United Journal of Veterinary Science and Technology

Mini Review

Application and Development of Triple Functional Features of the Novel Light-Emitting Diode Module in Pig Farms

Chia-Chi Chen[1], Tzu-Yun Chi[1], Cho-Lin Li[1], Ying-Ching Hung[1], Hsiao-Yun Chen[1], Wen-Der Fang[2], Chia-Yu Lin[1], Shao-Qun Lai[2], Cheng-Sheng Tsung[3], Chien-Chao Chiu[1], Jyh-Shiun Lin[1], Ping-Min Huang[1], Tsung-Han Wu[1], Yuan-Hao Chen[1], Pao-Hsueh Lin[1], Sheng-Fu Hsu[4], and Shao-Wen Hung[1,5,*]

[1]Division of Animal Industry, Animal Technology Laboratories, Agricultural Technology Research Institute, Hsinchu 300, Taiwan

[2]Division of Animal Resources, Animal Technology Laboratories, Agricultural Technology Research Institute, Hsinchu 300, Taiwan

[3]Department of Materials Science and Engineering, National Chung Hsing University, Taichung 402, Taiwan

[4]Division of Animal Technology, Animal Technology Laboratories, Agricultural Technology Research Institute, Hsinchu 300, Taiwan

[5]Department of Nursing, Yuanpei University of Medical Technology, Hsinchu 300, Taiwan

Volume 1 Issue 1 - 2020

Received Date: 21 Apr 2020

Accepted Date: 06 May 2020

Published Date: 09 May 2020

2. Keywords

Antimicrobial efficacy; Atmospheric fine particulate matter; Degradation; Harmful gas; Light-emitting diode

1. Abstract

In the traditional pig farms, disinfectants are applied for the effective cleaning and disinfection regimen. Disinfectants are used on pig farms for disinfecting the surfaces of floors, walls, equipment, tools. Moreover, it is also used to prepare boot dips which aim at disinfecting boots on the entry of animal accommodation. Disinfectants are also used to disinfect vehicles as they enter the site and to sanitize water delivery systems. The ideal detergents should be left no residue after use which might harbour micro-organisms. Additionally, it should be non-toxic to pigs and must have minimal environmental impacts. Therefore, in order to avoid detergent residues and possible effects on pigs, staffs, and environment, development of a novel method without chemicals to kill micro-organisms, degrade atmospheric fine particulate matter and harmful gases in the pig farms is pioneering and future potential. According to our recent publications and research results, the novel light-emitting diode module with triple functional features, $PM_{2.5}$/PM_{10} and harmful gas degradation, and antimicrobial efficacy, have been successfully developed. This novel clean and disinfect tool will be applied in the pig farms in the future to decrease disease occur and reduce the economic losses in pig farms.

3. Application of LED for Antimicrobial Efficacy and Harmful Gases and $PM_{2.5}$ Degradation

Ultraviolet (UV) light has been developed for surface decontamination. However, UV light has some limitations at harmful effects for human and animals [1, 2]. Development of antimicrobial LED visible light is safer than UV. Previously, visible light at 405 nm wavelength can caused the dead of microorganisms without affecting exposed mammalian cells [3, 4]. Despite of LED at 405 nm of wavelength, LEDs at 405, 460, 470, and 520 nm wavelength have also demonstrated antibacterial effects against various foodborne pathogens [2, 5-12]. Antimicrobial efficacy via LED commonly produced reactive oxygen species (ROS) to kill pathogens. The antimicrobial mechanisms included as production of superoxide anion (O_2^-), and hydroxyl radical (•OH), triplet oxygen, and /or the reactive singlet oxygen. Finally, LED-caused antimicrobial efficacy via these ROS to induce a number of cellular cytotoxic reactions [11, 13-16].

Recently, hot season than cold season can produce a strong oxidative air condition. The positive $PM_{2.5}$-O_3 correlations prevailed for high air temperature samples. High O_3 concentrations in a strong oxidative air condition promoted the formation of secondary large size particles, which could decrease atmospheric $PM_{2.5}$ concentration. However, It is need to further verify whether LED-caused $PM_{2.5}$ degradation is related with air temperature and O_3 [17, 18].

Production of gases in the conventional pig industry affects the environment and climate. In the pig husbandry, there are produced mainly ammonia (NH_3), carbon dioxide, nitrous oxide, and methane. NH_3 is a toxic gas with a direct negative effect on the pigs, staffs, and environment. The urine of pigs is the main source of

***Corresponding Author (s):** Shao-Wen Hung, Division of Animal Industry, Animal Technology Laboratories, Agricultural Technology Research Institute, No.1, Ln. 51, Dahu Rd., , Xiangshan, Hsinchu 300, Taiwan, Tel: +886 37 585930, Fax: +886 37 585969, E-mail: lymphoma2002@yahoo.com.tw*

Citation: Shao-Wen Hung. Application and Development of Triple Functional Features of the Novel Light-Emitting Diode Module in Pig Farms. United Journal of Veterinary Science and Technology, 2020; 1(1): 1-4.

NH_3 and increase ventilation is a method for elimination of NH_3 in pig farms. Therefore, development of another efficacious eliminated tool/method is need and important in the pig husbandry [19].

4. Application of LED Module on Antimicrobial Efficacy and Harmful Gas and $PM_{2.5}$/PM_{10} Degradation in Pig Farms

Previously, according to our previous publication [20], our LED device at 450 nm wavelength significantly induced highly cytotoxic ability for HT-29 and CT-26 colon cancer cell lines *in vitro* and significantly suppressed the tumor growth in the CT-26-bearing mice *in vivo* [20]. On other hand, we also have demonstrated that our developed LED at 450 nm wavelength had the abilities to kill *Staphylococcus aureus* and *Pseudomonas aeruginosa*, and degrade atmospheric fine particulate matter, $PM_{2.5}$ in laboratory stage. The dual functional features, $PM_{2.5}$ degradation and antimicrobial efficacy, of our LED devices were first demonstrated previously [21]. Recently, according to our previous results, we develop the new applied environment, pig farms, to test whether our LED devices is feasible in pig farms. Therefore, the specific-pathogen free (SPF) pig farm and the traditional pig farm were used in this study (Figure 1). According to our results, our LED devices posed antimicrobial efficacy. Antimicrobial efficacy after 8 hour-LED lighting in the SPF pig farm was between about 34.87%-91.63% and antimicrobial efficacy of our LED device was light height-dependent manner (Figure 2A). The degradation percentage of NH_3 were between about 8.98%-9.58% in the SPF pig farm and the degradation efficacy of our LED device was light time-dependent manner (Figure 2B). The degradation percentage of $PM_{2.5}$ and PM_{10} were respective between about 8.89%-86.67% and 12.5%-85.0% in the traditional pig farm and the degradation efficacy of our LED device was light time-dependent manner (Figure 3A). Antimicrobial efficacy after 8 hour-LED lighting in the traditional pig farm was between about 11.58%-13.33% and antimicrobial efficacy of our LED device did not present the light height-dependent manner (Figure 3B).

Figure 1: Test of LED device in the SPF pig farm and the traditional pig farm. (A) SPF pig farm. (B) Replace the LED lamp in SPF farm. (C) Erection of LED lamps in the traditional pig farm. White visible LED light was at 450 nm wavelength.

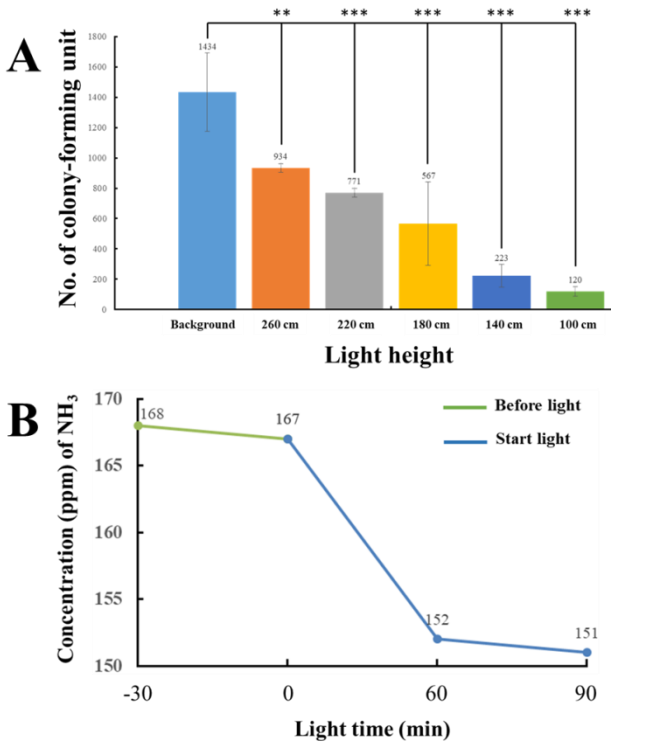

Figure 2: Antimicrobial efficacy and degradation of NH_3 via LED device (white visible light at 450 nm wavelength) in the SPF pig farm. (A) Antimicrobial efficacy. (B) Degradation of NH_3.

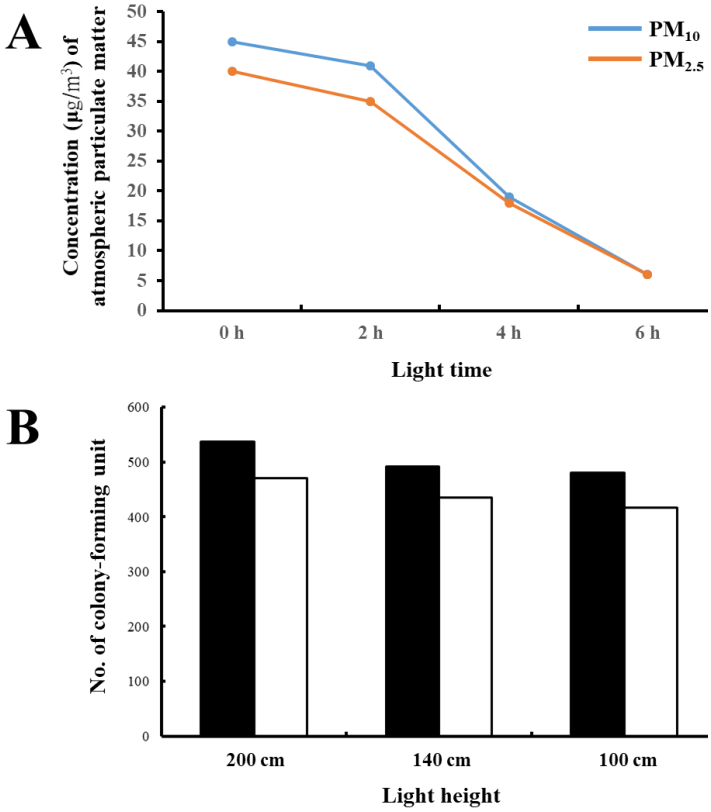

Figure 3: Degradation of $PM_{2.5}/PM_{10}$ and antimicrobial efficacy via LED device (white visible light at 450 nm wavelength) in the traditional pig farm. (A) Degradation of $PM_{2.5}/PM_{10}$. (B) Antimicrobial efficacy.

5. Conclusion

The triple functional features, degradation of atmospheric fine particulate matter, $PM_{2.5}$ and PM_{10}, harmful gases, and antimicrobial efficacy, in our LED device were first demonstrated in this study. In the future, this powerful LED devices have the promising applications in the human and animal life environment and biomedical application to serve as disinfection, bacteriostatic, and improvement of pig farms.

6. Acknowledgements

All authors thank the Council of Agriculture in Taiwan(Executive Yuan) [grant numbers 108AS-14.1.2-ST-a7;109AS-12.1.2-ST-a1] for fully supporting this study.

References

1. Maclean M, MacGregor SJ, Anderson JG, Woolsey G. Inactivation of bacterial pathogens following exposure to light from a 405-nanometer light-emitting diode array. Appl Environ Microbiol. 2009; 75(7): 1932-7.

2. Kim MJ, Mikš-Krajnik M, Kumar A, Yuk HG. Inactivation by 405 ± 5 nm light emitting diode on Escherichia coli O157: H7, *Salmonella Typhimurium*, and *Shigella sonnei* under refrigerated condition might be due to the loss of membrane integrity. Food Control. 2016; 59: 99-107.

3. Dai T, Gupta A, Huang YY, Yin R, Murray CK, Vrahas MS, et al. Blue light rescues mice from potentially fatal *Pseudomonas aeruginosa* burn infection: efficacy, safety, and mechanism of action. Antimicrob Agents Chemother. 2013; 57(3): 1238-45.

4. McDonald RS, Gupta S, Maclean M, Ramakrishnan P, Anderson JG, MacGregor SJ, et al. 405 nm Light exposure of osteoblasts and inactivation of bacterial isolates from arthroplasty patients: potential for new disinfection applications? Eur Cell Mater. 2013; 25: 204-14.

5. Kim MJ, Bang WS, Yuk HG. 405 ± 5 nm light emitting diode illumination causes photodynamic inactivation of *Salmonella* spp. on fresh-cut papaya without deterioration. Food Microbiol. 2017; 62: 124-32.

6. Guffey JS, Wilborn J. Effects of combined 405-nm and 880-nm light on *Staphylococcus aureus* and *Pseudomonas aeruginosa in vitro*. Photomed Laser Surg. 2006; 24: 680-3.

7. Brovko LY, Meyer A, Tiwana AS, Chen W, Liu H, Filipe CD, et al. Photodynamic treatment: a novel method for sanitization of food handling and food processing surfaces. J Food Prot. 2009; 72: 1020-1024.

8. Luksienė Z, Kokstaite R, Katauskis P, Skakauskas V. Novel approach to effective and uniform inactivation of Gram-positive *Listeria*

monocytogenes and Gram-negative *Salmonella enterica* by photosensitization. Food Technol Biotech. 2013; 51: 338-44.

9. Ghate V, Ng KS, Zhou W, Yang H, Khoo GH, Yoon WB, et al. Antibacterial effect of light emitting diodes of visible wavelengths on selected foodborne pathogens at different illumination temperatures. Int J Food Microbiol. 2013; 166: 399-406.

10. Kumar A, Ghate V, Kim MJ, Zhou W, Khoo GH, Yuk HG. Antibacterial efficacy of 405, 460 and 520 nm light emitting diodes on *Lactobacillus plantarum, Staphylococcus aureus* and *Vibrio parahaemolyticus*. J Appl Microbiol. 2016; 120: 49-56.

11. Kumar A, Ghate V, Kim MJ, Zhou W, Khoo GH, Yuk HG. Kinetics of bacterial inactivation by 405 nm and 520 nm light emitting diodes and the role of endogenous coproporphyrin on bacterial susceptibility. J Photochem Photobiol B. 2015; 149: 37-44.

12. De Lucca AJ, Carter-Wientjes C, Williams KA, Bhatnagar D. Blue light (470 nm) effectively inhibits bacterial and fungal growth. Lett Appl Microbiol. 2012; 55: 460-6.

13. Gillespie JB, Maclean M, Given MJ, Wilson MP, Judd MD, Timoshkin IV, et al. Efficacy of pulsed 405-nm light-emitting diodes for antimicrobial photodynamic inactivation: effects of intensity, frequency, and duty cycle. Photomed Laser Surg. 2017; 35: 150-6.

14. Luksiene Z, Brovko L. Antibacterial photosensitization-based treatment for food safety. Food Eng Rev. 2013; 5: 185-199.

15. Ramakrishnan P, Maclean M, MacGregor SJ, Anderson JG, Grant MH. Cytotoxic responses to 405 nm light exposure in mammalian and bacterial cells: involvement of reactive oxygen species. Toxicol In Vitro. 2016; 33: 54-62.

16. Luksiene Z. Photosensitization for food safety. Chemine Technologija. 2009; 4: 62-5.

17. Jia M, Zhao T, Cheng X, Gong S, Zhang X, Tang L, et al. Inverse relations of $PM_{2.5}$ and O_3 in air compound pollution between cold and hot seasons over an urban area of East China. Atmosphere. 2007; 8: 59.

18. Zhu J, Chen L, Liao H, Dang R. Correlations between $PM_{2.5}$ and Ozone over China and associated underlying reasons. Atmosphere. 2019; 10: 352.

19. Mihina S, Sauter M, Palkovičová Z, Karandušovská I, Brouček J. Concentration of harmful gases in poultry and pig houses. Anim Sci Pap Rep. 2012; 30: 395-406.

20. Hung YW, Tsung CS, Lin YH, Chiu CF, Chiu CC, Chiu HW, et al. Study of phototoxicity of LED light for colon cancer. Biomed J Sci Tech Res. 2019; 13: 10167-9.

21. Chi TY, Li CL, Tsung CS, Chen CC, Hung YC, Lin CY, et al. Research and development of dual functional features of light-emitting diode: degradation of atmospheric fine particulate matter and antimicrobial efficacy. Biomed J Sci Tech Res. 2019; 20: 15273-7.