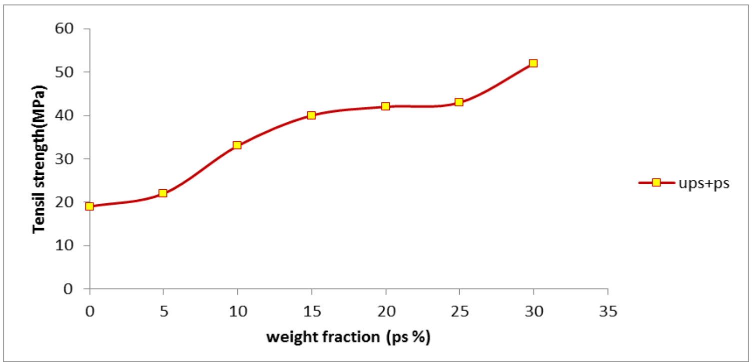

Figure 10. Tensile Modulus Parameters of Composite (PS + UPS)

Bending Resistance

Figure (11) shows the results of bending resistance values when mixing pistachio shells particles with resin (UPS). The values were higher than pure resin. The highest value was at the weight fraction (5%) by (25MPa) due to the distribution of stress forced on each of the resin material (UPS) and particles (PS). The resin material is a plastic material which has a high strain rate when affected by a certain stress. When it was reinforced with particles of (PS), the values of the elastic modulus of the composite material were improved, as these particles were distributed homogeneously on all dimensions of the sample and thus prevented from deformations in the adhesive material. Then the bending resistance values decreased gradually, this decrease was due to the adhesive material (UPS) was filled with particles which had not the ability to have a percentage of reinforcement greater than (PS) particles.

From one hand, these particles will gather and agglomerate in the appropriate manner, which leads to weak bonding between the adhesive material and the reinforcing material. On the other hand, the accumulation of (PS) particles leads to the formation of cracks around these particles. These cracks merge with each other to weaken the composite material during applying an external load. The surface and inside cracks of the sample will cause a decrease in the modulus of elasticity values for the samples of the test (Nayak, Heckadka, Kini, Thomas, & Gupta, 2017).

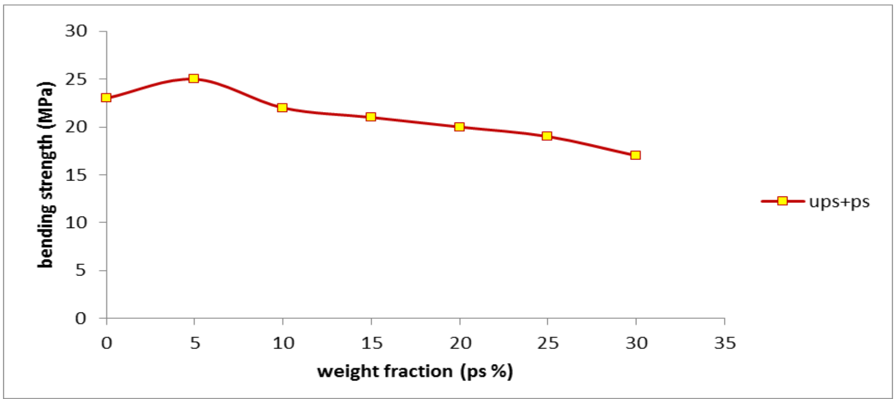

Figure 11. Shows the Bending Resistance of the Composite (PS + UPS)

Hardness Resistance

The hardness test gives us an adequate idea of the resistance of the surfaces of polymeric materials. The hardness test was carried out using a (Shore-D) device. Form Figure (12) it was found that the hardness values of the samples increased with the increase of the strength ratios of (PS) particles. Where the highest hardness value at the weight fraction (30%) reached (87.1 N/mm2), this improvement is due to the diffusion of (PS) particles and their appropriate penetration in the polymeric samples during the process of preparing and molding these samples, which increasing the cohesion and agglutination of these components with each other (UPS) and (PS). The increase in bonding (agglutination) is due to the reduction of the brown spaces between the (PS) particles that acted as an obstacle to decrease the movement of the polymeric particles, which led to an increase in the resistance of the samples to scratching or penetration (puncture).

One of the properties on which the hardness of polymeric materials depends on is the bonding strength between atoms and molecules, as well as the distance between their polymeric chains, which agrees with the researcher (Yaseen, Al Saadi, Hussein, & Bdaiwi, 2020). As (PS) particles have a high strength and hardness which helped to improve the hardness of the polymeric material, and these particles also closed the gaps and voids formed by the hand molding. In addition, the size of the particles has a great effect on the hardness of polymeric materials, as the more the reinforcement is done with very small particles; the better hardness results are obtained. This is because these small particles can easily penetrate into the polymeric liquid, which increases the cohesion of the adhesive and the supported materials, as well as increasing the agglutination (bonding) of the composite material, which helps obtaining high hardness test results (Kiyotsukuri, Tsutsumi, & Chen, 1990).

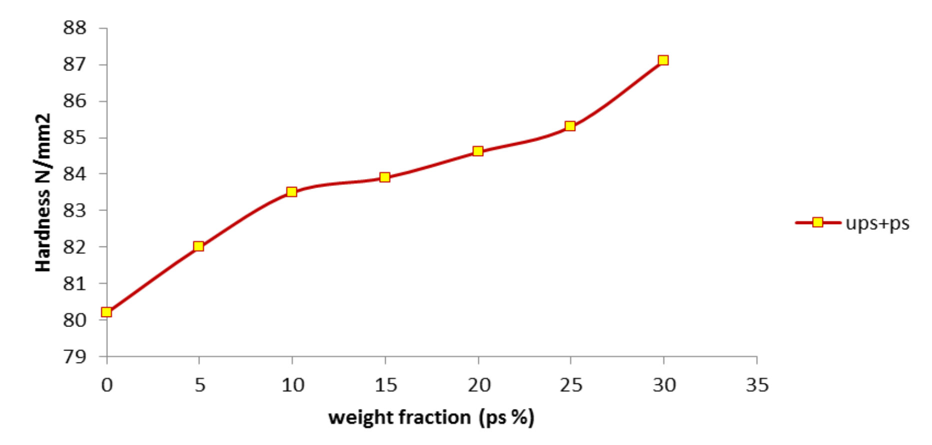

Figure 12. Resistance to the hardness test of the compound

Conclusions

The results show us that when using (PS) particles with polymeric adhesive (UPS) led to an improvement in the mechanical properties (the modulus of tensile elasticity, bending resistance, and hardness resistance) with an increase in the reinforcement ratios of (PS) particles.

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