Ibn Al-Haitham Journal for Pure and Applied Sciences
Journal homepage: jih.uobaghdad.edu.iq
PISSN: 1609-4042, EISSN: 2521-3407
IHJPAS. 2025, 38(4)

Thermal and Mechanical Characteristics of Unsaturated Polyester and Epoxy Blend

Doaa J. Abed[1], Shatha H. Mahdi[2*] and Demiral Akbar[3]
[1,2]Department of Physics, College of Education for Pure Science(Ibn Al-Haitham), University of Baghdad, Baghdad, Iraq.
[3]Department of Mechanical Engineering, OSTİM Technical University, Ankara, Türkiye.
[*]Corresponding Author

Received: 23 January 2025 Accepted : 6 May 2025 Published: 20 October 2025
doi.org/10.30526/38.4.4120

Abstract

Epoxy resin and a mixture with unsaturated polyester resin (UPE) were prepared as the matrix materials. The preparation technique included preparing circular and square molds with different weight ratios. Standard samples (40 mm diameter) were prepared for thermal conductivity tests. The results of the thermal conductivity test of the mixture showed that it decreased from (0.014) to (0.013) significantly, which helps in thermal insulation. The decrease in its thermal conductivity means that the structure of the base material is irregular. Hardness test was performed on samples made of epoxy resin with unsaturated polyester resin, and the best hardness reading was (64.5), but when replacing the unsaturated polyester resin with a higher percentage of epoxy resin, the ratio was (30.6), so the value (30.6) is the best hardness value. The test results show that the highest hardness value is (64.5), as for the results of the differential scanning calorimetry measurement. From these curves, it is clear that the value of the glass transition temperature increases from 50 to 179, and the value of the glass transition temperature decreases from 171 to 145**.**

Keywords: Thermal conductivity, Hardness, Mechanical characteristics, Differential scanning calorimetry (DSC).

1. Introduction

Polymers are considered one of the most important materials used in industries. Polymers are used to improve mechanical and thermal properties. Mechanical properties are used because they are inexpensive (1-4). Some factors affect the mechanical properties of polymers, including particle size (5, 6) , amount, and type of additive. Polymers have several properties, including low weight and density (7) and very high resistance. Polymers have good mechanical properties, and through these properties, they help us use them in industry(8,9) . Epoxy resin has high temperature resistance(10). Polymers are mostly used to protect the surface of materials(11). The mechanical properties of materials are improved by mixing(12). That is why epoxy resin is used in industry, because it is highly insulating(13). In 2023, researcher Rehab R. studied the preparation of a wooden furniture treatment coating using mixtures (epoxy and unsaturated polyester) reinforced with pistachio shells. She used mixtures of epoxy and unsaturated polyester reinforced with nano powder from pistachio shells. The mixtures showed that the best mixtures are Blend1 and Blend2. The two coatings

were applied to two types of teak and Javanese wood, and she noticed a big difference in the results (14) . In 2016, Researcher Safaa studied some physical properties of epoxy reinforced with nanoparticles, using epoxy material, in different mixing ratios, to prepare nanocomposites of epoxy, to study the physical properties (15). The study aims to prepare polymer compounds that have mechanical and thermal properties that help us in industries.

2. Materials and Methods

2.1.The Materials

2.1.1. Epoxy Resin (EP)

Epoxy resin is considered one of the most important materials, to produce a material used in industries, mixing epoxy resin with other materials helps to improve the mechanical and thermal properties, epoxy turns into a solid material, by adding a hardener to it (17-19). epoxy resin was used, which was manufactured by Emirates Industrial Resins Company Limited.

Table 1. The Characteristics of Epoxy resins. (EP)

Properties	Epoxy resins(EP)
Sheif Life	2 Year
Color	pale yellow,Clear
Mixing Ratio	A:component B:2:1
Viscosity	200cps
Pot Life	30 Minutes

2.1.2.Unsaturated polyester resin(UPE)

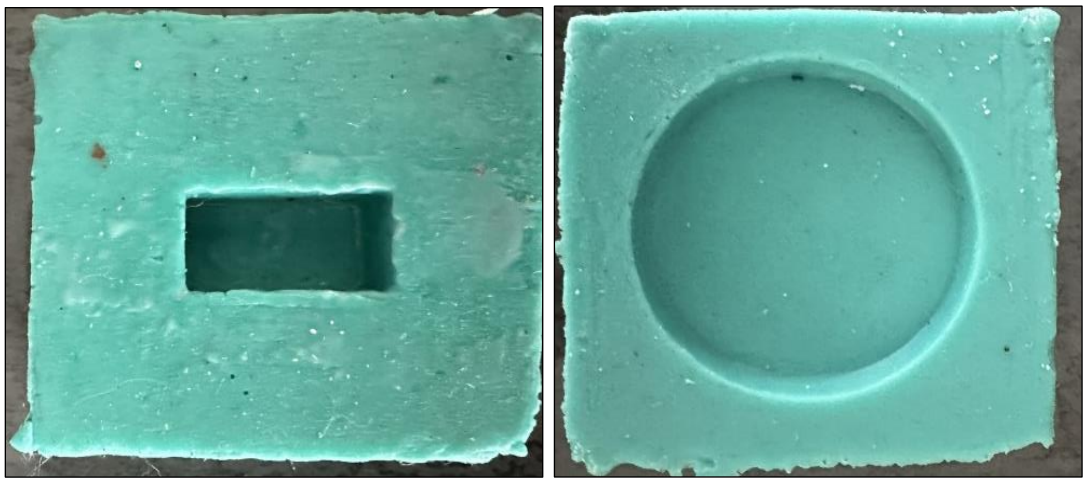
Unsaturated polyester resin is obtained from Saudi Industrial Resins Co. Ltd. The unsaturated polyester resin is mixed with hardener to turn into a solid material(19-21).

Table 2. The Characteristics of Unsaturated Polyester Resin

Properties	Unsaturated polyester resin(UPE)
Percent Solids	61-70%
Viscosity	450-700 cps
Acid Value	18-24
Flash Point Rang C	33

2.1.3. Preparation of Silicone Molds

Silicone molds were cast to obtain the sample shapes according to international specifications (ASTM standard) for each test, as shown in **Figure 1.**



a b

Figure 1. Silicone molds for the tests (a) Hardness (b) thermal conductivity.

2.2. Methods

Epoxy resin was prepared and hardener was added to it in a ratio of (1:3) and mixed for half an hour, then unsaturated polyester resin was used and hardener was added to it in a ratio of (2:98) and mixed, after which epoxy resin was mixed with unsaturated polyester resin and mixed for ten minutes, and **Figure 2** is a picture of the samples**.**

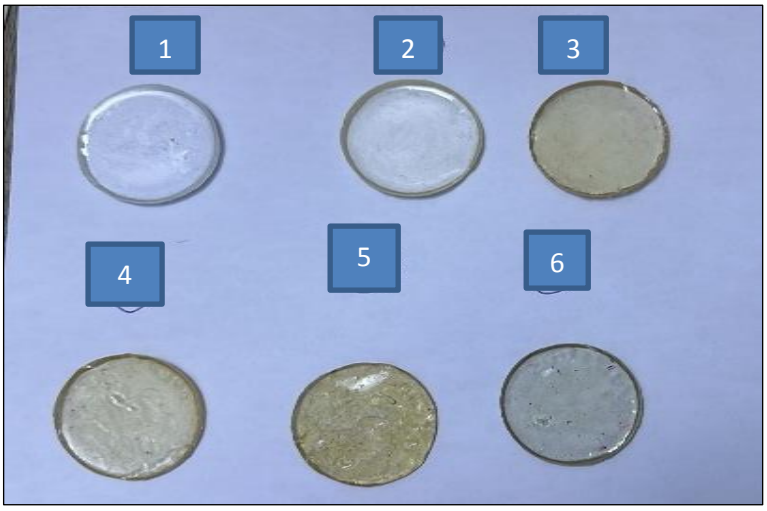


Figure 2. A photograph of polymer blends (EP+ UPE)

Table3: Shows percentage of polymer blends (EP+ UPE)

Sample No	EP	UPE
100%EP+ 0% UPE	18.75	0
80%EP+ 20% UPE	12	2.88
60%EP+40% UPE	6.75	0.31
40%EP+ 60% UPE	3	0.71
20%EP+ 80% UPE	0.75	1.25
0%EP+100% UPE	0	1.96

3. Results and Discussion

Thermal conductivity is one of the tests used to determine the thermal properties of polymers. The materials are mixed and placed in a circular mold (22, 23) then tested in a special device. The results are placed in a specific matrix, and thermal conductivity is determined (24, 25). The results of the thermal conductivity test of the mixture showed that it decreased from (0.014) to (0.013) significantly, which helps in thermal insulation. The decrease in its thermal conductivity means that the structure of the base material is irregular **(Figure 3)**.

Surface hardness testing was performed on the prepared samples using a Shore-D digital hardness tester. This device measures the width or area of the cavity as well as its depth. Six readings were taken for each sample. Unsaturated polyester resin has high hardness(26). Hardness of pure Unsaturated polyester resin increases to the highest values, due to the compatibility between the base material and the reinforcement materials (27, 28). Hardness test was performed on samples made of epoxy resin with unsaturated polyester resin, the best hardness reading was (64.5), but when replacing unsaturated polyester resin with a higher percentage of epoxy resin, the ratio was (30.6), so the value (30.6) is the best hardness value. The test results show that the highest **(Figure 4)**.

Differential scanning calorimetry (DSC) is a quantitative measurement of heat flow used to measure the temperature of a sample or time. This device is used to determine the behavior of a material with increasing temperature, as the curve gives information about the glass temperature, which changes the resin from a solid (glassy) liquid to a viscous liquid (29). From these curves, we determine the glass transition temperature. The glass transition temperature depends on the strength of the bond. The glass transition temperature decreases at the vacuum temperature (31, 32). Through these curves, it is clear that the glass transition temperature value increases from 50 to 179, and the glass transition temperature value decreases from 171 to 145. In the first curve, there is a clear decrease in temperatures, and the temperature begins to rise until it reaches the fourth curve, then the temperature decreases again from the fifth curve, and then decreases to the sixth curve **(Figure 5)**.

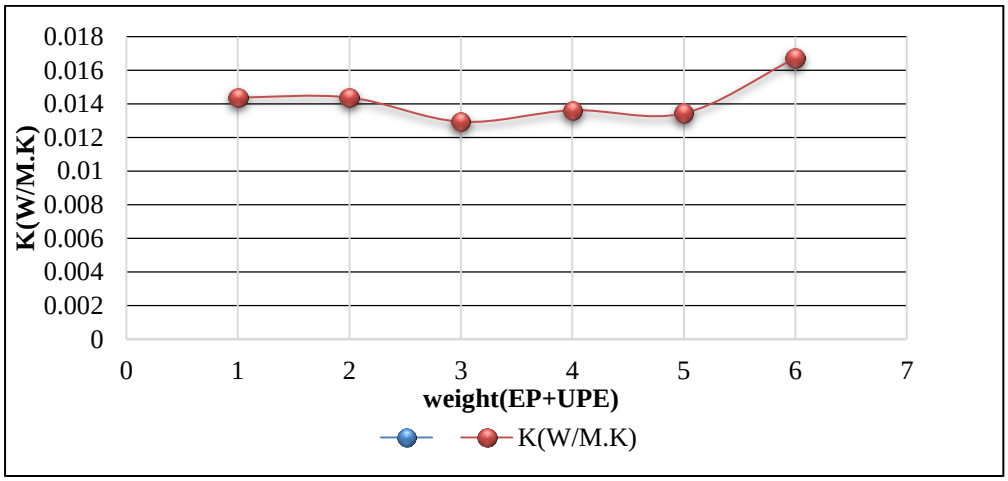


Figure 3. Shows thermal conductivity values of samples. (EP+UPE)

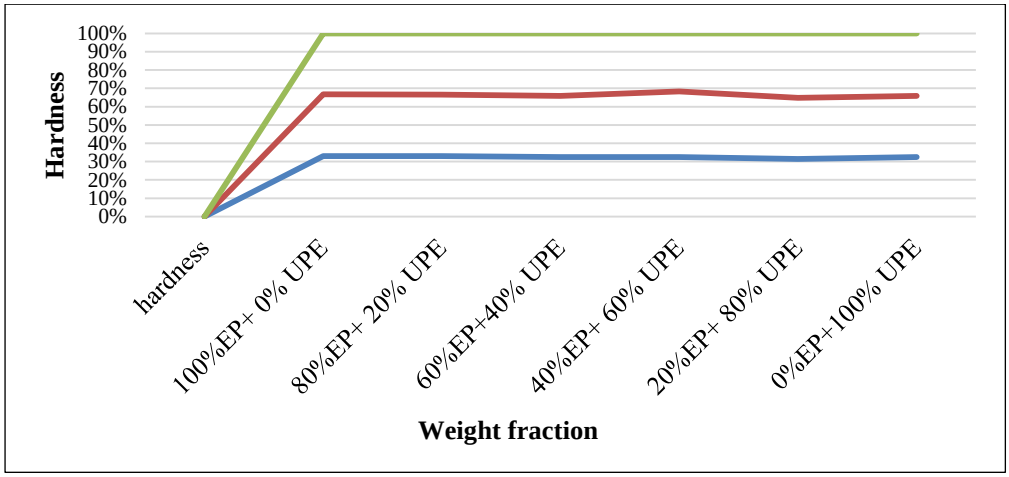
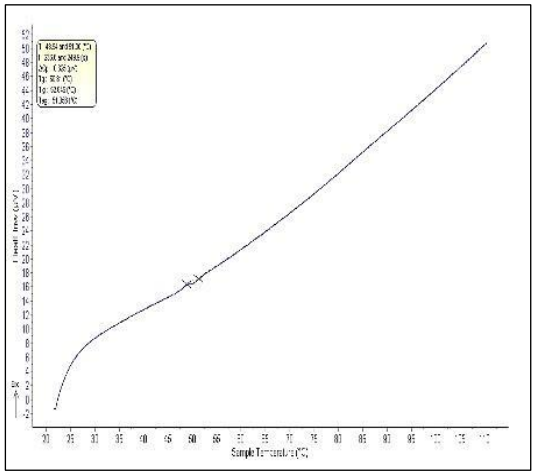
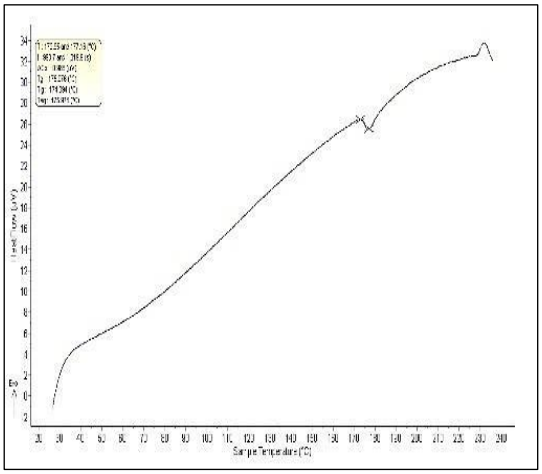


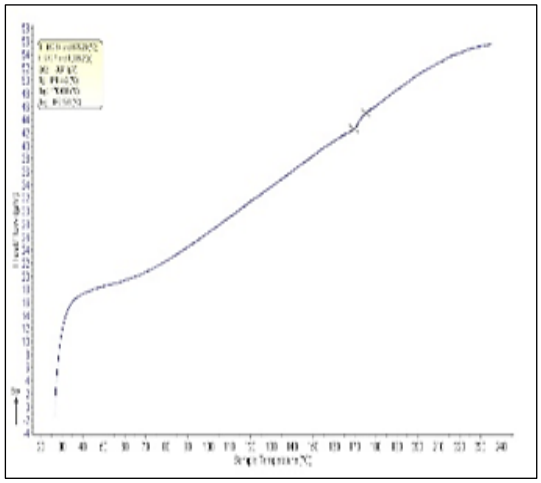
Figure 4. Shows hardness values of samples. (EP+UPE)



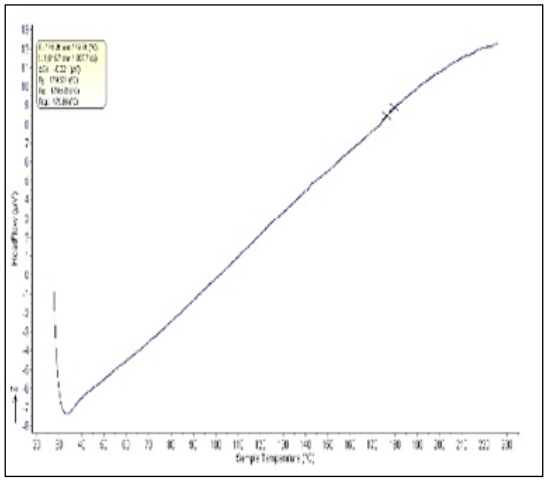
Glass transition temperature of the sample (1)



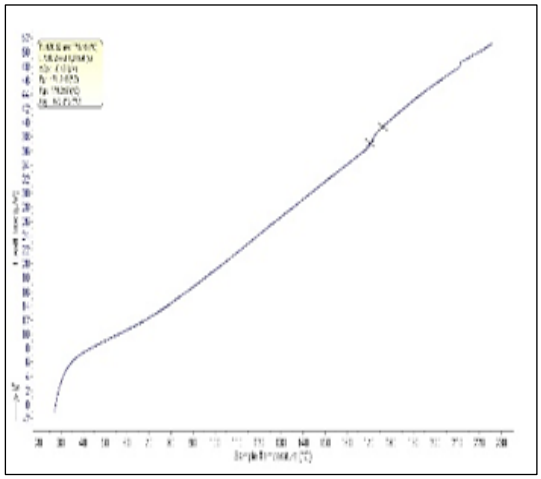
Glass transition temperature of the sample (2)



Glass transition temperature of the sample (3)



Glass transition temperature of the sample(4)



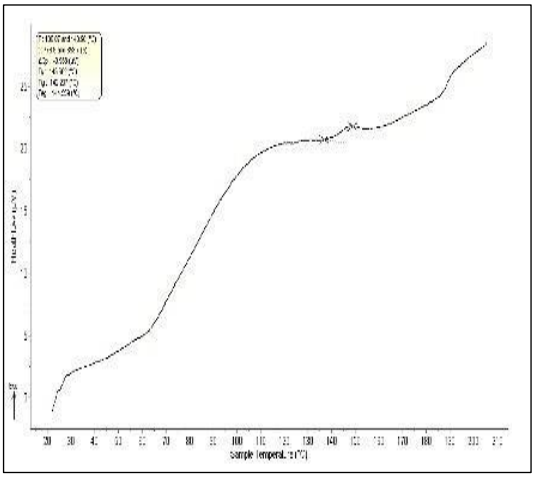


Figure 5. Shows the glass transition temperature values of the samples. (EP+UPE). Glass transition temperature of the sample (5). Glass transition temperature of the sample(6)

4. Conclusion

By studying pistachio shell powder, the following results can be reached: The results of the thermal conductivity test of the mixture showed that it decreased from (0.014) to (0.013) significantly, which helps in thermal insulation. The decrease in its thermal conductivity means that the structure of the base material is irregular.. Hardness test was performed on samples made of epoxy resin with unsaturated polyester resin, the best hardness reading was (64.5), but when replacing unsaturated polyester resin with a higher percentage of epoxy resin, the ratio was (30.6), so the value (30.6) is the best hardness value. The test results show that the highest As are for the results of the differential scanning calorimetry. Through these

curves, it is clear that the value of the glass transition temperature increases from 50 to 179, and the value of the glass transition temperature decreases from 171 to 145.

Acknowledgment

I would like to present my deep acknowledgment to the University of Baghdad, College of Education for Pure Science, Ibn Al-Haitham, Department of Physics, staff for their support. For providing analysis tests.

Funding

None.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

1. Lutfi R, Jassim W. Improvement of Dental Composite Resin Using Supra-Nano Chicken Thigh Bone Fibers. Ibn Al-Haitham J Pure Appl Sci.2023;36(2):165-170. https://doi.org/10.30526/36.2.2998.
2. Ali S, Al- Sarraf A. Influence of Bioactive and Bio-Inert Ceramic Powders on Tribology Properties of PMMA Composite Denture Base. Bi Eng.2022;57:1-8. https://doi.org/10.4028/p-3f74k7
3. Lutfi R, Jassim W. Fabrication natural gelcoats of (epoxy/coffee fibers) and (epoxy/cantaloupe fibers) composites with high wear and thermal resistance. AIP Con. 2023;2769(1):1-12. https://doi.org/10.1063/5.0129371.
4. Al- Sarraf A. Study the contrast of thermal expansion behavior for PMMA denture base, single and hybrid reinforced using the thermomechanical analysis technique (TMA). AIP Con.2023;2769(1):1-7. https://doi.org/10.1063/5.0129372 .
5. Fadhil F. Preparation and improvement of Thermal Expansion Coefficient and Impact Strength of (PMMA\CaAl2O4)system. ICP Pro.2019;1362(1):1-11. https://doi.org/10.1088/1742-6596/1362/1/012158.
6. Lutfi R, Jassim W. Improving the Mechanical Properties of Epoxy by Adding Sub-micron Cantaloupe Peel Fibers. Ibn Al-Haitham J Pure Appl Sci. 2023;36(2):156-169. https://doi.org/10.30526/36.2.2998
7. Haque M. Physico-mechanical properties of chemically treated palm and coir fiber reinforced polypropylene composites. Bi Tech. 2009;100(20):4903-4906. https://doi.org/10.1016/j.biortech.2009.04.072
8. Abidnejad R, Baniasadi H, Fazeli M, Lipponen S, Kontturi E, Rojas O, Mattos B. High-fiber content composites produced from mixed textile waste: Balancing cotton and polyester fibers for improved composite performance, International. IJBM.2025;292:1-10. https://doi.org/10.1016/j.ijbiomac.2024.139227
9. Fadhil R, Mahdi S. Effect of Pistachio Husks Powder Additive on Unsaturated Polyester Composites. Ibn Al-Haitham J Pure Appl Sci. 2023;36(2):191-200. https://doi.org/10.30526/36.2.3055
10. Yahyaa M. Aleabi S. Enhancing Some Mechanical Properties (Compression, Impact, Hardness, Young modulus) and Thermal Conductivity, Diffusion Coefficient of MicroEpoxy Composites. Ibn Al-Haitham J Pure Appl Sci. 2022;35(3):32-43. https://doi.org/10.30526/35.3.2841.
11. Hussein S. Hashim A. Jasim S. Ali N. Ali I. Rashad M. Abd-Elnaiem A. The structural, wettability, thermal, and electromagnetic irradiation shielding characteristics of acrylic polymer/graphene and acrylic polymer/graphene/carbon fiber hybrid polymers. DRM 2025;154:112-190. https://doi.org/ 10.1016/j.diamond.2025.112190

12. Abd El-Baki R, Abdullah A, Hakamy A, Abd-Elnaiem A. Nanoarchitectonics of Nickel Dimethylglyoxime/γ-alumina Composites: Structural, Optical, Thermal, Magnetic and Photocatalytic Properties. JIOPM, 2023;23: 3760-3778. https://doi.org/10.1007/s10904-023-02758-x.
13. Jasim S, Ali N, Hussein S. Al Bahir A ,Abd EL-Gawaad N. Sedky A. Mebed A, Abd-Elnaiem A. Enhancement of Mechanical Properties, Wettability, Roughness, and Thermal Insulation of Epoxy–Cement Composites for Building Construction.*Buildings*.2025;15(4):643. https://doi.org/10.3390/buildings15040643
14. Fadhil R, Mahdi S. Manufacture of wooden furniture paint using pistachio shell waste. JPCS.2024;2857:1-10. https://doi.org/10.1063/5.0183146
15. Hameed T. Study Of Some Physical Properties Ofstudy Of Epoxy Reinforce With Nano Particles. IJPH. 2017;15(32): 2070-4003 . https://doi.org/10.30723/ijp.v15i32.157
16. Žmindák M, Dudinský M. Computational Modelling of Composite Materials Reinforced by Glass Fibers. Pr Eng.2012;48: P 701-710. https://doi.org/10.1016/j.proeng.2012.09.573.
17. Mahdi S, Jassim W, H amad I, Jassim K. Epoxy/Silicone Rubber Blends for Voltage Insulators and Capacitors. En Pro. 2017;119:501-506. https://doi.org/10.1016/j.egypro.2017.07.059
18. Jassim K, Thejee M, Mahdi, S. Study characteristics of (epoxy–bentonite doped) composite materials. Ibn Al-Haitham J Pure Appl Sci. 2017;119:670-679. https://doi.org/10.30723/ijp.v13i26.289
19. Hirayama D, Nunnenkamp L, Braga F, Saron C. Enhanced mechanical properties of recycled blends acrylonitrile–butadiene–styrene/high–impact polystyrene from waste electrical and electronic equipment using compatibilizers and virgin polymers. Ap Pol.2021;139(13):1-11. https://doi.org/10.1002/app.51873
20. Rasheed Z, Hussein S. Experimental study of food waste powder FWP influence on compressive and wear behaviour of polyester composite. JPCS.2021;1795(012037):1-12. https://doi.org/10.1088/1742-6596/1795/1/012037.
21. Ahmad H, Waheed A, Aljundi I. Use of Aliphatic Polymeric Polyvinyl Amine as an Aqueous Phase Reactant During Interfacial Polymerization for Fabricating Efficient Organic Solvent Nanofiltration Membrane for Molecular Sieving. Po Sci.2025;63(8):1835-1847. https://doi.org/10.1002/pol.20240961.
22. Hamad Q, Hamad Q. Study the Effect of Nano Ceramic Particles on Some Physical Properties of Acrylic Resins.En Tech. 2017;35(2):124-129. https://doi.org/10.30684/etj.2017.127322.
23. Haq M, Burgueño R, Mohanty A, Misra M. Bio-based unsaturated polyester/layered silicate nanocomposites: Characterization and thermo-physical properties. CPA.2009;40(4):540-547. https://doi.org/10.1016/j.compositesa.2009.02.008.
24. Gupta H, Kumar H, Gehlaut A, Singh S, Gaur A. Sachan S, Park J. Preparation and characterization of bio-composite films obtained from coconut coir and groundnut shell for food packaging. MCW Man. 2022;24(2):569-581. https://doi.org/10.1007/s10163-021-01343-z.
25. Cecen V, Tavman I, Kok M, Aydogdu Y. Epoxy-and polyester-based composites reinforced with glass, carbon and aramid fabrics: Measurement of heat capacity and thermal conductivity of composites by differential scanning calorimetry. Po Com. 2019;30(9):1299-1311. https://doi.org/10.1002/pc.20695.
26. Obaid M, Berto N, Radhi S. Preparation and characterization of UHMWPE reinforced with polyester fibers for artificial cervical disc replacement (ACDR). Bi Sci. 2023;34(12):1758-1769. https://doi.org/10.1080/09205063.2023.2182576.
27. Azeez A, Rhee K. Park S. Hui D.Epoxy clay nanocomposites – processing. PAC Eng. 2013;45(1): 308-320. https://doi.org/10.1016/j.compositesb.2012.04.012.
28. Favasa A, Bavanish B. Nanoindentation and mechanical characteristic TiO_2/ polypropylene polymer nanocomposite. Na Bio. 2024;19(3): 1255-1263. https://doi:10.15251/DJNB.2024.193.1255.

29. Hamdi W, Habubi N. Preparation of epoxy chicken eggshell composite as thermal insulation. A C Soc. 2017;54:231-235. https://doi.org/10.1063/5.0184746.
30. Fadhil R, Jassi K.The Effect of Aluminum and Copper Powder on the Physical properties of the Epoxy Composite. Ph Conf 2018;1003(1):012082. https://doi.org/10.1088/1742-6596/1003/1/012082.
31. Jasim K, Fadhil R, Shaban A.The effects of copper additives on the glass transition temperature and hardness for epoxy resin. PI Eco. 2019;13(2):163-172. https://doi.org/10.1504/PIE.2019.099357.
32. Campana C, Leger R, Sonnier R, Ferry L, Ienny P. Effect of post curing temperature on mechanical properties of a flax fiber reinforced epoxy composite. CPA. 2018;107:171-179. https://doi.org/10.1016/j.compositesa.2017.12.029.