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Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: http://qu.edu.iq/journaleng/index.php/JQES

Study the mechanical properties of epoxy resin reinforcement by ziziphus spina-christi powder

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ARTICLE INFO

Article history:
Received 26 April 2022
Received in revised form 25 May 2022
Accepted 2 July 2022

Keywords:
Epoxy
Ziziphus
Impact test
Flexural test

ABSTRACT

Ziziphus Spina-Christi bark and other natural debris may be found in abundance in the nearby area. The mechanical qualities of all of these waste natural resources are outstanding, and they may be utilized more professionally to create composite materials for a variety of applications. Epoxy resin modified with organic natural particles such as Ziziphus Spina-Christi bark powder has been used as reinforcements in polymer matrixes instead of non-degradable synthetic reinforcement such as glass, carbon, or aramid. The tensile, impact and flexural characteristics of the Ziziphus Spina-Christi bark particles enhanced epoxy resin are examined in this publication. This paper studies the effects of weight fraction (3, 5, 7 & 9%) on the characterization of composite materials. The results show that the mechanical characterization of epoxy improved when added 7% from the particles of Christi. Where the hardness increased up to 77 (Mpa). Also, the impact strength reached 8.7 (KJ/m^2) with a 7 wt% filler added, and the tensile strength increased from 18 (MPa) to 45 (MPa). The flexural strength of pure epoxy is 160 (MPa), and it increases linearly with the addition of Ziziphus Spina-Christi bark to 173 (MPa).

1. Introduction

Epoxy resins may be made to display outstanding chemical resistance, high thermal & electrical resistance, tremendous adhesion, little shrinkage, and useful mechanical features, such as great toughness and strength, in addition to superior mechanical properties. Manufacturing, packaging, aerospace, and building all benefit from epoxy resins. As a result, they are used in a broad range of applications from bonding & adhesive applications to electrical laminates to garment finishes to fiber-reinforced plastics to flooring and pavements [1]. Zizyphus Lotus bark (Z. Lotus), sometimes called jujube, is an angiosperm member of the Rhamnaceae family. This family contains around 135–170 Zizyphus species [2]. Z. Soil conditions in China, Africa, Iran, Europe, and South Korea, particularly Cyprus, Greece, Sicily, and Spain, are ideal for growing the lotus [3–4]. tea, Honey, jam, oil, juice, bread, and cake are just some of the ways this plant is used in nutrition, health, and beauty. Traditional medicine in the Middle East and North Africa uses a few sections of Z. lotus to treat a wide range of ailments, including urinary tract infections, diabetes, fungal infections, skin infections, insomnia, bronchitis, and low blood sugar [5–6]. In contrast, the jujube, a delicious red fruit, was consumed by indigenous peoples in huge numbers fresh, dried, and processed as a food source. [7].

Table 1. Mechanical properties of epoxy resin

Flexural strength (N/)	53
Compressive strength (N/)	50
Tensile strength (N/)	25
Viscosity (poise)	0.5-1.0 poise
Young's modulus (N/)	1.060
Density(gm/)	1.1

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https://doi.org/10.30772/qjes.v15i1.812

Purpose of the study: to make samples of composites of epoxy resin reinforced with Zizyphus Lotus bark and study its effect on mechanical properties (hardness "shore D", tensile test, impact test, and flexural test). M. Alsaadi & flexural qualities & colleagues [8].R. Pragathees & S. Senthil [9] investigated the flexural properties & tensile of an epoxy resin filled with 3Percentage, 5Percentage, 7Percentage, & 9Percentage vol percent groundnut shell powder. The findings indicated that the additive of Zizyphus Lotus bark improves mechanical characteristics.

2. Experimntal setup

2.1. Epoxy Resin

The hardener used was Poly inject EP 10. It is liquid and added to the resin in a weight ratio of 1:3 (hardener: resin), and thus the chemical bonding and crosslinking were formed within the epoxy resin. produced by (Al-Rakaez Building Materials in Amman) and made in (Egypt Arabic). Typical properties of a resin used in the current experimental work are listed in Table **1.**

2.2. Zizyphus lotus bark

The root barks of Zizyphus lotus were extracted with water, chloroform, ethyl acetate, and methanol to determine their anti-inflammatory and analgesic activities. Aqueous extract (50, 100, and 200 mg/kg) given intraperitoneally (i.p.) showed a significant and dose-dependent anti-inflammatory and analgesic activity. Chemical analysis of Ziziphus lotus bark after (X-ray Fluorescence) using reagents Compton secondary molybdenum and Barkla scatters HOPG. Showing in Table 2. The test was completed at the University of Technology, Baghdad, Iraq .

Table 2. Chemical analysis of Ziziphus lotus bark

Z	Symbol	Element	Concentration	Abs. Error
16	S	Sulfur	< 0.00020%	0.0%
15	P	Phosphorus	0.00033%	0.0005%
14	Si	Silicon	< 0.00058 %	0.0%
13	Al	Aluminum	< 0.0013%	0.0%
12	Mg	Magnesium	< 0.0065%	0.0%
11	Na	Sodium	< 0.045 %	0.0%

2.3. Preparation of composites

All specimens were composited using a rubber mold. A layer of wax was applied to the mold to allow for easy removal of the specimen.

Table 3. Composition of specimen composites

Specimen	Composition
1	100% Epoxy resin
2	Epoxy + 3% (ZP)
3	Epoxy + 5% (ZP)
4	Epoxy + 7% (ZP)
5	Epoxy + 9% (ZP)

Determining quantities of Ziziphus Spina-Christi bark particles(ZP) (3, 5, 7, and 9wt%), and epoxy resin were combined carefully in a container to make a uniform mixture. The mixture was swirled for ten minutes after adding the hardener. After 24 hours, samples were removed from the mold & heated in a furnace set to 55 degrees for (3) hours to eliminate every tension and to complete the bonding between the filler & resin [11& 12]. Table 3. summarizes the composition of specimen composites.

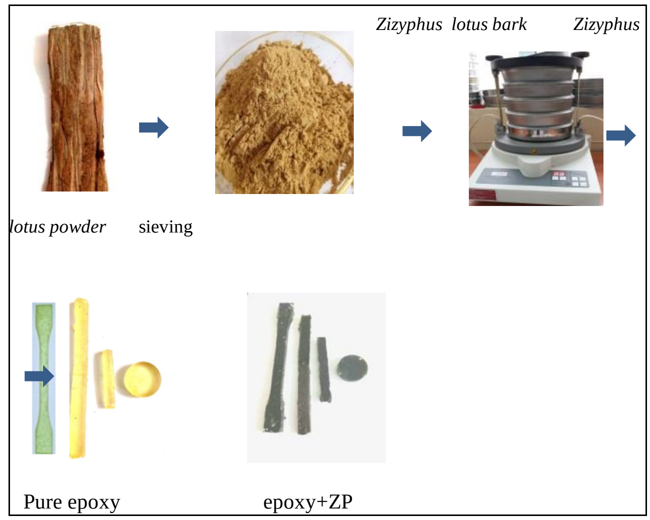


Figure 1. Preparation of composites

3. Mechanical tests

3.1 Tensile test

This test is performed according to (ASTM D638) in room temperature. Fig.1.shows specimens for tensile test stander matching with ASTM D638-03[13]., Figure (3) shows the tensile strength machine used in this research, the test was completed in the material engineering department/ University of Technology/ Baghdad/Iraq.

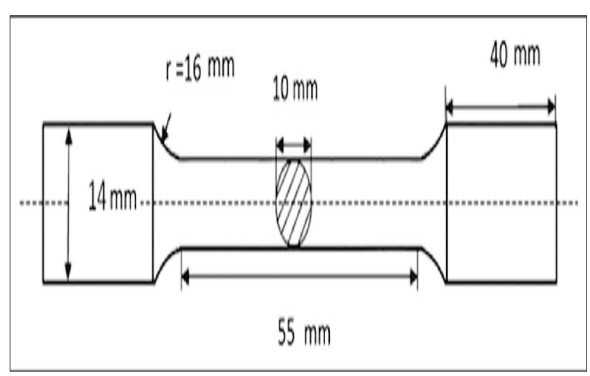


Figure 2. Tensile test stander

3.2. Flexural test

The flexural test can also be called as bend test, Samples have been cut into the dimensions (125*12.7*3.2) mm according to ASTM D 790- 86 [14].

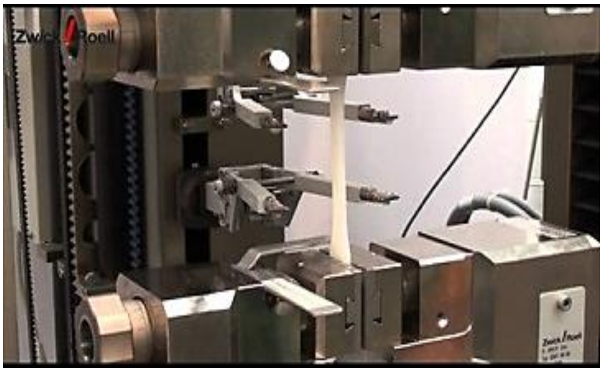


Figure 3. Tensile test device

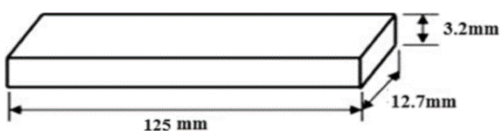


Figure 4. Show flexural test stander.

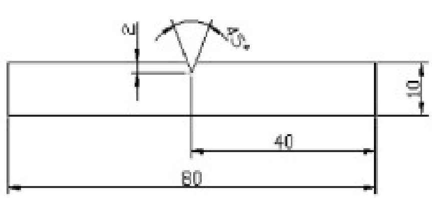
The flexural strength is calculated according to the equations.

$$F.S = \frac{3PL}{2bd^2} \quad (1)$$

Where
F.S: flexural strength (MPa).
P: force at fracture (N).
L: Length of the sample between Predicate (mm).
b:thickness (mm).
d:width (mm).

3.3. Impact test

Fig.5.demonstrates the standard dimension of samples according to (ISO-180) [15]. Impact resistance is calculated for samples from the following relationship [16].



Thickness=4 mm

Figure 5. Show impact test stander

$$Gc = \frac{Uc}{A} \quad (2)$$

Where
G_c: impact strength of the material (J/m^2).
Uc: impact energy (J).
A: cross-sectional area of the specimen (m^2).

This test is performed according to (ISO- 180) at room temperature. Samples have been cut into the dimensions (80*10*5) mm. the inspection was done in the material engineering department/ University of Technology/ Baghdad/Iraq.

3.4. Hardness shore (D)

The ASTM of hardness shore D test is conducted related on (D-2240) at room temperature(Annual Book of ASTM Standard, 1988). samples cut off into a diameter of 40mm and a thickness of 5 mm. device founded in the polymer laboratory at the Materials Engineering Department, University of Technology. Per each sample, five hardness tests were taken, and the average hardness was fixed.

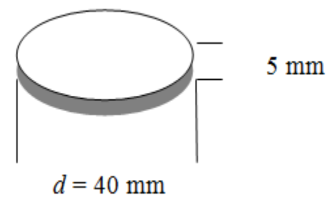


Figure 6. Hardness shore test stander

4. Results and discussions

4.1 Tensile test

The tensile strength of samples epoxy/ Ziziphus Spina-Christi bark powder in fig.7. Shows increases with the addition of additional 5 percent and 7 percent weight fractions of Ziziphus Spina-Christi bark powder, but begins to decline with the addition of a 9 percent weight fraction of Ziziphus Spina-Christi bark powder, according to the findings. Increased tensile strength values were observed at (5 percent and 7 percent weight fraction Ziziphus Spina-Christi bark) concentrations, which is likely due to the fact that tensile properties can be influenced by a variety of factors, including filler content rather than the particle-matrix interface, homogeneous particle distribution within the resin, & the stiffness of the reinforcing particles; all of these factors contributed to the enhancement of tensile properties [17 & 18]. There may have been a lack of bonding between resin and filler, which caused microcracks to form at the interfaces of the sample composites when 9 percent weight fraction Ziziphus Spina-Christi bark powder was used in epoxy resin [19].

Fig.8. illustrates the connection between the modulus of elasticity & the weight fraction of Ziziphus Spina-Christi bark powder in epoxy resin (2). It can be concluded that the elasticity modulus qualities of epoxy resin improve with increasing weight fractions of Ziziphus Spina-Christi bark powder (5 and 7 percent), but that the elasticity modulus qualities of epoxy resin decrease with the addition of Ziziphus Spina-Christi bark powder (9 percent) in epoxy resin. In part, the high strength of Ziziphus Spina-Christi bark powder is responsible for this rise in modulus of elasticity. Consequently, the modulus of elasticity enhanced from (2.3 GPa) for the epoxy to (11 GPa) for epoxy combined with 7 percent Ziziphus Spina-Christi bark powder, a significant increase. When compared to the pure sample, the elastic modulus values increased by around 4Percentage on average. In part, this is due to the average particle size & uniform distribution of Ziziphus Spina-Christi bark powder within the epoxy resin, as well as the ease with which the polymer matrix material diffuses; as a

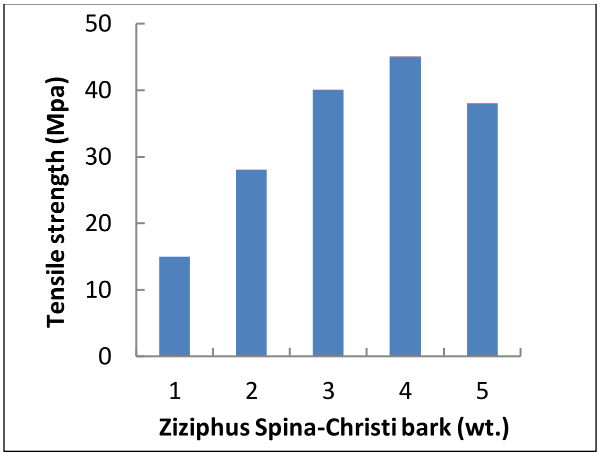


Figure 7. Tensile strength of the specimen

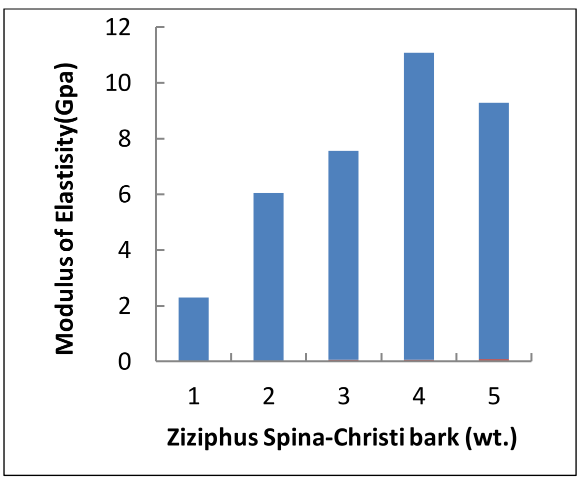


Figure 8. Modulus of elasticity of specimen

result, excellent interfaces between the reinforcing & matrix materials are required [20]. It was discovered that the addition of 9 percent weight fraction Ziziphus Spina-Christi bark powder to epoxy resin resulted in a drop in modulus of elasticity from 11.1 to 9.2 GPa. That's because reducing deformation by rising the surface contact area between the matrix & reinforcement [21]

4.2. Flexural Test

EPO/Ziziphus Spina-Christi bark composites with various filler weight percentages are shown in fig.9. Flexural strength of the pure epoxy was 160 MPa, which grew linearly with the addition of Ziziphus Spina-Christi bark up to 169 percent, or 7 wt. percent, but decreased to 165 with the addition of 9 percent). Unofficially, the inclusion of Ziziphus Spina-Christi (7 percent weight) increases the adhesive properties of the composite with increasing mechanical joining among epoxy and filler, which rallies stress transfer after application of loads [18]. When 9 percent weight Ziziphus Spina-Christi filler was added, flexural strength was reduced because the structure's integrity deteriorated due to the agglomeration and gaps. The losses in flexural strength were attributed in part to the existence of Ziziphus Spina-Christi in the matrix, which is in line with [22]. device established at Materials Engineering Department, University of Technology. by using the machine type Laryee, Chinese made (Model 1031).

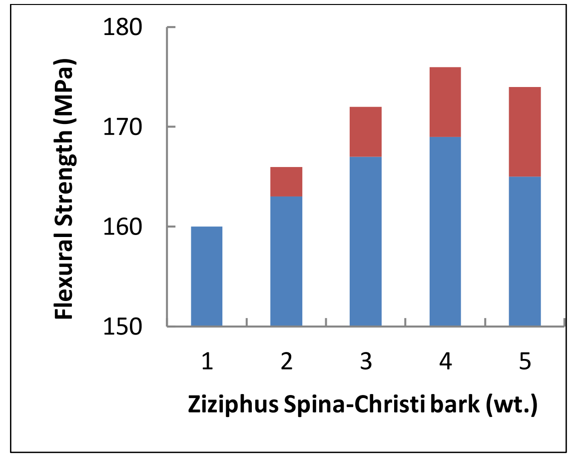


Figure 9. Flexural strength of the specimen

The fig.10. the flexural modulus of epoxy / Ziziphus Spina-Christi bark at various filler weight fractions 7. The pure epoxy has a flexural modulus of 2 GPa & is linearly increased by 7.8 GPa percent up to 7wt. percent Ziziphus Spina-Christi bark, but is decreased to 6.2 GPa when 9 percent Ziziphus Spina-Christi bark is added, as shown in figure (8). The stiffness of the epoxy in combination with its content may contribute to the composites' increased flexural modulus. The filler may restrict the polymer chain's free flow, hence limiting the polymer's capacity to deform. This might be attributed to the improved interfacial bonding between the filler & matrix, wherever stiffness is determined by the filler quantity, filler type, & filler dispersion similarity. These parameters, which determined the proper filler dispersion in the composite structure, may be checked by watching the composite's linear modulus increase [23]. By adding 9Percentage weight to the Ziziphus Spina-Christi bark, the flexural modulus qualities are limited. This is due to material aggregation & a lack of homogeneity between the filler & the cause polymer, which degrades the stiffness of the samples[24].

4.3.Hardness shore D

Figure 11. illustrates the hardness shore D values for the epoxy reinforced Ziziphus Spina-Christi bark The findings may indicate an increase in hardness with the addition of Ziziphus Spina-Christi bark, with 77 hardness shore D with 7 wt percent Ziziphus Spina-Christi bark. Increased Ziziphus Spina-Christi bark content owing to an increase in hardness. This might be because hardness is often thought to be a surface attribute, or because Ziziphus Spina-Christi bark includes materials that are harder than pure epoxy, resulting in a rise in hardness. The rationale for enhancing the hardness of composite materials is that the addition of filler results in a rise in resistance to plastic deformation; this outcome is consistent with [25].

4.4. Impact test

The impact strength results for the epoxy/Ziziphus Spina-Christi bark samples are shown in Fig. 12. With a powder content of 14.5 KJ/m^2 and a filler content of 7 wt percent, This characteristic implies increased adhesion

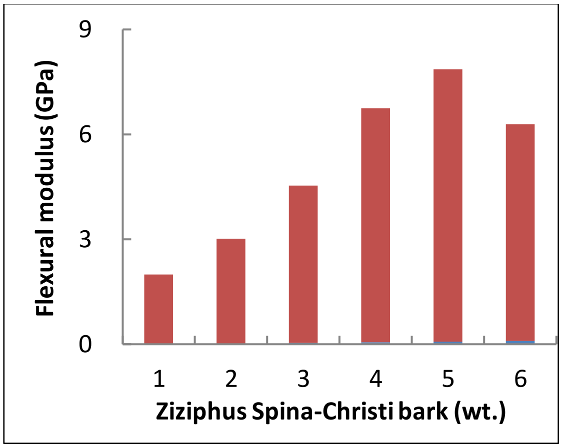


Figure 10. The flexural modulus of the specimen

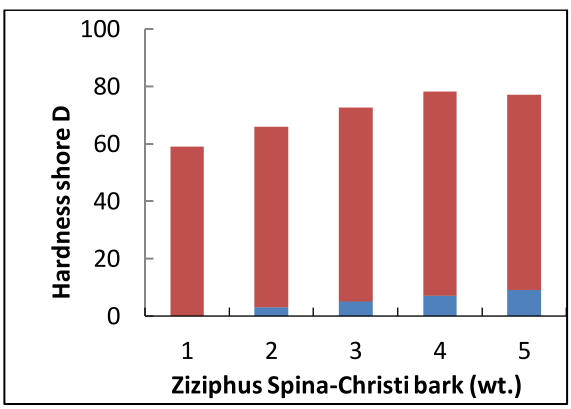


Figure 11. The hardness shore of the specimen

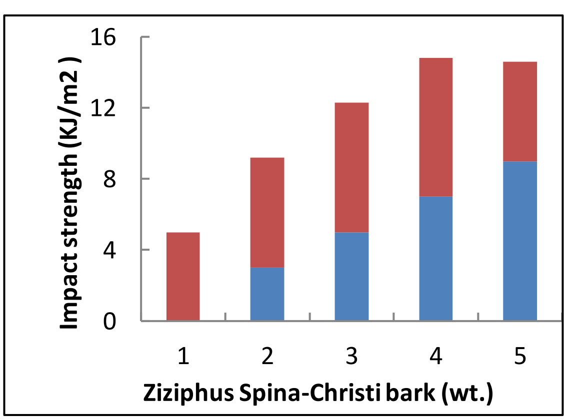


Figure 12. The impact strength of the specimen

of the filler matrix (epoxy) and was caused by the reduction of void spaces in polymeric composites. This may be because filler particles absorb more stress energy as their concentration in the matrix resin rises [26]. Additionally, this chart demonstrates that the impact strength is reduced with the addition of (9 percent by weight) Ziziphus Spina-Christi bark, indicating that the matrix resin is likely insufficient to effectively transmit the stress generated by a sudden impact when combined with the filler's low absorption capacity. A high filler content has been demonstrated to improve the possibility of fiber aggregation, resulting in regions of high stress that need less energy to propagate [27,28].

5. Conclusions

1. The tensile strength of samples epoxy/Ziziphus Spina-Christi bark powder rises with the addition of 5 percent and 7 percent weight fractions of Ziziphus Spina-Christi bark powder, but begins to diminish when the weight fraction of Ziziphus Spina-Christi bark powder is increased to 9 percent.

2. With the addition of 9 percent weight fraction Ziziphus Spina-Christi bark powder to the epoxy resin, the tensile strength reduced from (45 MPa to 40 MPa. This discovery may be explained by a lack of bonding between the resin and the filler, which resulted in the formation of microcracks at the interfaces during the loading of the sample composites.

3. Adding increasing weight fractions of Ziziphus Spina-Christi bark powder into epoxy resin results in the development of 3-properties of the elasticity modulus, while adding a higher weight fraction of Ziziphus Spina-Christi bark powder results in a reduction in 3-properties of the elasticity modulus. The nature of Ziziphus Spina-Christi bark powder in terms of high strength is responsible for this increase in the property modulus of elasticity.

When compared to the pure sample, the elasticity modulus values have increased by approximately (4 percent). This is because of the mean particle size of Ziziphus Spina-Christi bark powder in the epoxy resin & the ease with which the polymer matrix material diffuses into the epoxy resin. This indicates that the interfaces between the reinforcing material & the matrix material have been properly formed.

When Ziziphus Spina-Christi bark powder was added to epoxy resin, the modulus of elasticity reduced from (11 GPa to 9.2 GPa (9 percent weight fraction). This reduction is because of the reduction in deformation caused by the increased surface contact area between the matrix and reinforcement.

4. The flexural strength of pure epoxy is 160 MPa, & it increases linearly with the addition of Ziziphus Spina-Christi bark Ziziphus Spina-Christi bark until 173 percent, which is equivalent to 7wt. percent, but it decreases to 171 MPa with the addition of 9 percent Ziziphus Spina-Christi bark In conjunction with the addition of 9 percent weight of Ziziphus Spina-Christi filler, there is a decrease in structural integrity as a result of agglomeration & the existence of voids. This is the underlying reason for the lower flexural strength.

5. The flexural modulus of pure epoxy is 2 GPa, & it increases linearly with the addition of Ziziphus Spina-Christi bark, increasing by 7.8 GPa percent up to 7wt. percent Ziziphus Spina-Christi bark, but it decreases to 6.2 GPa with the addition of 9 percent Ziziphus Spina-Christi bark, indicating a reduction in strength. The addition of Ziziphus Spina-Christi bark at a concentration of 9 percent by weight results in a reduction in the flexural modulus characteristics. Due to aggregation of the material & homogeneity filler with the causing polymer, the stiffness of the samples is reduced as a result of this.

6. It is possible to see an increase in hardness with the addition of Ziziphus Spina-Christi bark content, with 7 weight percent Ziziphus Spina-Christi bark showing 77 with 7 weight percent Ziziphus Spina-Christi bark due to an increase in the hardness. The addition of fillers to composite materials results in a material that is more resistant to plastic deformation, which in turn increases the hardness rate of the composite material.

7. In the case of the epoxy/Ziziphus Spina-Christi bark samples, the impact strength results showed an 8.7 KJ/m2 with a 7 wt% filler adding; this behavior implies enhanced matrix (epoxy) filler adhesion, which may be attributed to the filler particles absorbing more stress energy as their presence in the matrix rises.

The impact strength drops with the addition of Ziziphus Spina-Christi bark (9 percent weight) to 7.5 KJ/m2 Ziziphus Spina-Christi bark owing to the matrix resin's inability to efficiently transmit the stress generated by a quick impact combined with the filler's poor water absorption characteristic. In certain circumstances, it has been shown that a great filler content enhances the possibility of fiber aggregation, resulting in areas of high stress that need less energy to propagate.

REFERENCES

[1] K. K. Chawala. springer Science+Business Media New York, Composite Materials: science and engineering (2013).

[2] M. Maraghni, M. Gorai, and M. Neffati, Seed germination at different temperatures and water stress levels, and seedling emergence from different depths of Ziziphus lotus, South African Journal of Botany,76 (3) (2010) 453–459.

[3] J. E. Richardson, L. W. Chatrou, J. B. Mols, R. H. J. Erkens, and M. D. Pirie, Historical biogeography of two cosmopolitan families of flowering plants: Annonaceae and Rhamnaceae, Philosophical Transactions of the Royal Society B: Biological Sciences, 359(1450) (2004) 1495–1508.

[4] M. Gorai, M. Maraghni, and M. Neffati, TPED Relationship between phenological traits and water potential patterns of the wild jujube *Ziziphus lotus* (L.) Lam. in southern Tunisia, Plant Ecology and Diversity, 3 (3) (2010) 273–280.

[5] B. Adzu, S. Amos, M. B. Amazon, and K. Gamaliel, Evaluation of the antidiarrhoeal effects of Zizyphus Spina-Christi stem bark in rats, Acta Tropica, 87 (2) (2003) 245–250

[6] K. K. Anand, B. Singh, D. Grand, B. K. Chandan, and V. N. Gupta, Effect of Zizyphus Sativa leaves on blood glucose levels in normal and alloxan-diabetic rats, Journal of Ethnopharmacology, 27(1-2) (1989)121–127

[7] M. Elaloui, A. Laamouri, A. Albouchi et al., Chemical compositions of the tunisian Ziziphus jujuba oil, Emirates Journal of Food and Agriculture, 26 (7) (2014)602–608.

[8] A. B. Abdul Hussein; E. S. AL-Hassani; R.A.Mohamed. , Influence of Coating with Some Natural Based Materials on the Erosion Wear Behavior of Glass Fiber Reinforced Epoxy Resin**,**(2015), 11(2), 20- 30.

[9] Suhas Y. N., Srinivas S. H. ; U. A. K; Linto G. T.; I. G., Pistachio Shell Flakes and Flax Fibres as Reinforcements in Polyester Based Composites*"*, International Conference on Engineering and Information Technology Held on 17th - 18th March 2017, in Kuala Lumpur, Malaysia ISBN: 9788193137314.

[10] R. Pragatheeswaran, S. Senthil Kumaran, Mechanical Behaviour of Groundnut Shell Powder / Calcium Carbonate /Vinyl ester Composite, International Journal of Current Engineering and Scientific Research, 2(2) (2015), 28-31.

[11] Lee, H., and Neville, K., Handbook of Epoxy Resins, McGraw-Hill, Inc., New York, 1975

[12] J. K. Oleiwi, S. I. Salih and H. S. Fadhil, Study Compression and Impact Properties of PMMA Reinforced by Natural Fibers Used in Denture, Engineering and Technology Journal, 36(6) ((2018)) 652-655.

[13] Annual Book of ASTM Standard, Standard Test Method for Tensile Properties of Plastics, D 638-03, PP. 1-12, 2003.

[14] Annual Book of ASTM Standard, "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics D 790- 86", Vol. 10.01 (1986).

[15] Annual Book of ISO- 180. Standard," Standard Test Methods for Unnotched Izod ImpactTesting of plastics", ISO-180, PP.1-2, (2006).

[16] A.B. Abdul-Hussein, E.S.Al-Hassani, R. A. Mohammed, Erosion Wear Behavior of Industrial Material Reinforced Epoxy Resin Composites and its Coating with Natural Based Material Eng. &Tech. Journal, 33(4), (2015) 902-918.

[17] J. K. Oleiwi, S. I. Salih & H. S. Fadhil, Effect of Siwak and Bamboo Fibers on Tensile Properties of Self-Cure Acrylic Resin Used for Denture Applications, Journal of Material Sciences and Engineering, 6(5) (2017).

[18] Annual Book of ASTM Standard**,** "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics D 790- 86", Vol. 10.01 (1986).

[19] S. I. Younis, J. K. Oleiwi, R. A. Mohammed, Some Mechanical Properties of Polymer Matrix Composites Reinforced by Nano Silica Particles and Glass Fiber, Engineering and Technology Journal, 36(12) (2018)1283- 1289.

[20] M. N. Prabhakar, Atta Ur Rehman Shah, K. Chowdoji Rao1, and J. Song, Mechanical and Thermal Properties of Epoxy Composites Reinforced with Waste Peanut Shell Powder as a Bio-filler, Fibers, and Polymers 16(5) (2015).1119-1124.

[21] P.A. Satapathy, A. Mahapatra, S. Dash, R. A comparative study on different ceramic fillers affecting mechanical properties of glass-polyester composites. J. Reinf. Plast. Compos. 28 (2009)1305–1320.

[22] A. M. Al-Ghabban, R. A. Mohammed, J. R. Mahmood, Analysing Some Mechanical Properties of Cinnamon Powder Reinforced with Polymeric Materials Used in Dental Application, Engineering and Technology Journal, 37(3),(2019).

[23] J. K. Oleiwi, S. I. Salih & H. S. Fadhil, Studying the Flexural Properties and Max. Shear Stress of Self Cure PMMA Resin for Denture Applications, The Iraqi Journal For Mechanical And Material Engineering, 17(4) (2017),746-75.

[24] R. S.Hadi and H..S.Fadhil The Mechanical Behavior of Polymer Composites Reinforced by Natural Materials. 25(2) (2021) , 2520-0917.

[25] G. U. Raju, S. Kumarappa, V. N. Gaitonde, Mechanical and physical characterization of agricultural waste reinforced polymer composites, J. Mater. Environ. Sci., 3(12) (2012), 907-916.

[26] P. A. Sreekumar, K. Joseph, G. Unnikrishnan, and S.Thomas, "A comparative study on mechanical properties of sisal-leaf fiber-reinforced polyester composites prepared by resin transfer and compression molding techniques", Composites Science and Technology, 67(3-4) (2007), 453–461.

[27] G. U. Raju, S. Kumarappa, V. N. Gaitonde , J. Mater. Environ. Sci., 3 (12) (2012), 907-916.

[28] P. A. S.; K. J.; G. U.; and S.T. Composites Science and Technology, 67 (3-4) (2007),453–461.