Advances in Nanoparticles, 2024, 13, 97-110
https://www.scirp.org/journal/anp
ISSN Online: 2169-0529
ISSN Print: 2169-0510

ZnO Influence on Thermophysical Characteristics of Natural Polymer-Based Nanofluids

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How to cite this paper: Arslan, M., Jamil, U., Bhatti, A.R., Yousaf, S. and Ahmad, Z. (2024) ZnO Influence on Thermophysical Characteristics of Natural Polymer-Based Nanofluids. *Advances in Nanoparticles*, **13**, 97-110.
https://doi.org/10.4236/anp.2024.134007

Received: January 28, 2024
Accepted: October 22, 2024
Published: October 25, 2024

Abstract

This thesis investigates the influence of zinc oxide (ZnO) on the thermophysical characteristics of natural polymer-based nanofluids. The focus is on pectin nanofluids with incorporated ZnO nanoparticles. In this experiment, varying concentrations of zinc oxide (ZnO) were combined with a constant amount of pectin to study their effects on the final solution's characteristics. Initially, ZnO and pectin solutions were prepared individually and subjected to magnetic stirring and sonication. The experiment involved three different concentrations of ZnO: 0.1 g, 0.02 g, and 0.03 g, while the weight of pectin remained constant at 0.05g throughout. After individual preparation, the solutions were mixed, further stirred, and subjected to sonication. Two analysis techniques, Scanning Electron Microscopy (SEM) and Thermogravimetric Analysis (TGA), were employed to characterize the samples. SEM provided insights into surface morphology and chemical composition, while TGA analyzed mass changes over temperature variations, offering valuable information on material properties. The significance and applications of these techniques in material characterization and analysis were discussed, highlighting their roles in understanding physical and chemical phenomena. The presence of ZnO nanoparticles enhanced the thermal stability of the pectin nanofluids. Contact angle measurements were performed to evaluate the hydrophilicity of the nanofluids. The contact angle trend indicated an increase in hydrophobicity with an increasing concentration of ZnO in the pectin nanofluids. The measured contact angles supported the high stability of the synthesized nanofluids. Overall, this study provides valuable insights into the incorporation of ZnO nanoparticles into pectin nanofluids and their impact on the thermophysical characteristics. The findings contribute to the development of nanofluids for potential applications in drug release and biomedical fields.

Keywords

Nano Fluids, Structural Analysis, Thermophysical Properties, Chemical Composition, ZnO

1. Introduction

The introduction of cooling systems is one of the most popular production technologies. Therefore, the selected heat transfer depth is crucial for energy growth, which is important for high efficiency. Nan-contemporary nanotechnology allows the production of nanometer-sized metallic or non-metallic particles. Nanomaterials have unique mechanical, optical, electrical, thermal, and magnetic properties. Nanoelement is produced by terminating nanoparticles with an average size of below 100 nm in conventional heat dissipation media such as water, oil, and ethylene glycol [1]. Very small When the number of guest nanoelements is uniformly disseminated and stabilized in the receiving liquid, the receiver can dramatically increase the thermal properties of the liquid. Ethylene glycol. When small amounts of guest Nano segments are evenly distributed and remain in the host fluid, the host fluid can greatly enhance the thermal properties of the host. Nanofluids (a suspension of liquid nanoparticles) is a term introduced by Choi (1995).

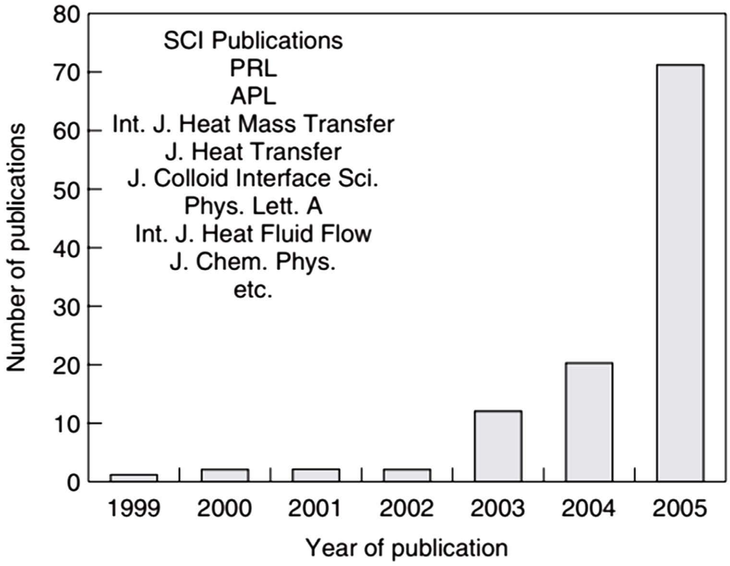

Figure 1. Annual SCI publications on nanofluids.

To mark out a current type of nanoscience based on heat dissipation fluid. Ordinary liquid suspension [2]. Nanofluids technology is an important interdisciplinary field that combines nanoparticles, nanotechnology, and thermal technology and has developed in recent periods. The purpose of the nanofluids is to obtain

Maximum thermal properties at the lowest concentration (Ideally 1%) by steadily stopping the nanoelement (preferably < 10 nm) in liquid hosts [3]. To do this, it is important to understand how nanoparticles transport energy. Because Choi invented a new theory of nanofluids in the year of 1993, expert and knowledgeable heat researchers and heat controllers from the rapidly evolving nanofluidic society have made scientific progress in detecting the unpredicted thermal characteristics of nanostructures, and have used nanostructured nanofluidic to enhance nanostructures. Possibility of developing new generation refrigerators, so as elegant refrigerators and safely cooled breeder furnaces [4]. The topic of nanofluids research is gaining worldwide attention. The recent increase in recent work in the nanofluids industry is most notable in the rapid increase in publications. **Figure 1** clearly shows the importance of nanofluid research. The Nanomaterials group has crafted more than 150 research papers on nanostructures since 1999 [5].

Journal of Scientific Quotation Index (SCI) such as Physical Assessment of Natural Materials

Letters and letters about electronic physics. Furthermore, increasing the number There are two articles that are published every year and two indicators that give weight. The view that nanofluid research is becoming more and more vibrant and important. First, world-renowned institutions such as the Massachusetts Institute of Technology (MIT), Leeds University, and the Royal Swedish Institute of Technology have established nanofluid research teams or interdisciplinary nanofluid research centers. Several universities have earned doctorates in this emerging nanotechnology field. Second, small businesses and large multinationals in different industries and markets are working on this prospect. Their special applications. The growing interest in nanofluids has made it possible to develop an ultra-high-performance refrigerator, whose thermal properties are fundamentally different from those of a conventional refrigerator, as nanostructures such as nanostructures are one of the main nanostructures in the nanoscale. Size, shape and surface interface. The main purpose of this introduction is to describe the big picture [6]. A small world of nanostructures through some of the most important general concepts in history Significant stages such as the concept of nanofluid, the production and performance of nanofluid, the mechanism and **prototype** of nanofluid, the potential application and advantage of nanofluids. Finally, research on the basis and application of future nanofluids was discussed [7]. The direction of future research described in this chapter is incomplete, but it explains how to address the challenges associated with advancing nanofluids theory and expanding nanofluids production. The nano-liquid is designed to achieve super-high-performance cooling [5].

2. Materials and Method

2.1. Materials

I. Zinc oxide (which is in pure form *i.e.* white powder).

II. Pectin (which is obtained from cell wall of plants.
III. Deionized water purchased from sigma-Aldrich.

2.2. Apparatus Used during Synthesis

Following apparatus are used during synthesis of these experiments is shown in Figure 2.

I. Beaker.
II. Beaker magnet.
III. Sonicator.
IV. Balance weight.

Figure 2. Various apparatus, including beakers, magnetic stirrers, sonicators, and balance weights, are employed during the synthesis process.

2.3. Synthesis

2.3.1. Sample 1

Zinc oxide is initially weighed by balance Weight, which was 0.1 g and then it mixed with 20 ml deionized water in a beaker. This solution heated about one hour (10.20 to 11.20) while keeping magnet in it and process is called magnetic stirring. After magnetic stirring this solution is kept on Sonicator (a device which provide sound energy to solution) about three hours (11.53 - 2.53) and this process is called sonication.

2.3.2. Sample 2

Now pectin is initially weighed by balance weight which was (0.05 g) and then it mixed with 20 ml deionized water in a beaker. This solution heated about one hour (10.46 to 11.46) while keeping magnet in it and process is called magnetic stirring. After magnetic stirring this solution is kept on Sonicator (a device which provide sound energy to solution) about three hours (11.53 - 2.53) and this process is called sonication.

2.3.3. Sample 3

In this experiment both solution of ZnO (0.01) and pectin (0.05) are kept on hot plates for magnetic stirring individually. After this, these solutions are mixed and magnetic stirring is done again for half an hour and then sonication is done in three hours.

2.3.4. Sample 4

Both solutions of ZnO (0.02) and pectin (0.05) in this experiment are kept on hot plates for magnetic stirring individually. After this, these solutions are mixed and magnetic stirring is done again for half an hour and then sonication is done in three hours.

2.3.5. Sample 5

Now solutions of ZnO (0.03) and pectin (0.05) are kept on hot plates for magnetic stirring individually. After this, these solutions are mixed and magnetic stirring is done again for half an hour and then sonication is done in three hours (only weight ZnO weight is changed in 3, 4 and 5 experiment).

2.4. Analysis Techniques

Different techniques are used for analysis of samples, two are described here: SEM and TGA.

2.4.1. Scanning Electron Microscopy (SEM)

The scanning electron microscope (SEM) uses a focused high-energy electron beam to generate a variety of signals on the surface of solid materials. Signals caused by the interaction of electrons with the sample provide information about the sample, such as external morphology, chemical formation, crystal structure, and the direction of the materials that make up the sample. In most applications, data is collected in a selected area of the sample surface and a 2D image is generated, indicating a change in the spatial properties of these properties. When scanning, you can specify SEM areas with a width of about 1 cm to 5 microns. SEM can also analyze specific points in a sample. This method is particularly useful in determining the quality or half-life of a chemical.

1) Fundamental Principles of Scanning Electron Microscopy (SEM)

The fast electrons in the SEM contain a large amount of kinetic energy, which is transmitted in the form of various signals generated by the interaction pattern of electrons. Electron drops in solid samples. These signals include the secondary electron (SEM image), the scattered electron (BSE), and the scattered electron scattered electron (EBSD), which are used for the initial analysis of the crystal structure and X-rays.), Visible light (cathodoluminescence-CL) and heat. In addition, secondary electrons and scattered electrons are used in sampling: the most valuable in describing the morphology and structure of the secondary electron samples are the scattered electrons in the multi-stage sample composition. The occurrence of X-rays is caused by the collision of electrons with incident electrons in the disk orbit (shell) of the atoms in the sample. When the excited electrons return to a low-energy state, they emit X-rays at a fixed wavelength (due to the difference in the energy levels of the electrons in the different shells of a particular element), so that X-rays of each element in the mineral are generated by electronic light. SEM analysis is considered to be "non-destructive" *i.e.* X-rays generated by the interaction of electrons do not cause loss of sample size, so the same materials can be re-analyzed is shown in **Figure 3**.

Figure 3. In scanning electron microscopy (SEM), fast electrons interact with solid samples, generating various signals such as secondary electrons (SEM image), backscattered electrons (BSE), and characteristic X-rays.

2) Applications of SEM

1—SEM is mainly used to generate high-definition (SEI) images of body shapes and to show spatial changes in chemical composition.

2—It is also used to acquire elemental maps. It is used by CL to differentiate the phases based on the differences in the "activators" of the micronutrients (usually transition metals and rare earths), based on a composite map of the average atomic number.

3—SEM is widely used in qualitative chemical analysis or phase identification based on crystal structure. Very small components and objects with a size of 50 nm are used for accurate measurement.

2.4.2. Thermogravimetric Analysis

Thermogravimetric analysis (TGA) is a heat analysis technique in which the mass of the sample is measured over time and the temperature changes. This measurement provides information on physical phenomena such as phase change, absorption, absorption, absorption, and chemical phenomena is shown in **Figure 4**.

Figure 4. Thermogravimetric Analysis (TGA) measures sample mass changes over temperature, offering insights into physical and chemical phenomena, especially useful for polymer analysis.

1) Working principle of TGA

Any typical thermographic analyzer consists of a clear balance with a sample boiler installed inside the oven with a program control temperature. Temperatures usually rise at a steady rate (or in some applications, the temperature is adjusted for constant weight loss) to produce a thermal reaction. Thermal reactions occur in a variety of environments, such as air, vacuum, inert gas, oxidation gas, gas reduction, corrosive gas, carbon dioxide, liquid vapor, or "self-generated atmosphere"; There are also various pressures, such as high vacuum, high pressure, constant pressure or controlled pressure. Thermogravimetric collections of thermal reaction data are plotted on a graph of the mass or time of the x-axis or the mass of the time or the initial mass. Most of these smooth looking graphics are called TGA curves. The first derivative of the TGA curve (DTG curve) can be planned to provide in-depth explanations as well as turning points useful for heat analysis. It is used to describe materials by analyzing the degradation model using

TGA. It is a particularly useful technology for the investigation of polymeric materials such as thermoplastic, thermoset, elastomer, compound, plastic film, fiber, glaze, paint and fuel.

3. Results and Discussion

3.1. Spectral Study of Nanofluids

SEM micrographs of Zinc Oxide incorporated pectin nanofluids Uniform distribution of Nano filler in base fluid is studied from scanning electron microscope (SEM) at different magnification for neat fluid versus filler reinforced nano fluid. **Figure 5** is depicted the SEM micrograph of designed nanofluids. **Figure 5** is for pectin nanofluids and **Figure 5** is for three different loading of ZnO in pectin based fluid-SEM morphological structure elucidate the even distribution of nano loading in based fluid which enhance the stability of designed nano fluid that may help for successful application of drug release. Barrel electron microscopy (SEM) analysis revealed a uniform distribution of ZnO nanoparticles in the pectin-based fluid, indicating higher stability of the nanofluid have diameter 100 micro meter and less than this. By Adding spherical nanoparticles to the lubricating fluid reduces friction and increases friction [8]. Resistance can be achieved on a variety of surfaces. The preparation of nanofluid solidity depends on the pH value, accumulation and deposition of particles. Aggregation of nanoparticles in a liquid forms a cluster cation that reduces the thermal conductivity of the liquid. Aggregation forming due to Vander Waals coherent forces between particles.

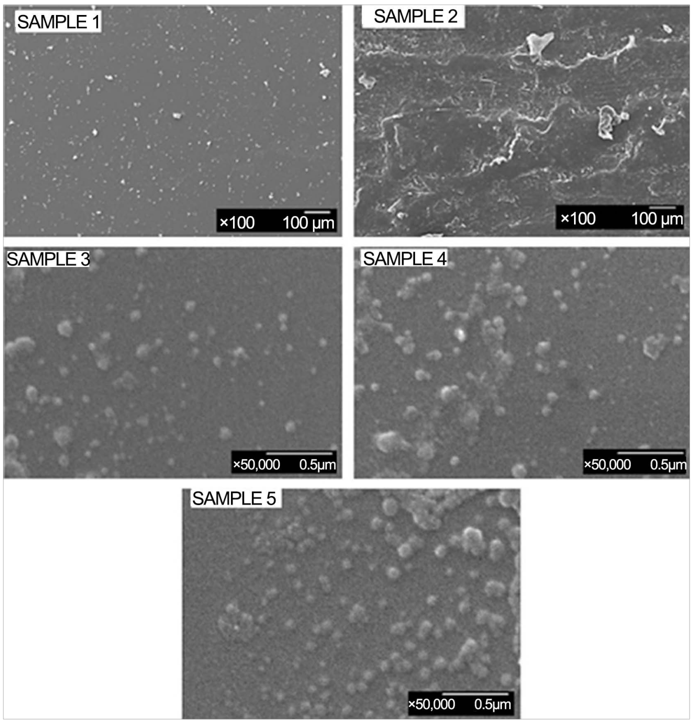

Figure 5. SEM Micrographs of ZnO reinforced Pectin designed nanofluids.

3.2. FTIR Spectra of ZnO Incorporated Pectin Nanofluids

Functional group study is done with Fourier transform infrared spectroscope (FTIR) **Figure 6** is shown the FTIR spectra of ZnO loaded pectin nanofluid. It is clear from transmit ions pattern of the design nanofluid in the figure print region from the range of 900 cm to 1300 cm showed the presence of carbohydrate of major identification of typical chemical group of polysaccharides carboxyl group and ester group are present in the FTIR spectra from the range of 1600 cm to 1700 cm and 1725 cm to 1825 cm respectively [9]. The effect of C=O in the range of 2800 cm to 3000 cm due to the effect of bond starching. As clear form **Figure 6**, sample 1 contains the FTIR SPECTRUM of ZnO which shows the IR absorption of in figure print region 700 to 500 cm and the remaining spectra the effective doping the ZnO in pectin which is a good promise of beneficial preparation of design nano fluid for biomedical application [10].

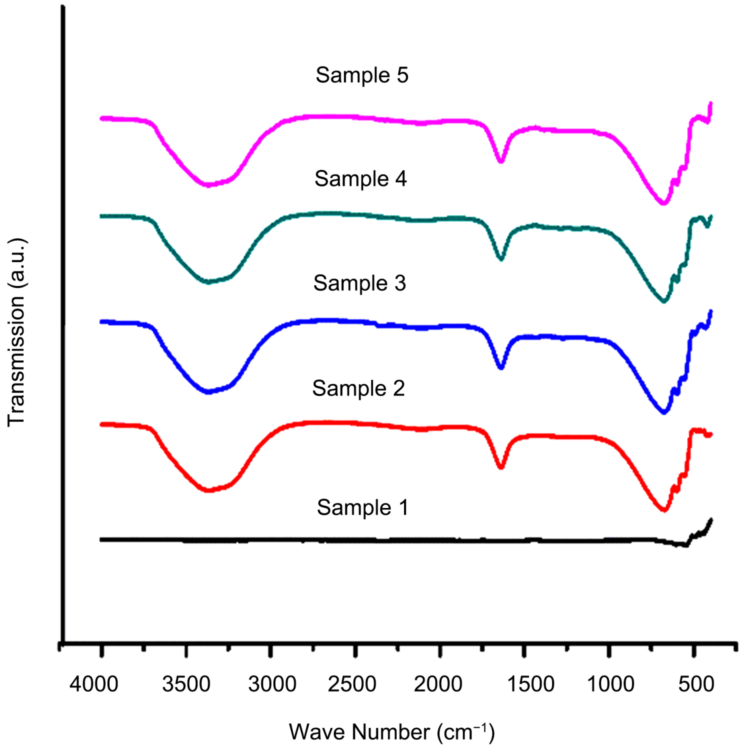

Figure 6. FTIR spectra of ZnO reinforced Pectin designed nanofluids.

3.3. EDX Analysis of Zinc Oxide Incorporated Pectin Nanofluids

EDX (Energy dispersive x-ray) study is performed to study the elemental analysis of resultant ZnO impregnated pectin nano fluid. **Figure 7** contains the EDX spectra of ZnO, pectin, and ZnO/pectin nano fluid. Sample 1 contains ZnO nano fluid with presence of Zink and oxygen sample to be EDX of pectin with carbon and oxygen presence and sample 3 comprise the existence of ZnO in cooperate pectin nano fluid [11]. **Figure 7** EDX analysis of ZnO reinforced Pectin designed nanofluids.

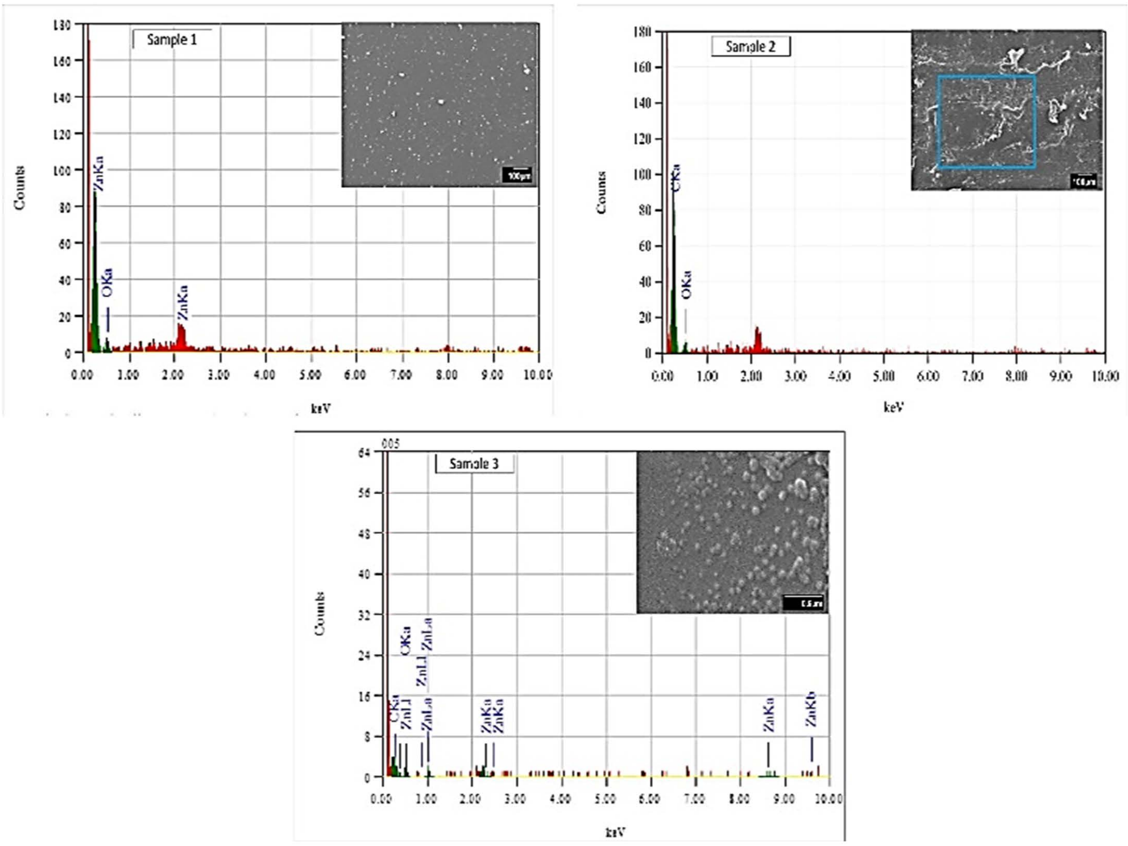

Figure 7. EDX analysis of ZnO reinforced pectin designed nanofluids.

4. Thermal Study of Nanofluids

4.1. Thermogravimetric Analysis of ZnO Incorporated Pectin Nanofluids

Thermogravimetric analysis is accomplished to study the thermal degradation response form room temperature to 600 c with 10 c rise per minute in oxygen environment [12]. **Figure 8** is discussed the thermograms of designed nanofluids with three steps of mass loss the first stage is associated with the evaporation of water vapor, second stage is related to the pyrolysis of the mean carbon chain of polymeric material and third stage is the combustion of remaining material of design nano fluid. Sample 1 (ZnO nanofluid) delay in second stage then the neat pectin nano fluid (sample 2) but with increasing the concentration of nano loading in polymeric matrices enhance the thermal stability of ZnO reinforced pectin nanofluid [13].

4.2. Stability Test Excellent

Contact Angle of ZnO Incorporated Pectin Nanofluids

Contact angle measurement is useful to judge the hydrophilic of designed nano fluid. **Figure 9** is the contact angle images with glass surface to nano fluid. Contact angle trend is as sample 1 < 2 < 3 < 4 < 5 with increasing concentration of ZnO in pectin nano fluid [14]. The measure contact angle of design nanofluid is 30 c, 52, 65, 75, 83, which express the increased hydrophobicity of synthesize nano fluid that is the clear evidence of high stability of nanofluid [15].

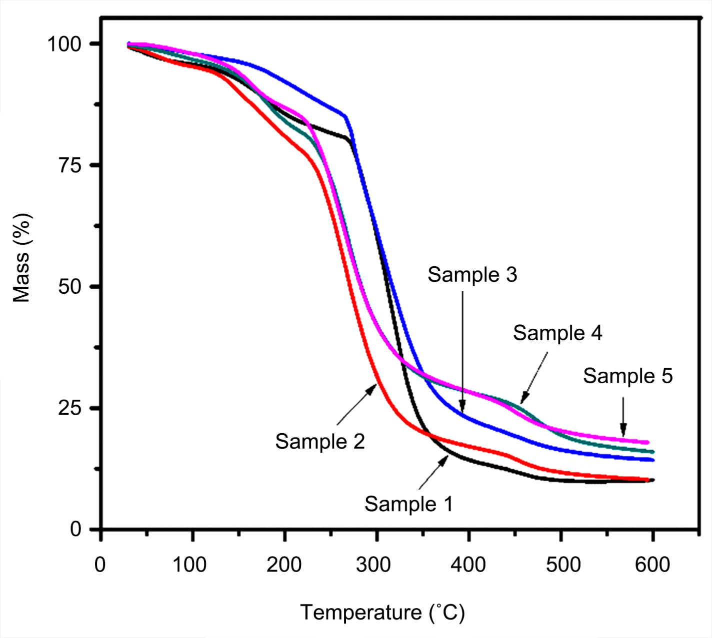

Figure 8. Thermogravimetric analysis of ZnO reinforced pectin designed nanofluids.

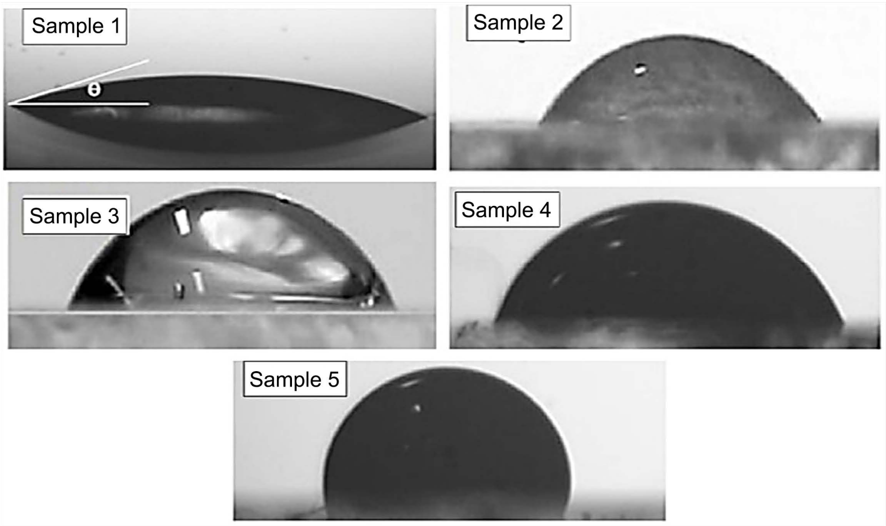

Figure 9. Contact Angle measurements of ZnO reinforced pectin designed nanofluids.

4.3. Antimicrobial Study

Figure 10 antimicrobial test is performed to the antibacterial activity with E. coli (Escherichia coli) gram–ve. Disc diffusion is used to study this activity in L. Agar [16]. **Figure 10** is depicted the photograph of this activity with 5 samples with increasing concentration of ZnO. The at most concentration provide the maximum antibacterial activity which maintain its usage as biomedical application [17].

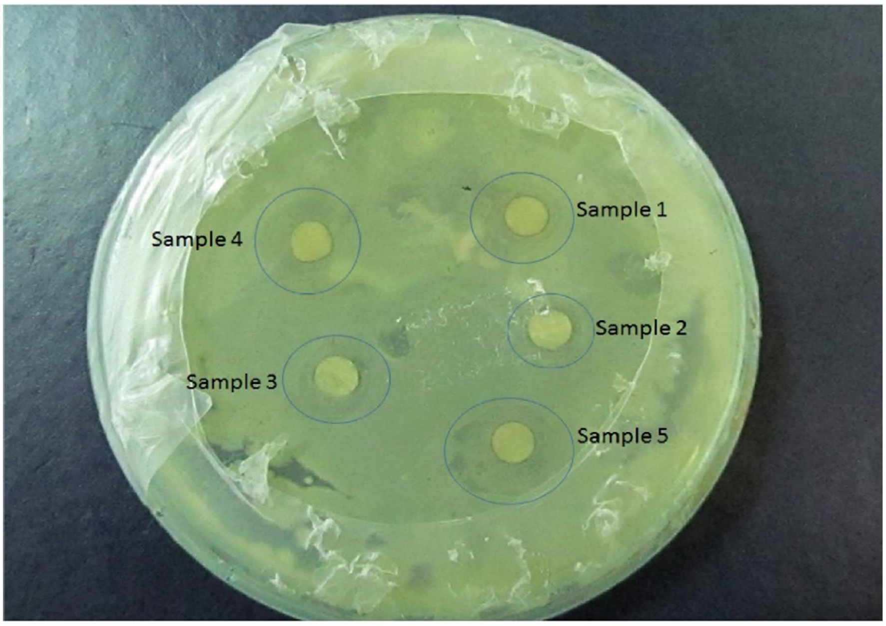

Figure 10. Antimicrobial activity of ZnO reinforced Pectin designed nanofluids.

5. Conclusion

This thesis is narrated the novel study of ZnO reinforced pectin nano fluid for bio medical application. The two steps method is used to synthesize with various concentration of ZnO in natural polymer based nano fluid. Structural, thermal, stability and antibacterial studies are done to confirm the beneficial preparation of novel nano fluid. Morphological study support the spectral investigation with the successful achievement of design nano fluid. Thermal study reveals that with the addition of nano filler in natural polymer thermal study is improved 30% against neat nano fluid. Contact angle attitudes shows great hydrophobicity with addition of nano reinforcement in base fluid. The designed nano fluid gives the outstanding response against gram–ve bacteria which is admirable for bio medical application such as drug release and cancer treatment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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