Trends in Biomaterials and Artificial Organs
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Original Article

Preparation and Characterization of Titanium Oxide, Zinc Oxide based Nanocomposite Material using Green Tea Extract

Suja Joseph[1], Deepak Nallaswamy[1], S. Rajesh Kumar[2], Pradeep Dathan[1], Shahin Ismail[1], Nazia Rasheed[1], Thara Munnuswamy[1], Leon Jose[3]

[1]*Department of Prosthodontics,* [2]*Department of Pharmacology, Saveetha Dental College, SIMATS, Chennai 602105, India*
[3]*Mechanical Engineering Department, Indian Institute of Technology Madras, Chennai 600036, India*

Received: *30 December 2023*
Accepted: *2 March 2024*
Published online: *17 April 2024*

Keywords: *green, tea, nanoparticles, TiO_2-ZnO nanocomposite*

This study presents the preparation and comprehensive characterization of nanoparticles and a nanocomposite synthesized through the mediation of green tea extract. Zinc oxide (ZnO) and titanium dioxide (TiO2) nanoparticles, as well as a TiO2-ZnO nanocomposite, were synthesized using green tea extract as a reducing and stabilizing agent. Characterization techniques including Scanning Electron Microscopy (SEM), Elemental Dispersive X Ray analysis (EDX), Fourier Infra-Red Spectroscopy (FT-IR) were employed to confirm the shape, elemental and chemical composition of the synthesized materials. The synthesized ZnO nanoparticles exhibited uniform spherical morphology, while the TiO2 nanoparticles displayed a fine, rounded rhombic shape. The TiO2-ZnO nanocomposite exhibited a combination of rhomboid and spherical particles, demonstrating its complex and heterogeneous structure. The study highlights the potential of green tea-mediated synthesis for producing nanoparticles and nanocomposites with diverse morphological features, offering opportunities for various applications in nanotechnology and materials science.

Introduction

Nanotechnology holds immense promise within the realm of dentistry, presenting a multitude of applications and advantages. It has the capacity to augment the mechanical properties of restorative materials, encompassing attributes like fracture toughness, flexural strength, and wear resistance [1]. By dispersing nanoscale materials within restorative compounds, it becomes possible to enhance their mechanical characteristics significantly [2]. Beyond this, nanotechnology extends its utility in dentistry to encompass anaesthesia induction, hypersensitivity alleviation, tooth repair, diagnosis and treatment of oral cancer [3]. This integration of nanomaterials and nanodevices into dental practices has the potential to revolutionize oral healthcare, delivering comprehensive and innovative treatment options [4]. The amalgamation of nanorobotics, nanomaterials, and biotechnology is poised to play a pivotal role in the pursuit of near-optimal oral health in the years ahead [5]. In summation nanotechnology stands as a beacon of progress in dentistry, ushering in an era of novel approaches for diagnosis, treatment, and preventive measures.

Titanium dioxide (TiO_2) nanoparticles indeed possess a remarkable set of properties that render them highly coveted for an array of applications. Notably, TiO_2 stands as a semiconductor characterized by outstanding optoelectronic attributes and a robust chemical stability [6]. The synthesis of TiO_2 nanoparticles in various shapes such as nanorods, nanowires, and nanotubes, can be achieved through diverse preparatory methods, lending flexibility to their applications [7]. One of the standout features of TiO_2 nanoparticles lies in their photocatalytic process, rendering them invaluable in domains spanning energy, environmental, and healthcare applications [8]. Their capacity to generate hydroxyl free radicals via water splitting has found application in augmenting radiotherapy treatments for solid tumors [9]. Moreover, TiO_2 nanoparticles may be doped with rare earth ions, enabling activation via X-rays and X-ray-generated electrons, a strategic maneuver for precise tumor targeting [10].

Zinc oxide nanoparticles (ZnO NPs) indeed stand out due to

* *Coresponding author*
E-mail address: *sjkt21@gmail.com* (Dr. Suja Joseph)

their distinctive properties, which have piqued the interest of researchers across various fields. These properties encompass exceptional opto-electric characteristics, robust electroactivity, and the remarkable ability to impede the growth of microorganisms. The synthesis of ZnO NPs can be achieved through diverse methods including precipitation, laser ablation, and thermal decarbonation [11,12]. Notably, the size of these nanoparticles can vary significantly depending on the chosen synthesis method, yielding diameters spanning from 0.066 μm to 21 nm [13]. One of the most captivating attributes of ZnO NPs is their demonstrated antimicrobial efficacy against a wide spectrum of microorganisms, encompassing both gram-positive and gram-negative bacteria as well as fungi [14]. The interaction of ZnO NPs with microorganisms often results in alterations to cell membrane integrity ultimately leading to cell death. The remarkable properties of ZnO NPs extend their potential utility vrious applications, including the development of advanced sensors, high-performance batteries, and innovative medical devices. These nanoparticles hold promise as agents that can address critical challenges across various domains, making them a focus of extensive research and exploration [15].

Green synthesis methods for nanoparticle production offer numerous compelling advantages. It serves as a sustainable and eco-friendly alternative to conventional chemical synthesis techniques. Green synthesis leverages the inherent properties of plant extracts, such as those derived from *Citrus limon* [16] and green coffee beans [17] which serve as both reducing and capping agents. These plant-based sources are rich in phytochemicals that play a dual role in reducing metal ions to form nanoparticles and stabilizing the resultant nanoparticles. Consequently, green synthesis methods not only minimize the environmental impact but also harness the inherent capabilities of nature for the controlled and sustainable production of nanoparticles [18].

Green tea boasts a multitude of health benefits and is prized for its positive impact on overall well-being. Abundant in polyphenols, notably flavonoids, it serves as a potent source of antioxidants with a wide range of health-promoting effects. Epigallocatechin gallate (EGCG), a prominent active component in green tea contributes significantly to its therapeutic properties [19]. Green tea has been recognized for its efficacy in alleviating sore throats, providing throat hydration, suppressing coughs, reducing inflammation, enhancing spleen function, supporting digestive health, nurturing the liver and even improving vision. Moreover, it aids in replenishing vital energy (qi) and nourishing the blood, thereby fortifying the immune system and combating fatigue. Its influence extends to neurological regulation, promoting better sleep quality, and exerting a positive impact on blood pressure and lipid levels [20]. When combined with dendrobium officinale, green tea unlocks additional benefits. This fusion enhances qi, nourishes the liver and kidneys, strengthens musculoskeletal health, and bolsters the body's immunity [21].

In this current research work, green tea was used as reducing and stabilizing agent to synthesize titanium dioxide nanoparticles, zinc oxide nanoparticles, titanium dioxide-zinc oxide nanocomposite. The green tea mediated nanoparticles and nanocomposites were subjected for characterization techniques such as SEM, EDX, and FT-IR analysis to analyze about its shape, elemental and functional composition.

Materials and Methods

Preparation of Green tea extract

In this experiment, 2 gms of green tea powder were carefully added to 100 μl of distilled water and gently mixed to create a green tea solution. The solution was then subjected to controlled heating using a heating mantle, maintaining a temperature of 60°C for a duration of 15 to 20 min. This controlled boiling process aimed to extract bioactive compounds from the green tea. The boiled green tea extract was meticulously filtered through a sterile muslin cloth, ensuring the removal of any particulate matter or impurities. The resulting filtered extract was then preserved for further use in the synthesis of titanium dioxide and zinc oxide nanoparticles.

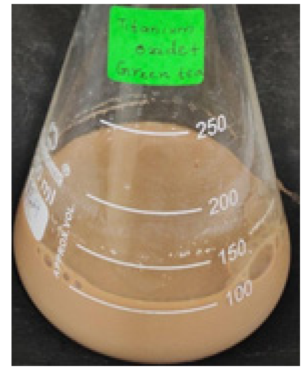

Figure 1: Green tea extract mediated titanium dioxide nanoparticles

Green synthesis of titanium dioxide nanoparticles

To synthesize titanium dioxide nanoparticles (TiO_2 NPs) using green tea extract, a two-step process was employed. First, 0.35 gms of titanium oxide (TiO) precursor were accurately measured and dissolved in 50mL of distilled water. Subsequently, 50mL of the previously filtered green tea extract were added to the titanium oxide solution. The green tea extract served both as a reducing agent and a stabilizing agent in the nanoparticle synthesis. The reaction mixture was placed on a magnetic stirrer and stirred at 700 revolutions per minute (rpm) for a duration of 48 hours. This extended the reaction time allowed for the controlled reduction of the titanium oxide precursor by the green tea extract, leading to the formation of TiO_2 nanoparticles.

After the 48-hour reaction period, the green-synthesized nanoparticle solution was subjected to centrifugation at 8000 rpm for 10 minutes. Centrifugation helped to separate the TiO_2 NPs from the solution. Following this process, the TiO_2 NPs pellet was carefully collected and then further processed by drying in a hot air oven at 80°C. This step aimed to obtain TiO_2 nanoparticles in a powdered form suitable for subsequent characterization.The supernatant, which was the liquid portion remaining after centrifugation was discarded as it contained unreacted or residual components.

Green synthesis of zinc oxide nanoparticles

To synthesize Zinc oxide nanoparticles (ZnONPs) using green tea extract, a two-step procedure was employed. Firstly, 30mM of Zinc nitrate precursor was dissolved in 50 mL of distilled water. Subsequently, 50 mL of filtered green tea extract was added to the Zinc oxide solution, acting both as a reducing and a stabilizing agent. The mixture underwent 48 hours of continuous stirring at 700 rpm on a magnetic stirrer, enabling controlled reduction of the zinc nitrate precursor by the green tea extract, leading to ZnO nanoparticle formation.

Following the reaction, centrifugation at 8000 rpm for 10 minutes separated the ZnO NPs from the solution. The resulting pellet

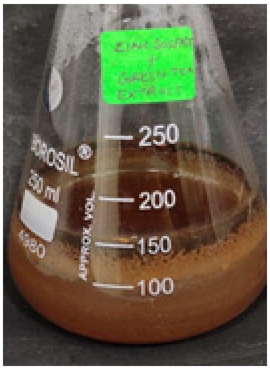

Figure 2: Green tea extract mediated zinc oxide nanoparticles

was then dried in an 80°C hot air oven to yield powdered ZnO nanoparticles suitable for subsequent characterization. The supernatant, containing residual components, was discarded. This method provided an efficient and environmentally friendly approach to synthesize ZnO nanoparticles using green tea extract.

Zinc oxide and titanium dioxide nanocomposites

To prepare the TiO_2-ZnO nanocomposite, equal volumes of 2 mL from the collected pellets of both titanium dioxide (TiO_2) and zinc oxide (ZnO) nanoparticles were combined. This mixing was achieved using a magnetic stirrer set at a rotation speed of 600 revolutions per minute (rpm). The purpose of this step was to ensure thorough dispersion and homogenization of the two nanoparticles types, facilitating their interaction and integration into the nanocomposite structure. The stirring process continued for a duration of 5-6 hours, allowing sufficient time for the nanoparticles to form a cohesive nanocomposite. Subsequently, the synthesized TiO_2-ZnO nanocomposite was carefully collected and transferred for further processing. To obtain a powdered form suitable for subsequent characterization and analysis, the nanocomposite was subjected to drying in an 80-degree Celsius hot air oven.This method of combining and drying the TiO_2 and ZnO nanoparticles resulted in the formation of a powdered nanocomposite material.

Characterization

The green tea mediated nanoparticles and nanocomposites were subjected for characterization techniques such as SEM, EDX, and FT-IR analysis. The SEM was done to analyze its shape and EDX to confirm the presence of elements and FT-IR to identify the functional compounds present in the synthesized solution.

Result and Discussion

Scanning Electron Microscopy (SEM)

The Scanning Electron Microscopy (SEM) analysis of the green-synthesized TiO_2 nanoparticles revealed distinct morphological characteristics (figure 3). The SEM image depicted the TiO_2 nanoparticles as small and rounded with a rhombic shape. This observation provides valuable insights into the size and shape of the synthesized nanoparticles.The small particle size is indicative of the effectiveness of the green synthesis method in producing fine TiO_2 nanoparticles. The rounded and rhombic shape suggests a certain degree of uniformity and regularity in the particle morphology, which is often desirable in nanomaterials for various applications. The SEM image corroborates the successful synthesis of TiO_2 nanoparticles using the green tea-mediated approach, highlighting the potential of this eco-friendly method for

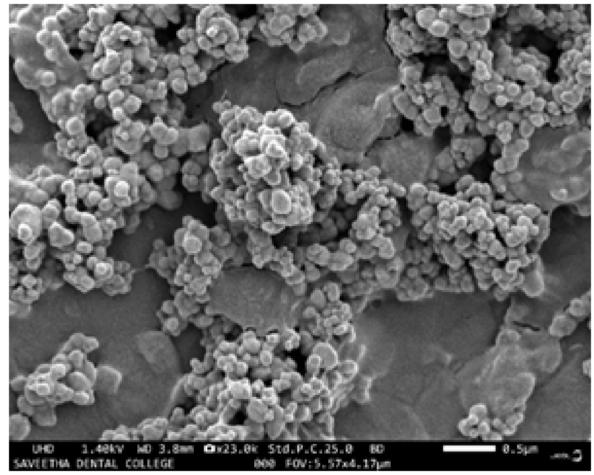

Figure 3: SEM image of green synthesized TiO_2 nanoparticles

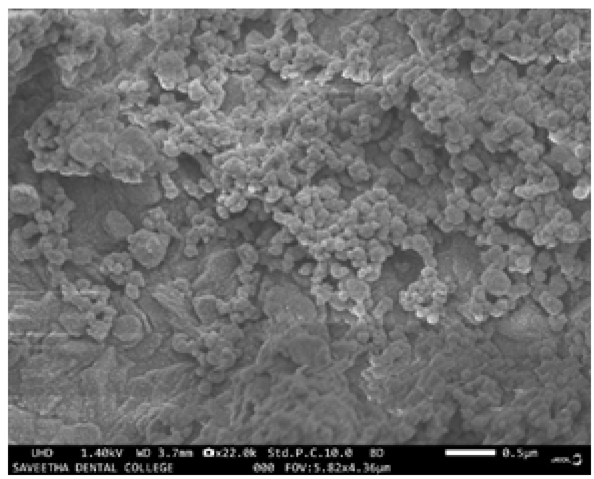

Figure 4: SEM image of green tea mediated zinc oxide nanoparticles

producing nanomaterials with specific morphological features.

The Scanning Electron Microscopy (SEM) analysis of green tea-mediated zinc oxide nanoparticles (ZnO NPs) revealed their morphology (figure 4). The ZnO nanoparticles appeared as small uniformly spherical particles. This observation indicates the effectiveness of the green tea-mediated synthesis method in producing ZnO nanoparticles with consistent and regular spherical shapes. Such uniformity in particle morphology is often advantageous for various applications. These SEM results affirm the success of the green synthesis approach for obtaining well-defined and uniformly shaped ZnO nanoparticles, showcasing its potential for environmentally friendly nanomaterial production.

The Scanning Electron Microscopy (SEM) analysis of the green-synthesized TiO_2-ZnO nanocomposite revealed its distinctive morphology (figure 5). The nanocomposite exhibited a combination of rhomboid-shaped and spherical particles. This intriguing observation suggests a complex and heterogeneous structure within the nanocomposite material, with two distinct particle shapes present. The coexistence of rhomboid and spherical particles in the TiO_2-ZnO nanocomposite may have implications for its unique

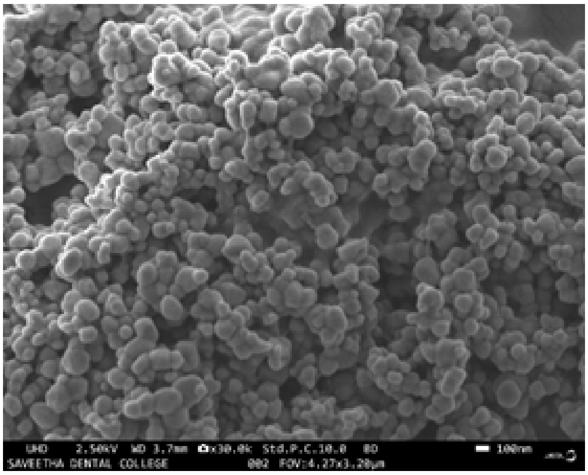

Figure 5: SEM image of green synthesized TiO_2-ZnO nanocomposite

properties and potential applications, making it a promising candidate for various biomedical applications.

Several previous research studies have delved into the synthesis of titanium dioxide (TiO_2) nanoparticles based on green synthesis method, shedding light on the unique properties and applications of these nanomaterials. Ahn et al. employed mangosteen pericarp extract for TiO_2 nanoparticle synthesis. Their research unveiled an aggregated structure characterized by a highly porous network. Such a porous morphology is significant in enhancing the surface area and reactivity of the TiO_2 nanoparticles, making them suitable for applications in photocatalysis and other fields [22]. Pavithra et al utilized Calotropis gigan tea plant extract in their study, leading to the creation of TiO_2 nanoparticles with size-dependent photocatalytic activity. This size-dependent activity suggests that the synthesized nanoparticles could be tailored for specific applications by controlling their size [23].

Anbumani et al. harnessed Luffa acutangula leaf extract to synthesize TiO_2 nanoparticles. Their investigation demonstrated the antimicrobial potential of these nanoparticles. This finding highlights the potential use of green-synthesized TiO_2 nanoparticles in various biomedical and healthcare applications [24].

Batbual et al. explored the synthesis of zinc oxide (ZnO) nanoparticles using Thalassia hemprichii leaf extract. Their research showcased particle size variations based on calcination temperatures, with sizes ranging from 60 nm to 35 nm. The ability to control ZnO nanoparticle sizes through green synthesis methods offers versatility for diverse applications [25].Velsankar et al utilized Paspalum scrobiculatum grains extract for biosynthesis of ZnO nanoparticles. High-Resolution Transmission Electron Microscopy (HR-TEM) imaging revealed hexagonal and rectangular-shaped nanoparticles with sizes ranging from 15 to 30 nm. These distinct shapes and sizes make the green-synthesized ZnO nanoparticles suitable for tailored applications in electronics, optics, and more [26].

In summary, these research studies underscore the versatility and potential of green synthesis methods using plant extracts, including green tea extract, in the production of TiO_2 and ZnO nanoparticles. The unique properties and morphologies of these nanoparticles offer opportunities for applications in diverse fields, ranging from photocatalysis and antimicrobial coatings to nanoelectronics and beyond.

Elemental dispersive analysis

The Energy Dispersive X-ray Spectroscopy (EDX) analysis of the green-synthesized Titanium Dioxide nanoparticles (TiO_2 NPs) provided insights into the elemental composition of the synthesized nanomaterial which was depicted in figure 6. The EDX spectra revealed the presence of several elements in the sample, with the following elemental composition:

Oxygen (O): Being the dominant element oxygen constitutes approximately 49.3% of the composition and is responsible for confirming the presence of titanium dioxide in the synthesized nanoparticles.

Titanium (Ti):, Titanium is the second most abundant element which accounts for approximately 34.9% of the composition and is the primary component of TiO_2.

Carbon (C): Minor presence of carbon which is 15.3% is responsible for the residual organic compounds from the green synthesis process, such as those from the green tea extract.

Potassium (K): Trace amount of potassium which is 0.5% of the composition may be attributed to the impurities or background signals.

The EDX analysis corroborates the successful synthesis of TiO_2 nanoparticles using the green tea-mediated approach, as evidenced by the dominant presence of oxygen and titanium, the main constituents of TiO_2. The presence of carbon and trace amounts of potassium can be attributed to the synthesis process and potential impurities [27].

The Energy Dispersive X-ray Spectroscopy (EDX) analysis of green-synthesized zinc oxide nanoparticles (ZnO NPs) revealed the elemental composition of the synthesized nanomaterial which was depicted in figure 7. The EDX spectra identified several elements in the sample, with the following elemental composition:

Carbon (C): Being the dominant element it constitutes approximately 59.6% of the composition and is likely attributed to organic residues or compounds from the green synthesis process.

Oxygen (O): Accounting for approximately 25.2% of the composition oxygen confirms the presence of zinc oxide in the synthesized nanoparticles.

Zinc (Zn): Zinc is approximately 8.4% of the composition and is a primary component contributing to the successful synthesis of zinc oxide nanoparticles.

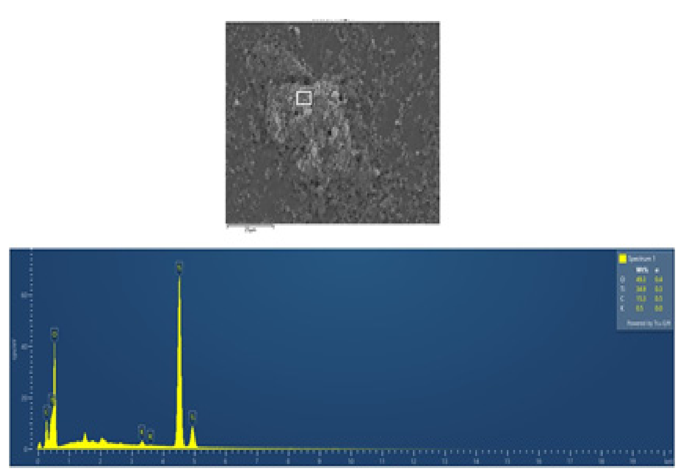
Figure 6: EDX spectra of green synthesized TiO_2 NPs

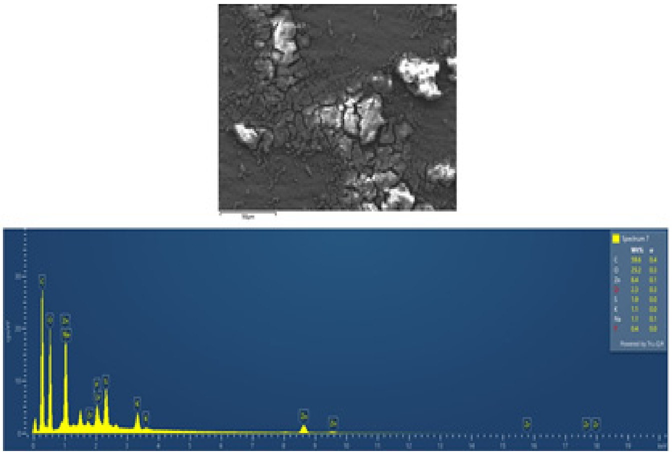

Figure 7: EDX spectra of green synthesized zinc oxide nanoparticles

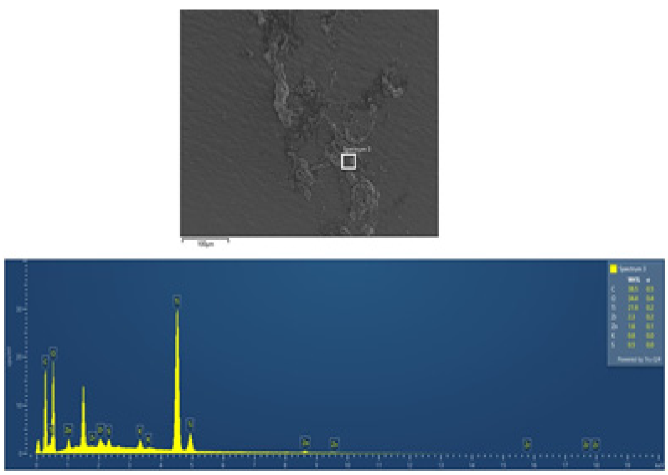

Figure 8: EDX spectra of green synthesized TiO_2-ZnO nanocomposite

Potassium (K) and Sodium (Na): Present in trace amounts at approximately 1.1%, these elements may be attributed to the impurities or background signals.

The EDX analysis underscores the presence of zinc and oxygen as the main constituents of the green-synthesized ZnO NPs, confirming their composition. The higher carbon content is indicative of potential organic residues, while trace amounts of potassium and sodium suggest minor impurities. These results provide valuable insights into the chemical composition of the ZnO nanoparticles and their suitability for various applications in nanotechnology and materials science [28].

The Energy Dispersive X-ray Spectroscopy (EDX) analysis of the green-synthesized Titanium Dioxide-Zinc Oxide (TiO_2-ZnO) nanocomposite provided insights into its elemental composition which was depicted in figure 8. The EDX spectra revealed the presence of several elements in the nanocomposite, with the following elemental composition:

Carbon (C): The dominant element, constituting approximately 38.5% of the composition. This significant carbon content suggests the presence of organic residues or compounds originating from the green synthesis process.

Oxygen (O): Oxygen is approximately 34.4% of the composition and is a common element in both TiO_2 and ZnO, confirming the presence of these oxides in the synthesized nanocomposite.

Titanium (Ti): Representing approximately 21.9% of the composition, titanium is one of the main component of TiO_2 in the nanocomposite.

Zinc (Zn): Approximately 1.6% of zinc contributes to the presence of ZnO in the nanocomposite.

Potassium (K): A minor presence at approximately 0.8% potassium may be responsible for the impurities or background signals.

The EDX analysis demonstrates the successful synthesis of the TiO2-ZnO nanocomposite, with the coexistence of titanium, zinc, and oxygen confirming the presence of both TiO_2 and ZnO components. The significant carbon content suggests the persistence of organic residues from the green synthesis process, which may contribute to the nanocomposite's unique properties [29].

Fourier Transform Infra-red Spectroscopy

The Fourier-Transform Infrared (FTIR) spectra of green tea powder were obtained, revealing several characteristic peaks in the spectrum which was depicted in figure 9. A strong peak at 2916.79 cm^{-1}, which corresponds to C-H stretching vibrations. This peak is indicative of the presence of aliphatic hydrocarbons and is commonly found in organic compounds. Another prominent peak at 2849.20 cm^{-1}, also associated with C-H stretching vibrations. This peak reinforces the presence of hydrocarbon functional groups in the green tea powder. A distinct peak at 1603.87 cm^{-1}, attributed to C=O stretching vibrations. This peak suggests the presence of carbonyl groups, which are often found in compounds like polyphenols and flavonoids, common constituents of green tea.

A notable peak at 1013.24 cm^{-1} indicative of C-O stretching vibrations. This peak is consistent with the presence of ether or alcohol functional groups, which are common in organic compounds like catechins found in green tea. These FTIR peaks provide valuable insights into the molecular composition of green tea powder, highlighting the presence of various organic functional groups and compounds that contribute to its unique chemical profile.

The FTIR spectrum of the green tea-mediated TiO_2 NPs revealed distinct peaks at specific wave numbers, indicating the presence of various functional groups and chemical bonds in the nanomaterial which was depicted in figure 10. The major peaks observed in the FTIR spectrum of the green tea-mediated TiO_2 NPs were identified as follows:

A notable peak at 3329.41 cm^{-1}, corresponding to a strong and broad band, signifies the presence of O-H stretching vibrations. This peak suggests the involvement of hydroxyl groups, which could be attributed to the phytochemicals and polyphenols from the green tea extract. These functional groups are known to play a crucial role in the reduction and stabilization of nanoparticles. A distinctive peak at 2114.69 cm^{-1} is indicative of a unique chemical interaction involving the green tea extract. Another significant peak at 1635.29 cm^{-1} suggests the presence of C=O stretching vibrations. This peak is commonly associated with carbonyl groups and is consistent with the involvement of organic compounds present in the green tea extract. These FTIR peaks in the spectrum of green tea-mediated TiO_2 NPs provide valuable information about the chemical composition and functional groups involved in the nanoparticle synthesis. The presence of hydroxyl and carbonyl groups in particular, highlights the role of green tea extract in

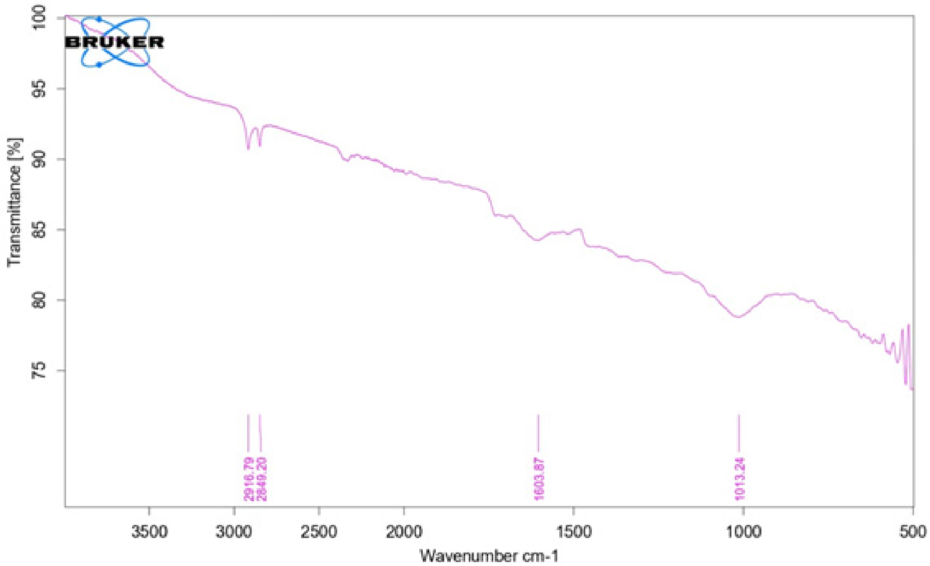

Figure 9: FTIR spectra of green tea powder

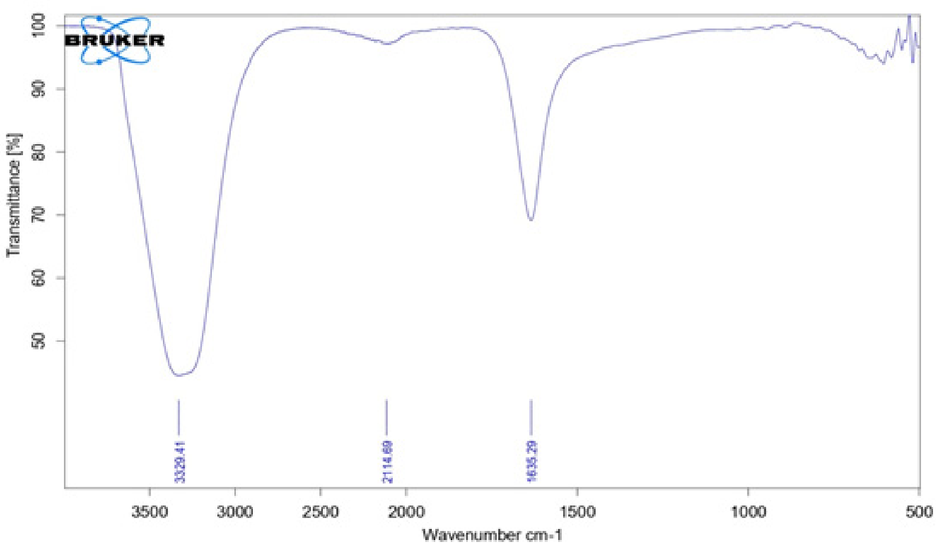

Figure 10: Green tea mediated titanium dioxide nanoparticles

reducing and stabilizing the TiO_2 nanoparticles, underscoring its potential as a green and sustainable synthesis method for nanomaterials.

The characterization of zinc oxide nanoparticles (ZnO NPs) synthesized using green tea extract as a mediator was conducted through Fourier-Transform Infrared (FTIR) spectroscopy which was depicted in figure 11. The FTIR spectrum of the green tea-mediated ZnO NPs revealed distinct peaks at specific wave numbers, indicating the presence of various functional groups and chemical bonds within the synthesized nanomaterial. The major peaks observed in the FTIR spectrum of the green tea-mediated ZnO NPs were identified as follows:

A significant peak at 3328.61 cm^{-1}, representing a strong and broad band indicates the presence of O-H stretching vibrations. This peak suggests the involvement of hydroxyl groups, which can be attributed to the phytochemicals and polyphenols present in the green tea extract. These functional groups are known to play a vital role in the reduction and stabilization of nanoparticles. A distinctive peak at 2102.22 cm^{-1} suggests a unique chemical interaction that involves the green tea extract.Another notable peak at 1635.05 cm^{-1} indicates the presence of C=O stretching vibrations. This peak is commonly associated with carbonyl groups and is consistent with the involvement of organic compounds present in the green tea extract.

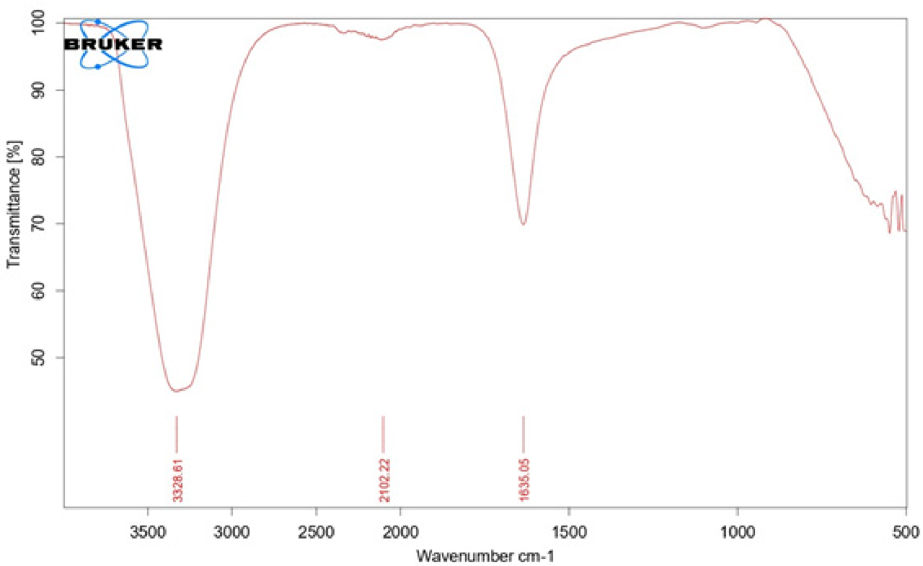

Figure 11: Green tea mediated zinc oxide nanoparticles

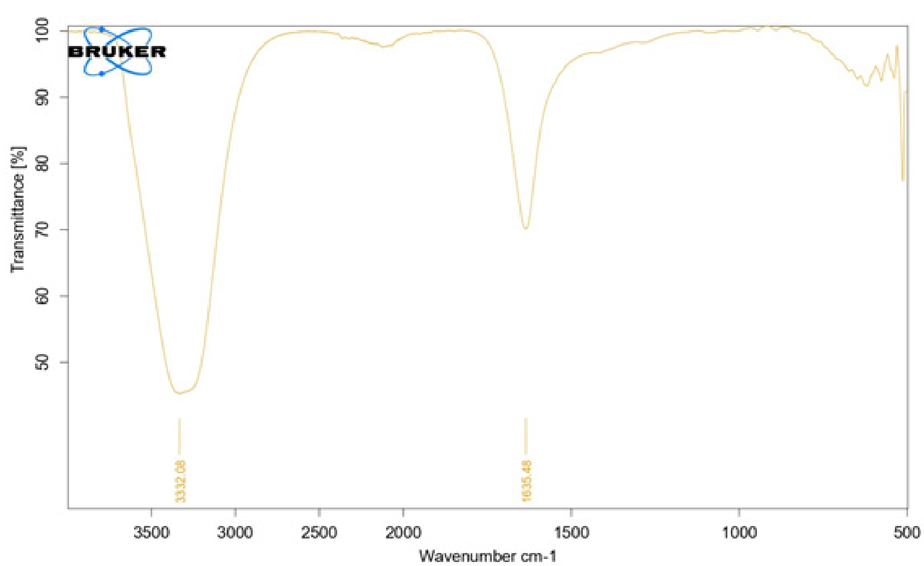

Figure 12: FT-IR spectra of green tea extract mediated TiO2-ZnO nanocomposite

These FTIR peaks in the spectrum of green tea-mediated ZnO NPs provide valuable insights into the chemical composition and functional groups involved in the nanoparticle synthesis process. The presence of hydroxyl and carbonyl groups underscores the role of green tea extract in reducing and stabilizing the ZnO nanoparticles, showcasing its potential as an environmentally friendly and sustainable approach for nanomaterial synthesis.

The Fourier-Transform Infrared (FT-IR) spectra of the TiO_2-ZnO nanocomposite, synthesized with the mediation of green tea extract, were analyzed to elucidate the chemical composition and functional groups present in this novel nanomaterial which was depicted in figure 12. The FT-IR spectrum of the TiO_2-ZnO nanocomposite exhibited distinct peaks at specific wave numbers, signifying the presence of characteristic chemical bonds and interactions within the composite. The major peaks observed in the FT-IR spectrum of the TiO_2-ZnO nanocomposite were identified as follows:

A prominent peak at 3332.08 cm^{-1}, representing a strong and broad band, indicates the presence of O-H stretching vibrations. This peak suggests the involvement of hydroxyl groups, likely originating from the green tea extract. Hydroxyl groups play a crucial role in the reduction and stabilization of nanoparticles and are instrumental in the synthesis of the nanocomposite. Another notable peak at 1635.48 cm^{-1} is indicative of C=O stretching vibrations. This peak is typically associated with carbonyl groups and is consistent with the presence of organic compounds, possibly from the green tea extract.

These FT-IR peaks in the spectrum of the TiO_2-ZnO nanocomposite highlight the presence of specific functional groups, such as hydroxyl and carbonyl groups, which are crucial in facilitating the synthesis and stabilization of this unique nanocomposite. The successful mediation of green tea extract in the formation of the nanocomposite is supported by these chemical bonds.

The extensive body of research on the FTIR analysis of nanoparticles synthesized with the assistance of green tea or natural extracts underscores the significance of these eco-friendly synthesis methods in nanomaterial production. These studies have not only confirmed the successful synthesis of various nanoparticles but have also provided valuable insights into their composition and potential applications.

The research conducted by Rupashree et al. and Widatalla et al. demonstrated the versatility of green tea-mediated synthesis. In the case of CuO NPs, the FTIR analysis revealed characteristic Cu-O bonding peaks, confirming the presence of the desired nanoparticles [30]. In the synthesis of AgNPs, the intriguing similarity between the FTIR spectra of green tea extract and AgNPs indicated the incorporation of polyphenols, polysaccharides, and proteins from the extract into the nanoparticles [31]. These findings highlight the role of green tea in mediating the synthesis and stabilizing the resulting nanoparticles.

The research on silver doped titanium dioxide (TiO_2) nanoparticles synthesized with green tea extract as a reducing agent provided insights into the composition and structure of these nanoparticles. FTIR analysis revealed the presence of flavonoids, polyphenols, and amide groups, emphasizing the influence of green tea components in the synthesis process. Such characterization is crucial for understanding the properties of TiO_2 nanoparticles, which have potential applications in fields like wound healing and water treatment [27].

Studies by Kaningini et al. [32] and Hassan et al. [33] highlighted the successful synthesis of zinc oxide (ZnO) nanoparticles using green tea or natural extracts. The use of FTIR analysis helped confirm the efficient synthesis of ZnO nanoparticles. These investigations illustrate the adaptability of green synthesis methods for various types of nanoparticles. The potential industrial applications of ZnO nanoparticles further underscore the significance of these eco-friendly approaches.

In summary, these research works collectively emphasize the promising role of green tea-mediated synthesis in nanomaterial production. The FTIR analysis, as demonstrated in these studies, provides a powerful tool for characterizing the composition and properties of nanoparticles. These eco-friendly methods not only offer sustainable alternatives but also open doors to innovative applications in areas like healthcare, environmental remediation, and materials science. Further research in this field holds great potential for advancing both the science of nanomaterials and their practical applications.

Conclusion

In conclusion, the green tea extract-mediated synthesis of zinc oxide (ZnO) and titanium dioxide (TiO_2) nanoparticles, as well as the TiO2-ZnO nanocomposite, has been successfully achieved. The SEM images displayed distinct morphologies, with ZnO nanoparticles exhibiting uniform spherical shapes, TiO_2 nanoparticles appearing as fine, rounded rhomboids, and the TiO_2-ZnO nanocomposite demonstrating a heterogeneous combination of rhomboid and spherical particles.Other characterization techniques, including EDX and FT-IR verified the elemental and chemical composition of the synthesized materials. These findings underscore the versatility of green tea-mediated synthesis in tailoring nanoparticle morphologies and offer potential applications in various fields of nanotechnology and materials science. This research contributes to the growing body of knowledge surrounding eco-friendly nanoparticle synthesis methods and their diverse applications.

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