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Compatibility Studies of Guar Gum (GG)/Methyl Cellulose (MC) Blend-Zinc Oxide (ZnO) Nanocomposites

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ABSTRACT

This original research article focuses on the burgeoning significance of nanocomposites in biomedical and pharmaceutical domains due to their heightened properties. The research aims to assess the compatibility of Guar Gum (GG)/Methyl Cellulose (MC) blend-Zinc Oxide (ZnO) nanocomposites using a range of analytical techniques. ZnO nanoparticles were synthesized utilizing banana leaf extract and zinc acetate solution. To validate compatibility within the aqueous solutions, the study employed density measurement, ultrasonic velocity measurement, and adiabatic compressibility measurements. The characterization of the morphology of thin films prepared via the solution casting-solvent evaporation method was accomplished through FESEM analysis. The outcomes unveiled the compatibility and stability of GG/MC blend-ZnO nanocomposites in aqueous solutions, presenting these materials as promising candidates for diverse biomedical and pharmaceutical applications. This study significantly contributes by examining the compatibility of GG/MC blend-ZnO nanocomposites through an array of analytical methods.

Keywords: nanocomposites, guar gum, methyl cellulose, zinc oxide, compatibility, biocompatibility.

1. INTRODUCTION:

Nanocomposites refer to materials that are composed of nanoparticles embedded in a matrix material, which possess distinct properties compared to conventional materials [1-3]. Guar

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gum (GG) is a water-soluble fiber obtained from the seeds of the guar plant, and is widely known for its biocompatibility, indicating that it does not cause any harm or irritation to living tissues [4-7]. Methyl cellulose (MC) is a cellulose derivative that is commonly used in the food, pharmaceutical, and cosmetic industries as a stabilizer, thickener, and emulsifier. Its non-toxic and biocompatible features have led to extensive research on its potential applications in biomedical fields, such as tissue engineering scaffolds and drug delivery systems [8-11].

Recently [12, 13], there has been growing interest in developing novel nanocomposites with enhanced properties by combining biocompatible polymers with nanoparticles, such as zinc oxide (ZnO). Before these nanocomposites can be employed in practical applications, it is crucial to assess their compatibility and stability. Therefore, this investigation aims to examine the compatibility of GG/MC blend-ZnO nanocomposites using various analytical techniques.

To confirm the compatibility of nanoparticles incorporated blends in aqueous solutions, simple and cost-effective methods, such as density measurement, ultrasonic velocity measurement, and adiabatic compressibility measurements, were utilized. By comprehending the compatibility and stability of these nanocomposites, we can enhance their properties and establish a pathway for their application [17] in various biomedical and pharmaceutical domains.

2. MATERIALS AND METHODS:

The study utilized biocompatible polymers, guar gum and methylcellulose, as matrix materials. Zinc acetate purchased from Merck, Mumbai, India was used for the green synthesis of ZnO nanoparticles in the solution, and double distilled water was used for the experiment. Banana leaf (leaf of *Musa acuminate*) was used for the preparation of ZnO nanoparticles in distilled water using a procedure described elsewhere [18]. Fresh banana leaves were washed with distilled water, cut into small pieces, blended in a mixer with distilled water to obtain a fine paste, and filtered using Whatman filter paper to obtain a clear extract. 10 mL of the banana leaf extract was mixed with 90 mL of 0.1 M zinc acetate solution, heated in a water bath at 60°C with constant stirring for 2 hours, and the color of the solution changed to yellowish white, indicating the formation of ZnO nanoparticles. The prepared solution was used for the preparation of pure polymer and blend-nanocomposite solutions.

Stock solutions of GG and MC were prepared separately (0.5 w/v) in the ZnO nanoparticle solution with ultrasonication. GG/MC blend-ZnO nanocomposites of different compositions (10/90, 20/80, 30/70, 40/60, 50/50, 60/40, 70/30, 80/20, and 90/10) were prepared by mixing the stock polymer solutions.

Ultrasonic velocity measurements of GG-ZnO nanocomposite, MC-ZnO nanocomposite, and GG/MC blend-ZnO nanocomposite solutions of 0.5 % (w/v of polymer) were conducted at 30ºC and 40ºC using an interferometric technique and an ultrasonic interferometer (Mittal Enterprises, New Delhi) at a frequency of 2 MHz. The densities of the GG/MC blend-ZnO nanocomposites solutions (0.5 % w/v of polymer) were measured at 30ºC and 40ºC using a specific gravity bottle. The thermostat bath was used to maintain different temperatures with a thermal stability of ± 0.05ºC.

Thin films of GG-ZnO, MC-ZnO, and GG/MC blend-ZnO nanocomposites were prepared using the solution casting-solvent evaporation method. The morphology of the prepared thin films was characterized using the FESEM method.

3. RESULTS AND DISCUSSIONS:

3.1 UV-Vis characterization of synthesised ZnO nanoparticles

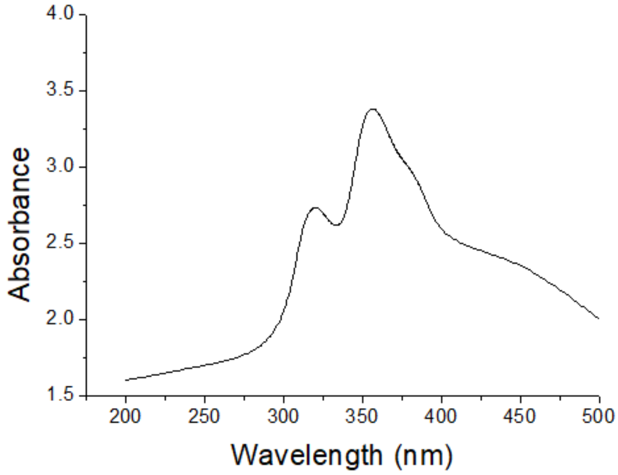


Fig. 1: UV-Vis spectroscopy of synthesised ZnO nanoparticels in solution

The ZnO nanoparticles, which were synthesized using banana leaf extract and zinc acetate solution, were characterized using UV-Visible spectroscopy. The absorbance spectra of the synthesized ZnO nanoparticles exhibited a characteristic peak (Figure 1) at approximately 355 nm, which is consistent with ZnO nanoparticle absorption [19, 20].

3.2 Density measurements

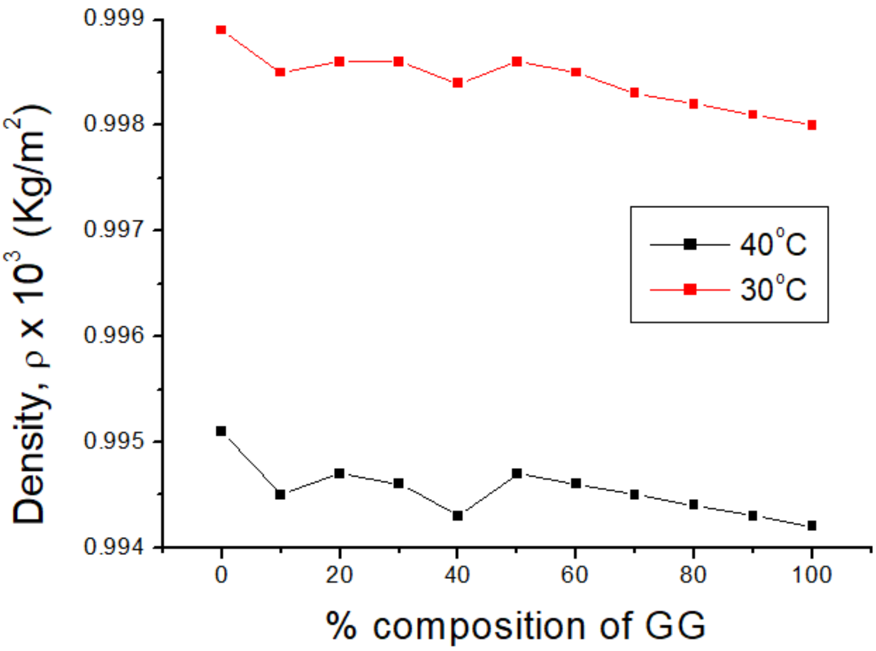


Fig. 2: Variation of density for GG/MC blend-ZnO nanocomposites

Previously [21], density values (ρ) of pure GG were determined to be $0.9972x10^3$ Kg/m^3 and $0.99376x10^3$ Kg/m^3 at 30°C and 40°C, respectively. For GG-ZnO nanocomposites, the values were found to be $0.9980x10^3$ Kg/m^3 and 0.9942 $x10^3$ Kg/m^3. Similarly, pure MC had density values of $0.9985x10^3$ Kg/m^3 and $0.99525x10^3$ Kg/m^3 at 30°C and 40°C, respectively, while MC-ZnO nanocomposites had values of $0.9989x10^3$ Kg/m^3 and $0.9951x10^3$ Kg/m^3, respectively. The density studies of GG/MC blend indicated that all compositions were immiscible. The graph (Figure 2) showed both linear and non-linear regions. Non-linearity was observed in compositions 10/90, 20/80, 30/70, and 40/60, confirming their incompatibility, while linearity was observed in compositions 50/50, 60/40, 70/30, 80/20, and 90/10, indicating compatibility [22, 23]. Therefore, the density measurement method suggests that GG/MC blend-nanocomposites are compatible when the GG composition is 50% or more.

3.3 Ultrasonic velocity measurements

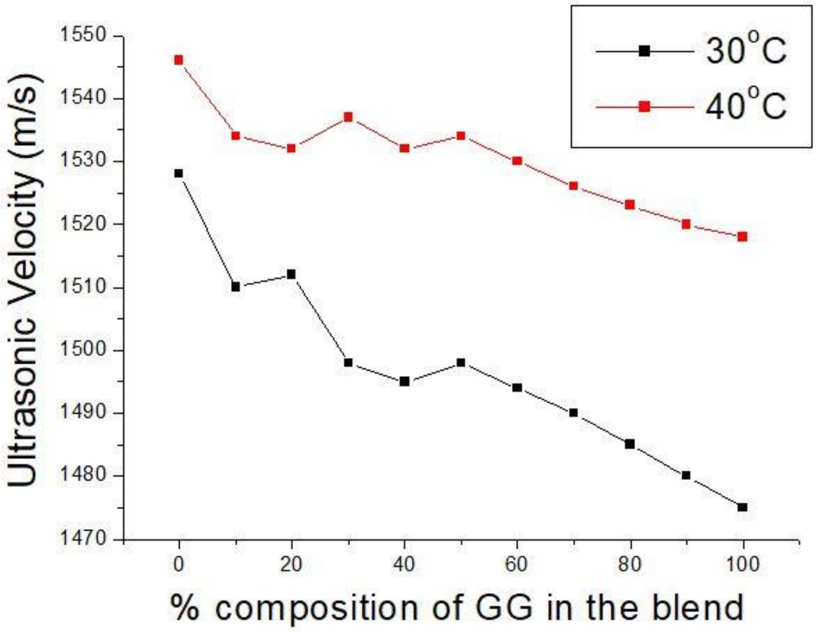


Fig. 3: Variation of ultrasonic velocity for GG/MC blend-ZnO nanocomposites

In a previous study [21], we investigated the compatibility of GG/MC blends using the ultrasonic velocity measurement method to determine the values of ν for pure GG, MC, and their blends. The values obtained for methylcellulose were 1525 m/s and 1545 m/s, and for GG were 1479 m/s and 1519 m/s, at 30°C and 40°C, respectively, which revealed that the GG/MC blend is immiscible at all compositions. In the present study, we measured the ultrasonic velocity values of MC-ZnO nanocomposite solution and found them to be 1528 m/s and 1546 m/s, while for GG-ZnO nanocomposites, the values were 1475 m/s and 1518 m/s at 30°C and 40°C, respectively. The results of the ultrasonic velocity studies suggest [24-26] that GG/MC blend – ZnO nanocomposites are compatible when the composition of GG is 50% and above.

3.4 Adiabatic compressibility measurements

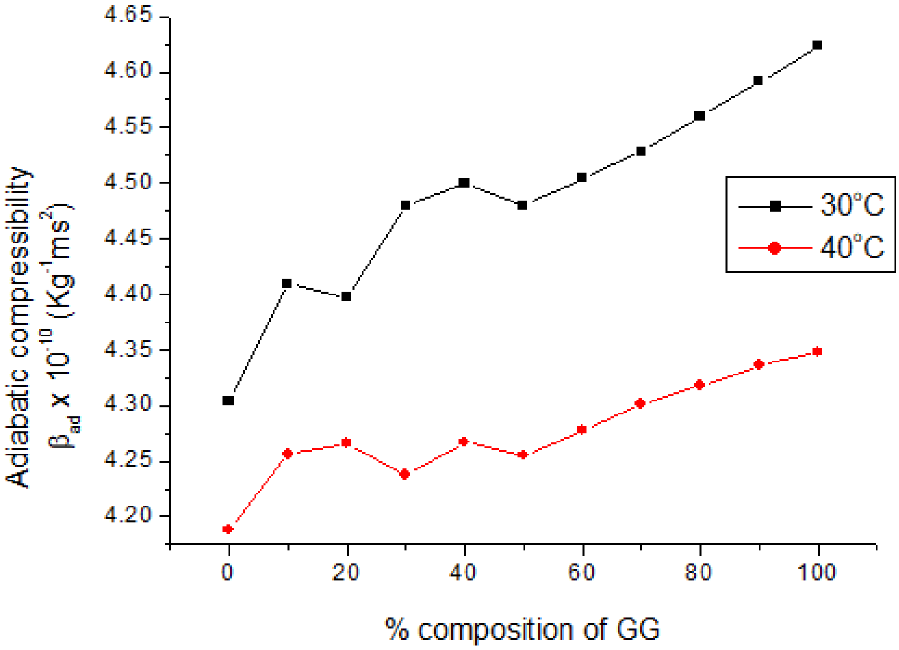
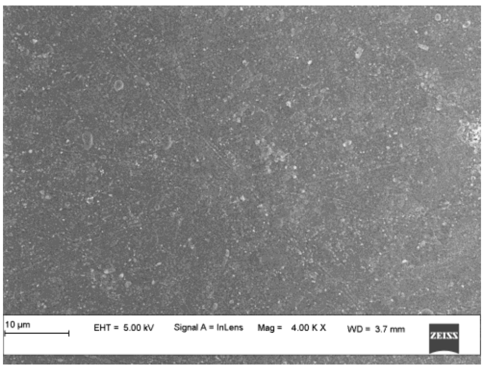
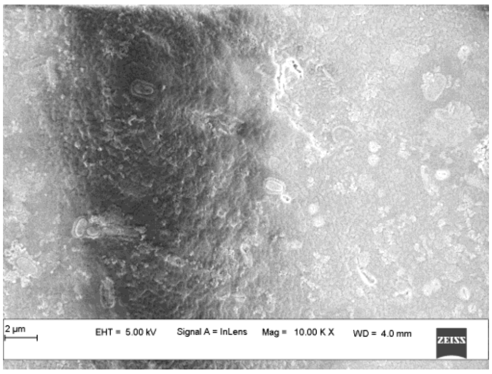


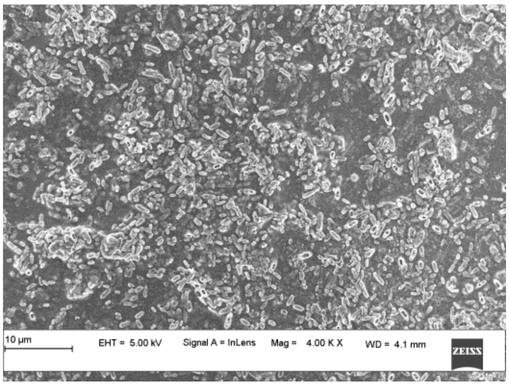
Fig. 4: Variation of adiabatic compressibility for GG/MC blend-ZnO nanocomposites

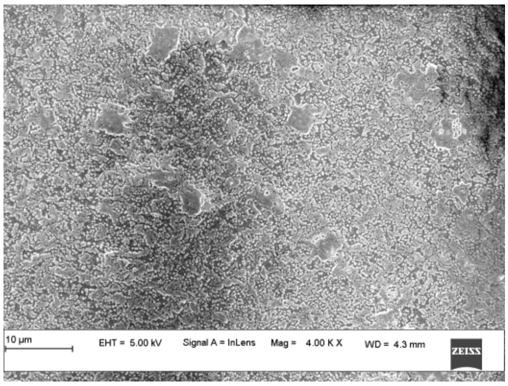
The values obtained for the adiabatic compressibility of MC-ZnO nanocomposite at 30°C and 40°C were 4.308x10^{-10} $Kg^{-1}ms^{2}$ and 4.188x10^{-10} $Kg^{-1}ms^{2}$, respectively. Similarly, the adiabatic compressibility values for GG-ZnO nanocomposites were found to be 4.623x10^{-10} $Kg^{-1}ms^{2}$ and 4.348x10^{-10} $Kg^{-1}ms^{2}$ at 30°C and 40°C. It can be concluded from the adiabatic compressibility measurement method [27] that the blend-nanocomposites are compatible when the composition of GG is 50% and above.

3.5 FESEM studies on thin films of GG/MC blend-ZnO nanocomposites

A) 

B) 

C) 

D) 

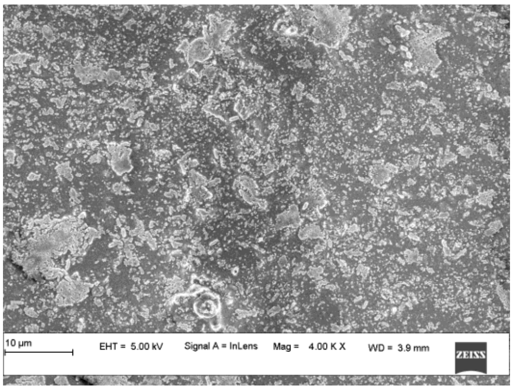
E) 

Fig. 5: FESEM images of A) GG-ZnO nanocomposite, B) MC-ZnO nanocomposite, C) 30/70 GG/MC blend-ZnO nanocomposite, D) 50/50 GG/MC blend-ZnO nanocomposite, and E) 70/30 GG/MC blend-ZnO nanocomposite

The interaction between ZnO nanoparticles and the polymers and the impact of nanoparticles on the miscibility of GG/MC blend were studied through morphology analysis. The FESEM images of ZnO incorporated GG, MC, and 30/70, 50/50, 70/30 GG/MC blends were recorded, as shown in Figure 5. The images indicate that ZnO nanoparticles form weak interactions with methylcellulose, but they are well dispersed in guar gum. The morphology studies reveal that there is a phase separation of nanoparticles and polymers for the 30/70 GG/MC blend-ZnO nanocomposite, while such separation is not observed in the 50/50 GG/MC blend-ZnO and 70/30 GG/MC blend-ZnO nanocomposites.

4. CONCLUSION:

The study shows the synthesis of ZnO nanoparticles using a green method and the preparation of GG/MC blend-ZnO nanocomposites. The compatibility of these nanocomposites was evaluated using various analytical techniques. The density, ultrasonic velocity, and adiabatic compressibility measurement studies showed compatibilization of green synthesised ZnO nanoparticles on GG/MC blends when the percentage composition of GG is 50% and more. The prepared thin films were characterized for morphology using FESEM. The findings from this study provide insights into the compatibility and stability of nanocomposites and pave the way for their use in various biomedical and pharmaceutical applications.

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