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Hydrothermal syntheses and characterization of bio-modified TiO_2 nanoparticles with Aqua Rosa and Protein powder for their biological applications

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Highlights

- Pure Titanium dioxide (TiO_2 NPs), Aqua Rosa and Protein powder modified TiO_2 NPs were synthesized by hydrothermal method using Titanium tetra isopropoxide as precursor.
- Antibacterial and anticancer activities of Pure TiO_2, Aqua Rosa and Protein Powder modified TiO_2 nanoparticles were investigated.
- Antibacterial activities were performed against five bacterial strains namely ***Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Staphylococcus aureus*** and ***Streptococcus mutans***.

- Anticancer activities for the samples were performed in KB Oral cancer cell line.
- The modified TiO_2 NPs indicate a greater efficiency on anticancer and antibacterial properties when compared with the Pure TiO_2 NPs.

Abstract

TiO_2 nanoparticles (NPs) are capable of inhibiting the growth of bacterial strains and are responsible for causing damages to the cancer cells. Pure TiO_2, Aqua Rosa-modified TiO_2 and protein powder-modified TiO_2 NPs are synthesized using hydrothermal method. The particle size is found to be 7.5 nm for pure, 6.5 nm for protein-modified and 5.5 nm for Aqua Rosa-modified TiO_2 NPs using TEM analysis. UV spectra shows that the absorption peaks of the modified samples are blue shifted with respect to pure TiO_2 nanoparticles. The surface-modified nanoparticles show maximum growth inhibition against the pathogenic organisms. The research experiments exhibited highest anti-cancer activities for the surface modified TiO_2 NPs.

Introduction

Nanomaterials due to their excellent biocompatibility and photocatalytic property have gained significant attention in medicine and health care applications [[1], [2], [3]]. TiO_2 NPs under ultraviolet radiation generates Reactive Oxygen Species (ROS) which can be used as a photocatalytic disinfectant. TiO_2 photocatalyst have the capacity to damage the cancer cells [[4], [5], [6], [7]], other than bacteria, viruses and algae [[8], [9], [10],[11], [12], [13], [14], [15], [16], [17]] under UV illumination. Shokoh Parham et al., [18] reported that their higher anti-bacterial and anti-cancer activity were due to their excessive ROS generation mechanism. According to Jin C et al. [19], the anatase TiO_2 NPs can produce more ROS than the rutile phase, and this was demonstrated by various researchers using X-ray absorption fine structure spectrometry (XAFS). The biological activities of TiO_2 NPs increase with the doped and modified chemical agents. But they are found to be more toxic and expensive. To reduce the toxic nature and cost, plant materials can be used as modifiers. Plants are found abundance in the environment and they have been used from ancient time in many medicinal systems such as Siddha, Ayurvedha etc. to cure many diseases. From the literature, it is reviewed that rose petals [20,21] and proteins [22,23] tend to destroy bacterial and cancer cells. Among them, Aqua Rosa and protein powder are found to exhibit excellent biological activities. Hence, modified TiO_2 NPs have been prepared using Aqua Rosa and protein powder to enhance the antibacterial and anticancer activities.

Titanium dioxide (TiO_2) is an excellent photocatalyst [[27], [28], [29]] having large band gap of 3.2 eV. They are used in optoelectronic devices [[30], [31], [32]] and dye–sensitized solar cells [[33], [34], [35]]. They play an important part in the bacterial growth inhibition by their production of ROS in the presence of UV light [[24], [25]]. They serve as an excellent antibacterial agent [26]. TiO_2 has been increasingly used for its better biocompatibility and photocatalytic property [[36], [37]]. Reactive Oxygen Species formed during the reduction of oxygen was found to be the most important step in many photocatalytic reactions. This is clearly true with the case of TiO_2 nanoparticles. The antibacterial and photocatalytic activities of TiO_2 nanoparticles have been attributed to their ability to produce Reactive Oxygen Species (ROS) [[38], [39], [40]]. High surface area of TiO_2 nanoparticles accommodates more number of microbes which is in contact with the nanoparticles and this results in the death of the cell wall. The positive charge of the TiO_2 nanoparticles attracts the negatively charged cell membrane and so more number of nanoparticles are able to penetrate quickly and attack the cell wall. This in turn damages the cell wall and results in the cell death. The modification of bio agents on TiO_2 surface can also greatly increase the amount of ROS production which results in the enhanced photocatalytic and biological activity [41]. Due to their tendency to generate excessive reactive oxygen species in cancer cells, they also serve as an efficient anticancer agent [[42], [43]]. Chakra et al., [44] synthesized the ZnO and TiO_2 nanocomposites and then the synthesized nanocomposites were subjected to Gram positive bacteria such as *S. aureus* and Gram negative bacteria such as *E. coli*. The ZnO has lower antibacterial action than TiO_2 but when combined increases the action when compared with ZnO nanoparticles. Agarwal et al. [45] and Eikani et al. [46] studied the chemical composition of Rosa damascena (Aqua Rosa) and observed that phenethyl alcohol (81.27%), geraniol (4.43%) and β-citronellol (5.72%) were the main constituents.

Mahmoodreza Moein et al. [47] observed that Rosa damascena comprises of other components such as linalool, m-thymol, eugenol, methyl eugenol, curzerene, myristicin, dibutyl phthalate, nonane, α-pinene, m-cymene, benzyl alcohol, γ-terpinene, α-terpineol, carvacrol, trans-caryophyllene, eugenol acetate, heptadecane, nonadecane, docosane in addition to the three main components. Aqua Rosa is used as a remedial measure for various intestinal problems [48], acne [49] and bacterial infections [50]. According to Si et al. [51], the geraniol exhibited excellent antimicrobial activity against *E. coli* and *S. typhimurium* among sixty-six essential oils. Zanetti et al. [52] reported that geraniol showed good antibacterial nature when compared with Cinnamic acid.

Protein powder comprises of soy protein isolate (82.26%), wheat protein (10.0%) and pea protein (7.50%). Isoleucine, leucine, lysine, methionine, phenylalanine, tyrosine, threonine, tryptophan, valine and histidine are the essential amino acids present in the protein powder. Isoleucine and leucine combined peptide shows anticancer activity against MCF-7 cells, and it is reported by Che Wang [53]. Soy protein isolates exhibits antimicrobial activity, and it is observed by many researchers [[54], [55], [56]]. Fig. 1 represents the chemical structure of geraniol, phenyl ethyl alcohol, β-damascenone, β-citronellol and soy protein isolate.

For Biological applications, TiO_2 NPs are synthesized by various methods such as sol-gel [57], coprecipitation [58], hydrothermal [59], sonication and spray pyrolysis [3], DC reactive magnetron sputtering [60], but hydrothermal technique is a conventional method under which pressure and temperature can be maintained for the preparation of inorganic materials in a nanocrystalline form which is reported by Byrappa K [61]. In the present work, Pure TiO_2, Aqua Rosa modified TiO_2 and Protein powder modified TiO_2 were synthesized by hydrothermal synthesis, and then the obtained nanoparticles were subjected to characterizations such as XRD (X-Ray diffraction), UV–Vis (UV–Vis Spectrophotometer), FTIR (Fourier Transform InfraRed spectrometer), TEM (Transmission Electron Microscopy), MTT assay and Agar diffusion method. The Pure and Surface-modified samples showed excellent antibacterial and anticancer activity.

Section snippets

Materials and methods

Titanium tetra-isopropoxide and isopropanol were purchased from Sigma-Aldrich Chemicals. Fresh Aqua Rosa (Rose Petals) and Protein powder were purchased from the market. Titanium (IV) tetra-isopropoxide, Isopropanol and water were mixed separately and stirred for 120 min at room temperature for 2 h. Consequently, a sol was obtained. The sol was transferred to the Teflon autoclave and then heated for 2 h at 200 °C. The obtained products were centrifuged and then annealed at the temperature of

Structural studies

Fig. 2 showed the X-ray diffraction patterns for Pure TiO_2, Aqua Rosa modified and Protein modified Titanium dioxide nanoparticles. The X-ray diffraction pattern exhibited peaks at 25.3°, 37.8°, 48°, 54.7°, 63°, 70° and 75.7° that denoted the crystal planes (1 0 1), (0 0 4), (2 0 0), (1 0 5), (2 0 4), (2 2 0) and (2 1 5), respectively. These peaks are matched with the peaks of anatase TiO_2 which is found to agree with the JCPDS file No: 21-1272. Ba-abbad M et al. [62] explained that the intense

Conclusion

The biological activities of the Pure, Aqua Rosa modified, and Protein modified TiO_2 NPs are studied. The research experiments confirmed that the dopants added to the TiO_2 NPs have increased the antibacterial and anticancer activities. The inhibitory bacterial zones are found to be maximum for Protein powder modified TiO_2 samples when compared with the pure TiO_2 samples against both Gram-positive and Gram-negative bacterial Strains. The Protein powder modified TiO_2 NPs exhibited minimum cell

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2020, Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy

> *Citation Excerpt :*
> …For elimination of these environmental pollutants, the most common method is the catalysis of environmental organic pollutants by catalytic or photocatalytic technology using various nanoparticles [2–10]. As an important wide-band gap semiconductor, titanium dioxide (TiO2) is the most investigated photocatalyst in the field of environmental protection because of its high photocatalytic activity, non-toxicity, low cost, as well as chemical stability and suitable positions of valence and

conduction bands [11–17]. However, pure titanium dioxide exists some defects such as low light utilization, light corrosion and low conversion efficiency....

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...He prepared 21 nm anatase TiO2 nanoparticles using Garcinia zeylanica extract and then examined the antibacterial nature against Methicillin-resistant Staphylococcus aureus. The Turmeric, Ginger, Garlic, Aqua Rosa extracts modified with pure Titanium dioxide nanoparticles showed good antibacterial and anticancer nature [52–53]. For cost-effective and less toxic, plant extracts can be used as dopants....

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