Disinfection of Salmonella typhi by Titanium Dioxide Photocatalytic Oxidation

by Asmiyenti Djaliasrin Djalil

Disinfection of *Salmonella typhi* by Titanium Dioxide Photocatalytic Oxidation

A.D. Djalil[1*], B. Yusriana[2], R. Wahyuningrum[1]

[1]*Faculty of Pharmacy, Universitas Muhammadiyah Purwokerto, Purwokerto 53182, Indonesia*

[2]*FKIP, Universitas Muhammadiyah Purwokerto, Purwokerto 53182, Indonesia*

Abstract

When titanium dioxide (TiO_2) is irradiated with near UV light, this semiconductor exhibits hydroxyl radicals that have bavtericidal activity. The aim of this research is to study the effect of photo catalyc oxidation by titanium dioxide to disinfection Salmonella typhi. Photo catalyc reactor was prepared from TiO_2 suspesion (1%) in 200 mL aqueous susension of Salmonella typhi. That solution was irradiated with UV A (black light). During treatment, the photo catalyc reactor was placed in LAF (Laminar Air Flow). The bacteria which resistant towards the treatment were counted using TPC (Total Plate Count) method. The kinetics of disinfection as a function of process variables including the incident light intensity, and initial cell concentration were investigated. The influence of rates on light insensity was investigated in the range of 100-300 Lux (light insensity from 1,2,3 UV black light @ 10 watt). UV irradiation 228 Lux for 180 minutes could disinfect Salmonella typhi ($2x10^5$ CFU/mL) up to 100%. Disinfection rate were found to be first order respect to initial cell concentration with k value: $3.78.10^{-5}$ det^{-1} at 116 Lux, $1.268.10^{-4}$ det^{-1} at 228 Lux, $2.134.10^{-4}$ det^{-1} at 301 Lux. Disinfection rate increased proportionally with the increasing of light insensity at the observed condition. Photo catalytic oxidation by titanium dioxide could disinfect Salmonella typhi.

Keywords : photocatalyticc disinfection, Titanium dioxide, *Salmonella typhi*

1. Introduction

The presence of microorganisms and the production of toxic products in the traditional process of chlorination for disinfection of potable water are considered serious problems. Alternatives to the chlorination method are being developed, mainly in an attempt to reduce the formation of trihalomethanes (THM) and any other product that presents a threat to human health.

During the past years, the advanced oxidation process (AOP) has been studied to determine its a viability. It is considered an oxidation process in which mainly hydroxyl radicals (OH) are generated, which have a greater oxidation potential and thus the ability to react with organic compounds and microorganisms.

When TiO_2 in the anatase crystal form absorbs light at a higher energy than its band gap (3.2 eV), the photon energy generates an electron hole pair on the TiO_2 surface. The hole in the valence band can react with H_2O or hydroxide ions adsorbed on the surface to produce hydroxyl radicals (OH•), and the electron in the conduction band can reduce O_2 to produce sueroxide ions ($\bullet O_2^-$). Both holes and OH• are extremely reactive with contacting organic compounds. Detection of other reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2) and singlet oxigen, has also been reported. The detailed mechanism of the TiO_2 photochemical reaction and the various ROS roduced have been well-documented [1].

$$TiO_2 \rightarrow TiO_2\,(h^+_{VB} + e^-_{CB}) \quad (1)$$
$$h^+_{VB} + H_2O \rightarrow OH\bullet + H^+ \quad (2)$$
$$h^+_{VB} + OH^- \rightarrow OH\bullet \quad (3)$$
$$e^-_{CB} + O_2 \rightarrow \bullet O_2^- \quad (4)$$
$$2\bullet O_2^- + 2H^+ \rightarrow H_2O_2 + O_2 \quad (5)$$
$$H_2O_2 + e^-_{CB} \rightarrow OH\bullet + OH^- \quad (6)$$
$$\bullet O_2^- + H^+ \rightarrow .OOH \quad (7)$$

In 1985, Matsunaga et al. Reported that *E. Coli* in the water could be killed by contact with a TiO2-Pt catalyst upon illumination with near-UV light for 120 min [2]. The findings of Matsunaga et al. created a new avenue for sterilization and resulted in attempts to use this novel photocatalytic technology for disinfecting drinking water and removing bioaerosols from indoor air environments [3-6]. Because of the widespread use antibiotics and the emergence of more resistant and virulent strains of microorganisms, there is an immediate need to develop alternative sterilization technologies.

The fundamental mechanism underlying the photocatalytic killing process has not been well-estabilished yet. The first mechanism proposed was the mechanism proposed by Matsunaga et al, who believed that direct photochemical oxidation of intracellular coenzyme A to its dimeric form was the root cause of decreases in respiratory activities that led to cell death [2,7]. They reported that the extent of killing was inversely proportional to the thickness and complexity of the cell wall. Saito and workers[5] proposed that the TiO_2 photochemical reaction caused disruption of the cell membrane and the cell wall of *Streptococus sobrinus* AHT, as shown by leakage of intracellular Kl ions that paralleled cell death. When irradiated TiO_2 particles are in direct contact with or close to microbes, the microbial surface is the primary target of the initial oxidative attack.

Salmonella typhi is a Gram-negative pathogen. It is important to conduct disinfection tests with it, because the microorganism produces endotoxin which cause disease. This study was carried out to demonstrate the TiO_2 biocidal ability against *Salmonella typhi*. The bacteria was disinfect and carefully monitored at different elapsed time, the bacteria concentration, and different UV intensity to optimize the photocatalysis of the biocidal reactions.

2. Experimental Method

2.1 Culture of Microorganisms

S. typhi strain NTCC 766 BCC 712 (Biofarma) was grown aerobically in nutrient broth (Oxoid) at 34°C 24 hr.

2.2 Reactor Construction and Operation

The irradiation source is UV lamp (Sankyo Denki® @ 10 watt, commonly referred as the black light lamp). The illuminating UV light was placed approximately 16 cm above the glass reaction vessel (Fig 1). The light intensity reaching the surface at the center of the glass reaction vessel determined by using a lux meter (JLL 10 Jeulin). The 200 mL total volume have *S. typhi* bacteria suspens ion and TiO_2 suspension (1%). The reactors were constantly stirred to provide good mixing. Bacterial cells were sampled in every 30 min for 4 hr. During treatment, the photo catalytic reactor was placed in LAF (*Laminar Air Flow*). The numbers of viable cells were determined by plating suspensions onto nutrient agar plates. The plates were incubated at 34°C for 24 hr, and then the numbers of colonies on the plates were counted. The kinetics of disinfection as a function of process variables including the incident light intensity, and initial cell concentration were investigated. The influence of rates on light intensity was investigated in the range of 100-300 Lux (light intensity from 1,2,3 UV black light @ 10 watt) Initial cell concentration was investigated ranging from $1x10^3$ - $3x10^6$ CFU/mL.

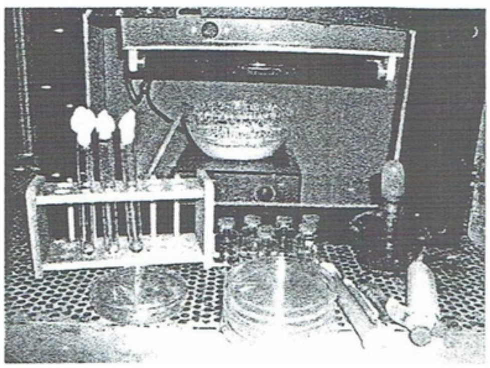

Figure 1 Experiment apparatus for photocatalytic reaction

3. Results and Discussion

The photoreactor employed in batch process was designed for the mixture of cells and TiO_2 to contact continuously. The inactivation of cells was evaluated by counting the viable cells with regular sampling. Photocatalys is TiO_2 with UV irradiation 228 Lux for 180 minutes could disinfect *Salmonella typhi* (initial concentration $2x10^5$ CFU/mL) up to 100% (Fig. 2).

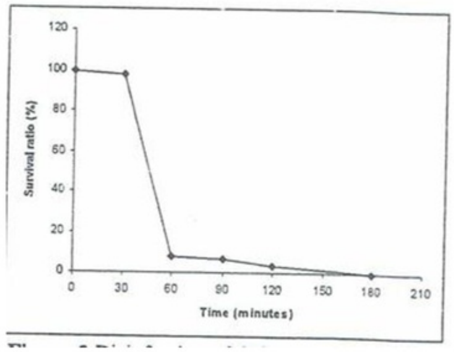

Figure 2 Disinfection of *Salmonella typhi* over 180 minutes by Titanium Dioxide Photocatalytic oxidation with UV irradiation 228 Lux

The kinetics of disinfection were investigated as a function of the incident light intensity and initial cell concentration. Disinfection rate as a function of initial cell concnentation is given by:

$$r_i = kC_i^n \qquad (8)$$

Where r_i is the initial reaction rate, C_i is the initial cell concentration, n is the reaction order, and k is the reaction rate constant. The above equation upon log transformation can be re-written as:

$$\log\ r_i = \log\ k + n\ \log\ c_i \qquad (9)$$

Consequently, a plot of log C_i vs r_i should be linear, with slope of n and an intercept of log k. And then, k and n can be calculated. Disinfection rate were found to be first order with respect to initial cell concentration, with k value: $3.78.10^{-5}$ sec^{-1} at 116 Lux, $1.268.10^{-4}$ sec^{-1} at 228 Lux, and $2.134.10^{-4}$ sec^{-1} at 301 Lux (Fig 3.)

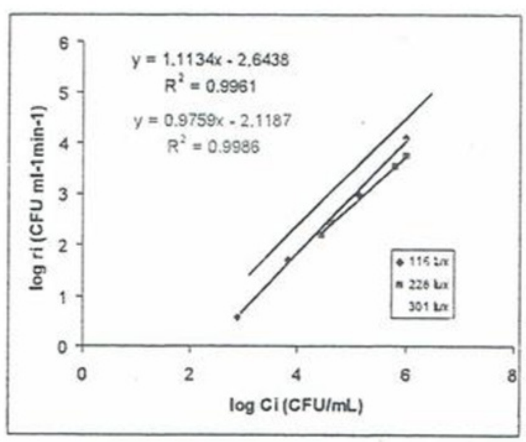

Figure 3 Effect of Initial cell concentration on the initial disinfection rate

The kinetics of disinfection as a function of the incident light intensity was investigated. The influence of rates on light intensity was investigated in the range of 100-300 Lux (light intensity from 1,2,3 UV black light @ 10 watt). As demonstrated in the Fig 4, disinfection rate increased proportionally with the increasing of light intensity at the observed condition.

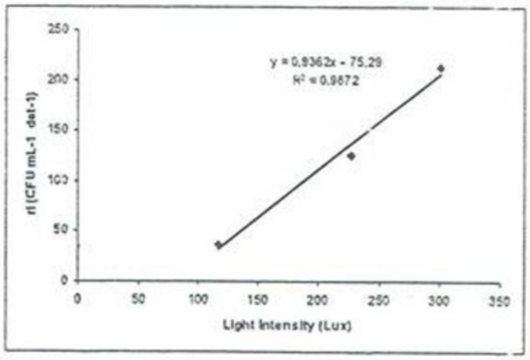

Figure 4 The influence light intensity on the initial disinfection rate

(C_i= $1x10^6$ CFU/mL)

4. Conclusions

The obtained data have demonstrated TiO_2's ability to disinfection microorganisms pathogen *Salmonella typhi*. It was also apparent that the efficiency of the inactivation increase with the increase of UV intensity at the observed condition, disinfection rate were found to be first order with respect to initial cell.

References

1. P.C Maness, S. Smolinski, D.M. Blake, Z. Huang, E.J. Wolfrum and W.A. Jacoby. *Appl. Environ. Microbiol.* **65(9)** 4094-4098 (1999).
2. T. Matsunaga, R. Tomada, T. Nakajima and H. Wake. *FEMS Microbiol. Lett.* **29** 211-214 (1985).
3. D. Y. Gaswami, D. M. Trivedi and S.S Block. *J. Sol. Energy Eng.* **119** 92-96 (1997).
4. J. C. Ireland, P. Klostermann, E. W. Rice and R. M Clark. *Appl. Environ. Microbiol.* **59** 1668-1670 (1992).
5. T.Saito, T. Iwase and T Morioka. *Photochem. Photobiol. B Biol* **14** 369-379 (1992).
6. C.Wei, W.Y. Lin, Z. Zaina, N. E. Williams, K. Zhu, A.P. Kruzic, R.L. Smith and K. Rajeshwar, *Environ. Sci. Technol.* **28** 934-938 (1994).
7. T. Matsunaga, R. Tomodo, Y. Nakajima, N. Nakamura and T. Komine. *Appl. Environ. Microbiol.* **54** 1330-1333 (1988).

Acknowledgment

This work was supported by the Unggulan Research at the LPPM-UMP.

Disinfection of Salmonella typhi by Titanium Dioxide Photocatalytic Oxidation

ORIGINALITY REPORT

23%	17%	23%	17%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	S. A. Ruffolo. "ZnO and ZnTiO3 nanopowders for antimicrobial stone coating", Applied Physics A, 03/31/2010 Publication	7%
2	Hyeon-Cheol Joo, Young-Jun Lim, Myung-Joo Kim, Ho-Beom Kwon, Jun-Hyun Han. "Characterization on titanium surfaces and its effect on photocatalytic bactericidal activity", Applied Surface Science, 2010 Publication	4%
3	H.J. Haugen, S.P. Lyngstadaas. "Antibacterial effects of titanium dioxide in wounds", Elsevier BV, 2016 Publication	4%
4	www.getcasia.com Internet Source	2%
5	Submitted to Florida Gulf Coast University Student Paper	2%

Saurabh S. Soni. "Visible-Light Photocatalysis

6	in Titania-Based Mesoporous Thin Films", Advanced Materials, 04/21/2008 Publication	1%
7	Nakano, Ryuichi, Hitoshi Ishiguro, Yanyan Yao, Jitsuo Kajioka, Akira Fujishima, Kayano Sunada, Masafumi Minoshima, Kazuhito Hashimoto, and Yoshinobu Kubota. "Photocatalytic inactivation of influenza virus by titanium dioxide thin film", Photochemical & Photobiological Sciences, 2012. Publication	1%
8	aem.asm.org Internet Source	1%
9	Submitted to Mahidol University Student Paper	1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		