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Generation of TiO_2 nanoparticle-based acacia saturated eggshell bio-composite for pathogen removal

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A R T I C L E I N F O

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A B S T R A C T

This study illustrates the preparation of *in situ* generated TiO_2 nanoparticle-based bio-composite and its application in pathogen removal. Pristine cellulose acetate gel was mixed with acacia extract impregnated egg shell and coated with TiO_2 nanoparticles. The resultant biocomposites were used as coatings and compared for their performances. All prepared coatings were analysed using Fourier transform infrared spectroscopy, scanning electron microscope, Energy-dispersive X-ray spectroscopy, scanning probe microscopy, thermogravimetric analysis and contact angle measurement. The antimicrobial activity of bio-composite was tested on *E. coli* bacteria using plating and fluorescent based assay. The bio-composites showed very good antimicrobial properties. Moreover, the easy and eco-friendly method for developing such bio-composite coatings and their application may prove effective against pathogens during effluent treatment.

1. Introduction

Man-made processes and activities have largely affected the available fresh water quality and quantity. The mixing of industrial, medical and household wastes in water bodies are deteriorating the water quality. The presence of pathogens in wastewater is the major concern due to the number of water-borne disease they cause among human population worldwide. Monitoring studies of water bodies reveal that the foremost cause of pollution is the discharge of sewage that continuously increases the microbial count (Belmont et al., 2004). Earlier technologies such as the use of UV radiations, chlorination, and membrane filtration have their own limitations, while engineered nano-system may show extended life and very less energy requirement.

The size-dependent properties of nanoparticles (NPs) are distinguishable and make them stand higher as compared to their larger counterparts. The unique properties of NPs also attract their use in water and wastewater treatment. However, most of the applications are still in the phase of laboratory research, few may have pilot-tested or field-tested (Li et al., 2008; Damodar et al., 2009; Singh et al., 2011; Zhan et al., 2014). Various studies involve the incorporation of NPs into the polymeric or inorganic membranes in order to develop synergistic or multifunctional properties in them. These include hydrophilic NPs such as Al_2O_3, TiO_2, antimicrobial NPs like nano-Ag, CNTs, and NPs with photo-catalytic activities like quantum dots, TiO_2 (Qu et al., 2013). The membranes with integrated catalytic NPs have both the properties; physical separation as well as ability to degrade the noxious wastes. The membranes with nano-photocatalysts have also been developed and usually consist of TiO_2 NPs or modified TiO_2 NPs (Choi et al., 2006).

There is a need of appropriate disinfection procedure without generation of harmful disinfection by-products (DBPs). Likewise, there is an increasing requirement for decentralized or point-of-use water treatment and recycling systems. All these actions need new technologies for proficient management of disinfection and pathogens (Li et al., 2008). Several natural and engineered NPs show strong microbicidal properties (Chowdhury et al., 2013). Their mode of action includes photo-catalytic generation of reactive oxygen species that (i) harm the cell organelles and viruses (*e.g.* TiO_2, ZnO and fullerol); (ii) disrupt the microbial cell membrane (*e.g.* peptides, chitosan, carboxyfullerene, carbon nanotubes, ZnO and silver NPs); (iii) cause alteration of energy transduction pathway (*e.g.* silver NPs and aqueous fullerene NPs); (iv) induce inhibition of enzymatic processes and DNA synthesis (*e.g.* chitosan) (Maness et al., 1999; Tsuang et al., 2008; Qu et al., 2013).

Several NPs, including Ag, ZnO, TiO_2, Ce_2O_4, CNTs, and fullerenes, demonstrated the microbicidal features exclusive of strong oxidation, and therefore with lesser inclination towards DBPs formation. Antimicrobial NPs are expected to solve the three key challenges in water/wastewater systems: disinfection, membrane biofouling control, and biofilm control on other relevant surfaces (Qu et al., 2013). The major uncertainty in this technology is the long term efficacy. Antimicrobial NPs that depends on the discharge of biocidal ion depletes in

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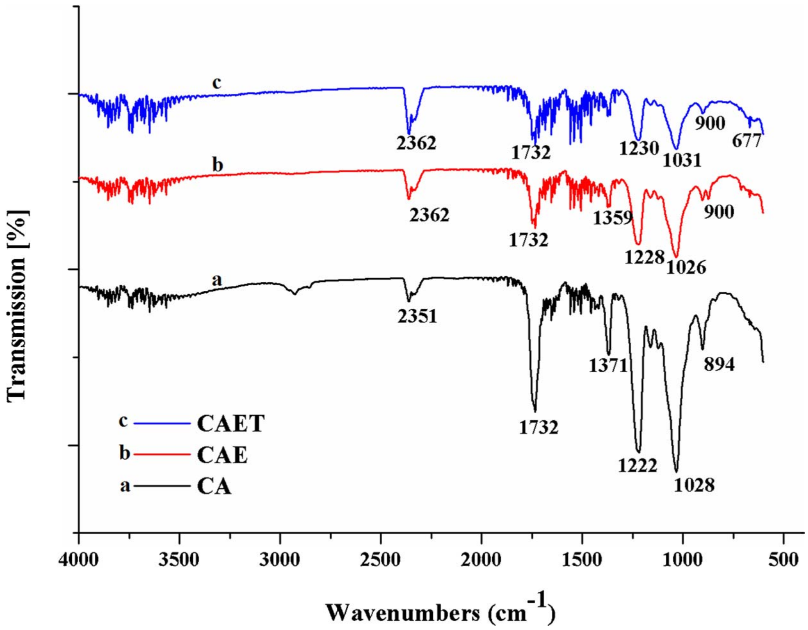

Fig. 1. FT-IR spectra of CA, CAE and CAET.

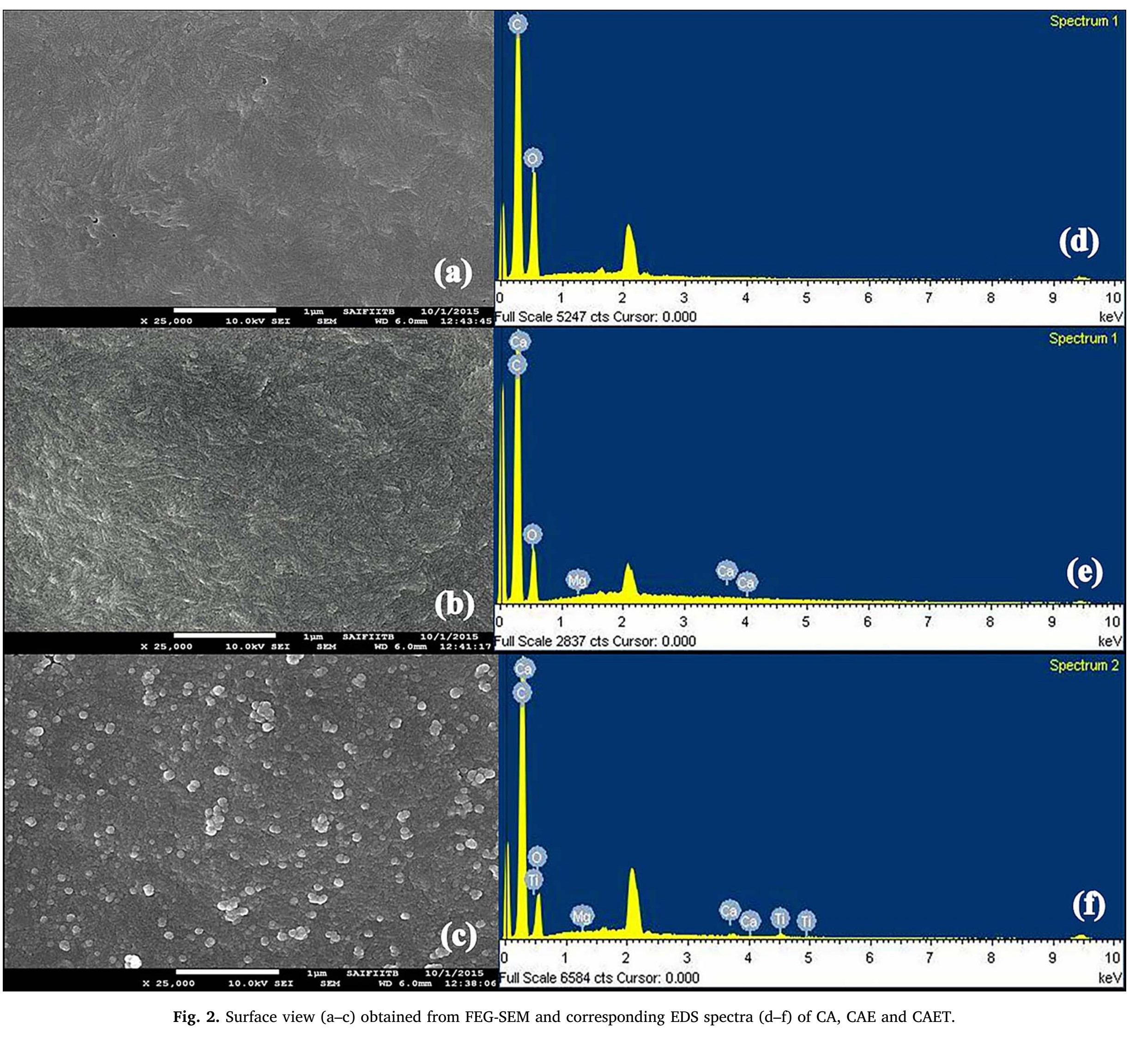

Fig. 2. Surface view (a–c) obtained from FEG-SEM and corresponding EDS spectra (d–f) of CA, CAE and CAET.