Facile and low-cost surface modification techniques using TiO_2-Fe for bacteria inactivation in hospital environments

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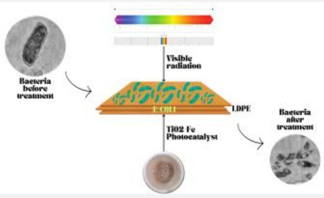

This study investigates the characterization and application of a TiO_2-Fe composite material for bacterial inactivation on LDPE surfaces under visible light. FTIR spectroscopy revealed characteristic bands indicating the presence of OH bonds, OH-Fe, and Fe-O or/and Ti-O-Ti bonds. SEM-EDS analysis confirmed porous materials with uniformly distributed iron, suggesting successful iron support in TiO_2. Notably, pretreatments with sandpaper and acetone significantly enhanced *E. Coli* inactivation. Under visible light, TiO_2-Fe-coated LDPE plates exhibited remarkable bacterial inactivation, while TiO_2 alone showed minimal effect. Dark tests indicated a decrease in bacterial concentration associated with an adsorption process. TiO_2-Fe-coated plates achieved complete *E.Coli* inactivation, suggesting activation under visible radiation through singlet oxygen and superoxide ion radical attack.

Introduction

In recent years, growing awareness has emerged about the environment's role in infections within medical institutions, acting as facilitators and generators of epidemiological outbreaks. Bacterial resistance has become a major concern, claiming an estimated 700,000 lives annually worldwide, with projections suggesting a post-antibiotic era by 2050, resulting in a death every three seconds [1-4].
Titanium dioxide (TiO_2) is widely used due to its non-toxicity, low cost, biocompatibility, and photocatalytic activity. However, its limited efficiency with visible radiation and in indoor is a drawback.
This study introduces antibacterial materials prepared using TiO_2 with iron oxide via a cost-effective soft synthesis method supported onto polymeric materials. They exhibit effective photocatalytic activity under visible light, eliminating *E.Coli* completely in 180 minutes with no bacterial regrowth observed. Given their inexpensive and easy application methods Implementing these materials offers significant health protection potential.

Material and Methods

Synthesis of photocatalyst

Photocatalyst 1.0% w/w was prepared mixing TiO_2 degussa P25, and iron oxide solution of $Fe_2(SO_4)_3.H_2O$ 0.1M. The mixture was stirred for 9 hours at 10°C, filtered, and the solid was washed until a conductivity < 20µs/cm and a constant pH. The solid obtained was dried (70°C, 3 h) and calcined (500°C, 1 h). The calcined material was macerated and sieved mesh 100 (0.15 mm).

Pretreatment of polymeric materials

To improve the catalyst's impregnation on the low-density polyethylene (LDPE) plates, a surface pretreatment was made. Two pretreatment methods were used: a chemical method using acetone and a physical method involving sanding the surface. The washed plates are immersed in undiluted acetone for 30 min for the chemical method.
In the physical method, the surface of the washed plates is sanded with sandpaper 3 times horizontally and 3 times vertically. The process is repeated 6 times. Subsequently, both modified plates were washed and dried (50°C, 1 h).

Loading of photocatalyst on pretreated polymer

The impregnation of the photocatalyst was performed utilizing the spray method. To do so, a solution containing the photocatalyst (TiO_2-Fe) at a concentration of 20g/L in 70% ethanol was prepared. The solution was evenly sprayed onto the surface of the polymer plate from a distance of 10 cm. The plates were impregnated on one side and subsequently dried at 45°C for 1 hour. This spraying and drying procedure was repeated 6 times until the desired film thickness was attained.

Characterization methods and bacterial inactivation

TiO_2-Fe and LDPE coated with TiO_2-Fe were characterized by FTIR, SEM, TEM, and XRD. On the other hand, the bacterial inactivation process is shown in Figure 1.

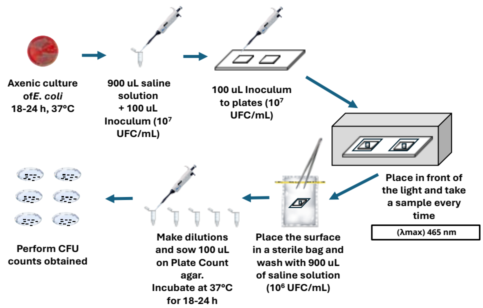

Figure 1. Methodology bacterial inactivation

Results and Discussion

Photocatalyst characterization

FTIR spectroscopy of material (TiO_2-Fe) (Figure 2) shows bands in 3369 cm^{-1}, 1632 cm^{-1}, and 684 cm^{-1} attributed to OH bonds, OH-Fe and Fe-O or/and Ti-O-Ti bonds, respectively. XRD (Figure 2) does not show the formation of a new crystalline phase in titanium dioxide due to the presence of iron. SEM-EDS analysis indicated porous materials with irregular surfaces and uniformly distributed iron, suggesting that iron had been supported in TiO_2.

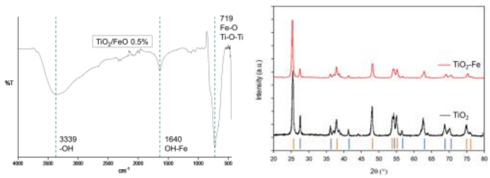

Figure 2. FTIR spectrum of TiO_2-Fe material and DRX

Effect of Pretreatment

Figure 3 illustrates the notable inactivation of *E.Coli* on LDPE surfaces. Both pretreatments—sandpaper and acetone—prior to catalyst deposition via the spray method, substantially improve the inactivation. The sandpaper pretreatment, in particular, yields favorable results, indicating that the characteristics of the pretreatment enhance the availability of active sites. This discovery holds significance as it combines the cost-effectiveness of pretreatment with a simple method, offering a practical solution for *E.Coli* inactivation.

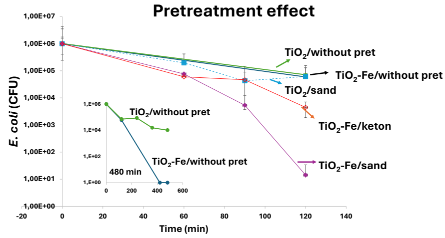

Figure 3. *E.Coli* inactivation under visible light of LDPE with TiO_2 or TiO_2-Fe using sanding or acetone pretreatment

Effect of photocatalyst type on *E.Coli* inactivation

Figure 4 shows *E.Coli*'s inactivation under LED (visible) light on LDPE surfaces pretreated with sandpaper and sprayed with TiO_2 and TiO_2-Fe. Results indicate that LDPE plates under visible light do not damage the bacteria's viability. Dark tests for both TiO_2 and TiO_2-Fe show a CFU decrease of 1 log in the *E.Coli* concentration, which may be associated with an adsorption process. The results with TiO_2 are similar to those found in darkness, confirming that TiO_2 is not activated under visible light. The plates coated with TiO_2-Fe decreased by 5 log at 120 min and complete inactivation of *E.Coli* at 180 min (data not shown), indicating that synthetized material is active under visible radiation (Graphical Illustration). Previous results suggest that the inactivation of bacteria under visible light occurs through the attack of singlet oxygen and superoxide ion radicals.

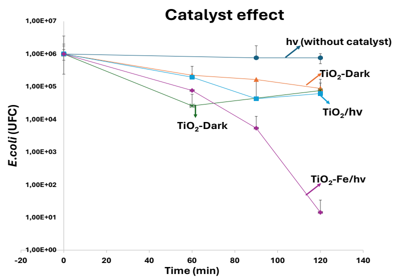

Figure 4. *E.Coli* inactivation under LED visible light on LDPE surfaces pretreated with sandpaper and impregnated TiO_2 and TiO_2-Fe by spray method

Conclusions

The new material is capable of promoting photodisinfection of *E.Coli* catalyzed by visible light. The morphological damage suffered by the bacteria due to oxidative attack by $O_2^{\cdot-}$ and $^1O_2$ prevents bacterial regrowth after 10 h of treatment. The synthesis method implemented showed good results, given the characterization that was carried out and the good performance in the photocatalytic activity with visible light.

Acknowledgments

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