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Characterization and Microbial Resistance Properties of Titanium Dioxide Nanoparticles in Food Products

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ABSTRACT

From the current state-of-the-art, it is clear that nanotechnology applications are expected to bring a range of benefits to the food sector aiming at providing better quality and conservation. Titanium dioxide (TiO_2) is one of the whitest materials known to exist. TiO_2 is commonly used as food additive. As a pigment, TiO_2 is used to enhance the white colour of certain foods. Advances in technologies, such as DNA microarrays, micro electromechanical systems, and micro fluidics, will enable the realization of the potential of nanotechnology for food applications. In this study four food grade TiO_2 materials was tested for being its particle size and pathogen resistant actions. TiO_2 content was determined by number-based size distribution of TiO_2 particles. The technique employed is inductively coupled mass spectrometry. The study reveals that most of the titanium were ranging from 0.02 to 9.0 mg TiO_2/g product and 3-4% of the particles in these food products had sizes below 100 nm which is comparable to that found in the standard food grade material (E171). In this segment we also tested the samples for their resistant against *E. Coli* and *Staphylococcus aures* microorganisms. The technique employed is disc diffusion method and the study of zone of inhibition of the samples proves that the samples containing TiO_2 is more resistant for the microorganisms and excellent biocompatibility.

1. Introduction

Titanium dioxide, also known as titania, is a naturally occurring oxide of titanium. The properties of titanium dioxide include high refractive index, light absorption, non-toxicity, chemical stability and relatively low-cost production [1-5]. TiO_2 particles catalyze the killing of bacteria on illumination by near-UV light. The generation of active free hydroxyl radicals (-OH) by photo excited TiO_2 particles is probably responsible for the antibacterial activity [6-7]. The antimicrobial effect of TiO_2 photo catalyst on *Escherichia coli* in water and its photo catalytic activity against fungi and bacteria has been demonstrated. There are also studies on bactericidal activity of nitrogen-doped metal oxide nanocatalysts [8] on *E. coli* bio films and on the photo catalytic oxidation of bio film components on TiO_2 coated surfaces [9]. TiO_2 photo catalysts can be used as effective bio film disinfectant in food processing industries [10, 11]. Suspensions containing TiO_2 are effective at killing *Escherichia coli and S. Aures*. This has led to the development of photo catalytic methods for the killing of bacteria and viruses using TiO_2 in aqueous media [12]. The major disadvantage of using TiO_2 is that UV light is required to activate the photo catalyst and initiate the killing of the bacteria. In recent years, visible light absorbing photo catalysts with Ag/AgBr/TiO_2 has proved to be successful at killing *S. aureus* and *E. coli*.

2. Experimental Methods

2.1 Antimicrobial Effects of Titanium Dioxide Nanoparticles

Four test samples were considered for evaluation of antimicrobial effect of nanoparticles of titanium dioxide and its photo catalyst type for each microorganism. The cell lines were obtained from MTCC and sub cultured. The first group of samples (including four beakers) was considered for evaluating the effect of TiO_2. All samples were placed in the oven at 180 °C for 1 h to get sterilized. Content of sample beakers for each microorganism included 20 mL of special liquid medium and 1 mL of the mixture suspension of microorganisms with nano-particles in certain concentration. Three control beakers all containing medium and related suspension for each microorganism without nanoparticles were also prepared. Using the disc diffusion method plates were incubated for certain time and temperature depending on the type of microorganism content i.e. *S. aureus* and *E. coli* bacteria incubated at 37 °C for 24 h. Then, the colonies were counted. All the steps were replicated three times during the entire process at Biochemistry Department, Mount Carmel College.

2.2 Electron Microscopy Characterization

Scanning Electron Microscopy (Carl Zeiss, Germany) was used for determination of diameter and also surface area to volume ratio of nanoparticles (ratios of the distribution). As shown in Fig. 1 nanoparticles of titanium dioxide are in a spherical shape with an average diameter of about 30 nm.

2.3 Analysis of the Total Mass as well as the UV-Visible Absorption

The mass spectrometer was used to determine the average size of the mass of the group of nanoparticles present. The absorption maximum of the nanoparticles were calculated using UV-Visible spectrophotometer.

3. Results and Discussion

3.1 Analysis of SEM image

Scanning Electron Microscopy was used for determination of diameter and also surface to volume ratio of nanoparticles. As shown in Fig. 1 nanoparticles of titanium dioxide are in a spherical shape with an average diameter of about 30 nm and the average ratio of distribution is 0.02 to 9.0 mg/TiO_2 in tested food samples.

3.2 The effect of Titanium Dioxide Nanoparticles against E. coli and S. Aures

The effect of different concentrations of titanium dioxide nanoparticles on *E. coli* is given in Fig. 2. It shows by increasing concentrations of nano-particles microbial population reduced compared to those of control sample. Microbial load significantly reduced by increasing the time of photocatalytic process. According to the obtained results, the efficiency of

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titanium dioxide nanoparticles undergone photo-catalytic process was much higher in *E. coli* population removal compared to that of nanoparticles with no exposure to irradiation. Fig. 3 shows the decrease in population of *S. aureus* in the presence of titanium dioxide nanoparticles. Fig. 3 shows the effect of titanium dioxide nanoparticles irradiated by UV radiation during certain time in photo catalytic process against *S. aures*. Fig. 4 and Fig. 5 shows the average particle size of the titanium dioxide nanoparticles and UV-absorption spectrum of the nanoparticles.

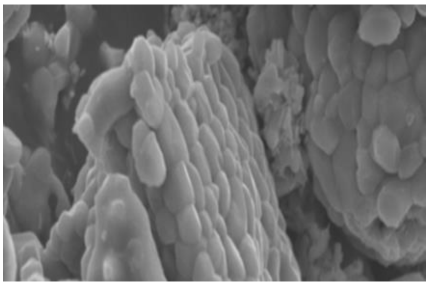

Fig. 1 Scanning electron micrographs of TiO_2 nanoparticles

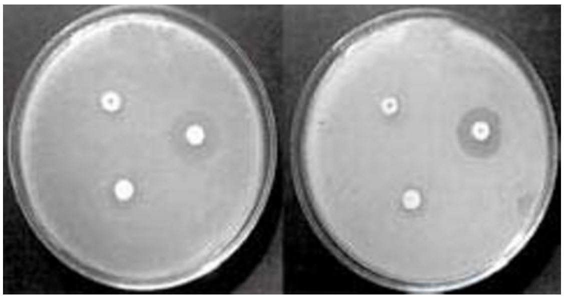

Fig. 2 Zone of inhibition observed against *S. aureus* microorganism with standard Tetracycline

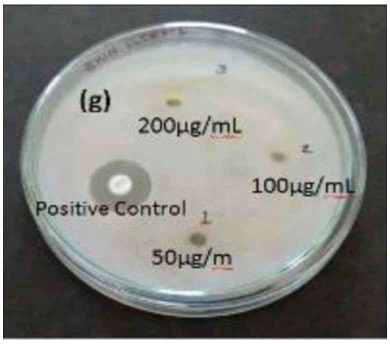

Fig. 3 Zone of Inhibition observed against *E. coli.* microorganism with standard Tetracycline

3.3 Effect of Titanium Dioxide Nanoparticles in UV and Mass Spectrophotometer Characterizations

Fig. 4 shows the average particle size analysis of titanium dioxide nanoparticles. Inductively coupled mass spectrometer shows particle size is the range of 20-80 average nm. UV-absorption spectrum of 1-2% titanium dioxide nanoparticles obtained by aqueous medium intrusion injection. The absorption wavelength is in the order of 200-400 nm.

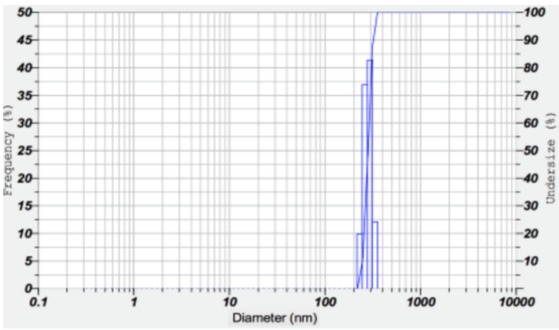

Fig. 4 Average particle size analysis of TiO_2 nanoparticles (Inductively coupled mass spectrometer)

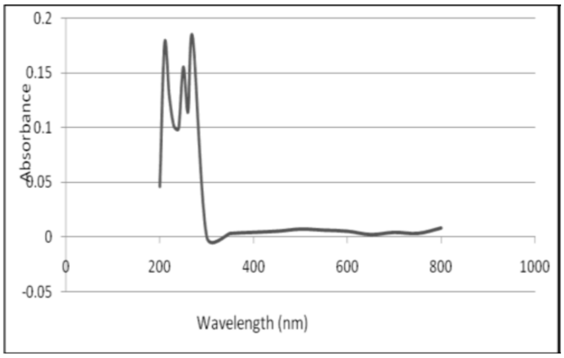

Fig. 5 UV-Vis absorption spectrum of 1-2% TiO_2 nanoparticles in water and ethanol (samples of food treated in aqueous medium)

4. Conclusion

Nowadays, there is a great competition in the food industry for application of novel technologies. Thus, utilization of the latest technologies is essential in order to maintain and expand the market of food industry. Nanoparticles today are widely used in food processing. One of their important applications is their ability in elimination of food borne pathogens as covered surfaces in food packaging industry. Thus, antimicrobial titanium dioxide nanoparticles can be a proper alternative to common antibiotics and anti-fungal since their use in packaging of food and dairy products would be more affordable. The present study indicated and proved the antimicrobial effects of titanium dioxide on some of milk borne pathogenic microorganisms. These antimicrobial properties can help to reduce microbial load of food and especially dairy products in the future.

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