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Synthesis of lignin based composites of TiO_2 for potential application as radical scavengers in sunscreen formulation

Mohamad Nasir Mohamad Ibrahim[1*], Anwar Iqbal[1], Chai Chuan Shen[1], Showkat Ahmad Bhawani[2] and Farook Adam[1]

Abstract

Titanium dioxide (TiO_2) is added in sunscreens due to its ability to absorb ultraviolet (UV) light. However, upon irradiation of UV light, reactive oxygen species particularly hydroxyl radical which can damage human skin will be generated. In this study, lignin/TiO_2 composites were employed to quench the hydroxyl radicals generated by the TiO_2. The lignin was extracted from oil palm empty fruit bunch (OPEFB) via kraft and soda pulping processes. The kraft lignin composite was labelled as KL/TiO_2 whereas the soda lignin composite was labelled as SL/TiO_2. The lignins and the composites were characterized by FTIR, UV spectroscopy, ^{13}C NMR, SEM, EDX, and XRD. The relative hydroxyl radical production of composites and TiO_2 were compared through photo-oxidation of coumarin to 7-hydroxycoumarin as a test medium. The effect of types and amounts of lignin used were studied. The KL/TiO_2 composite showed the least radical production due to higher phenolic hydroxyl content of kraft lignin. The activity of the hydroxyl radicals will be quenched when it abstract hydrogen atoms from the phenolic hydroxyl groups.

Keywords: TiO_2, Hydroxyl radical, Lignin, Oil palm empty fruit bunch, Lignin/TiO_2 composite

Introduction

Titanium dioxide (TiO_2) is used as an inorganic agent in sunscreens due to its ability to reflect, scatter and absorb a wide range of ultraviolet radiation in sunlight [1]. The maximum loading of TiO_2 in sunscreens is 25%, and the crystalline form of TiO_2 that mostly used for this application is anatase [2]. The TiO_2 is also employed as opacifiers and pigments in paints and paper coatings due to the whiteness and opaque characteristics [3]. Moreover, TiO_2 possesses excellent photocatalytic capability which makes it suitable for removal of organic compounds in contaminated water [4]. However, this capability of TiO_2 is a double-edged sword. The photocatalytic activity of TiO_2 can generate superoxide and hydroxyl radicals by the irradiation of sunlight. This is unfavorable for the application in sunscreens. These reactive oxygen species with cytotoxic and genotoxic characteristics can react with biomolecules such as protein and DNA upon formation on the surface of TiO_2 [5]. This may result in carcinogenesis, enzyme inactivation and potential damage of biomolecules [5]. The reactive oxygen species will cause the degradation of other organic agents in sunscreen [6].

A variety of methods have adopted by many researchers to reduce the photocatalytic activity of TiO_2. The alumina was used to coat TiO_2 by Picatonotto et al. [7]. The inorganic surface coating minimizes the photocatalytic activity by reducing holes and electrons generation and enhancing electron–hole recombination which leads to quenching of photocatalytic activity. The encapsulation of TiO_2 in zeolites reduced its photocatalytic efficiency by increasing the band gap so that excitation can only take place under ultraviolet radiation with the wavelength below 265 nm (ultraviolet C (UVC) region) [8]. The UVC can be absorbed by the ozone layer and will not reach the surface of the earth. Moreover, instead of inhibiting the photocatalytic activity of TiO_2, Chen et al. [9] utilized

*Correspondence: mnm@usm.my
[1] School of Chemical Sciences, Universiti Sains Malaysia, 11800 Gelugor, Penang, Malaysia
Full list of author information is available at the end of the article