Field study: Far-UVC effectively impairs airborne transmission of PRRS virus

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May 2024

Introduction

Porcine reproductive and respiratory syndrome (PRRS) is a viral infection causing both respiratory diseases and reproductive failure in pigs. In 2022, Danish agricultural stakeholders including the Danish Agriculture & Food Council, Danske Svineslagterier, the Danish Agriculture and Food Council's Pig Sector, and the Danish Veterinary Association, initiated a national strategy to mitigate PRRS in pig herds [1]. The virus can spread through direct contact between pigs or via airborne transmission, with the latter posing significant challenges as it can travel up to 9 km [2, 3], potentially infecting neighboring herds. Consequently, there is an unmet need for innovative technologies to prevent airborne PRRSV transmission between farms.

Traditional UVC light, emitted at 254 nm from low-pressure mercury lamps, has been used for its germicidal properties for over a century. Although effective at inactivating microorganisms, its application is restricted to unoccupied spaces or ventilation systems due to its harmful effects on humans and animals [4].

Far-UVC light, emitted from krypton chloride excimer lamps at 222 nm, has gained recognition for its germicidal effectiveness while being safe for humans and animals [5, 6]. Unlike conventional UVC, far-UVC light is highly absorbed by proteins, limiting its penetration to the outermost layer of dead skin cells [7, 8, 9] and the protein-rich tear layer of the eye [10, 11]. Numerous laboratory studies have demonstrated far-UVC's germicidal capabilities [6, 12, 13], including its effectiveness against PRRSV [14, 15], but real-world studies are still scarce [16, 17]. This field study explores the use of far-UVC light in a small-scale pig pen to assess its practical efficacy in agricultural settings. Our findings highlight the potential of far-UVC in inactivating PRRSV and thereby prevent transmission between neighboring herds.

Experimental setup

The field study was conducted in a controlled setting at the Department for Veterinary and Animal Science, University of Copenhagen. Four identical rooms of approximately 19 m^2 each were used; two were equipped with far-UVC lamps and designated as intervention rooms, while the remaining two served as control rooms without far-UVC lamps. Each room featured one fenced pen and had ventilation inlets and outlets. In each intervention room, six IP66 rated UV222 Industrial lamps, emitting far-UVC light at 222 nm with a 60-degree dispersion angle, and an output of 115 mW, were installed. These lamps were positioned around the pen at a height of 2.3 meters and angled at 45 degrees to direct light toward the floor of the pen (Figure 1).

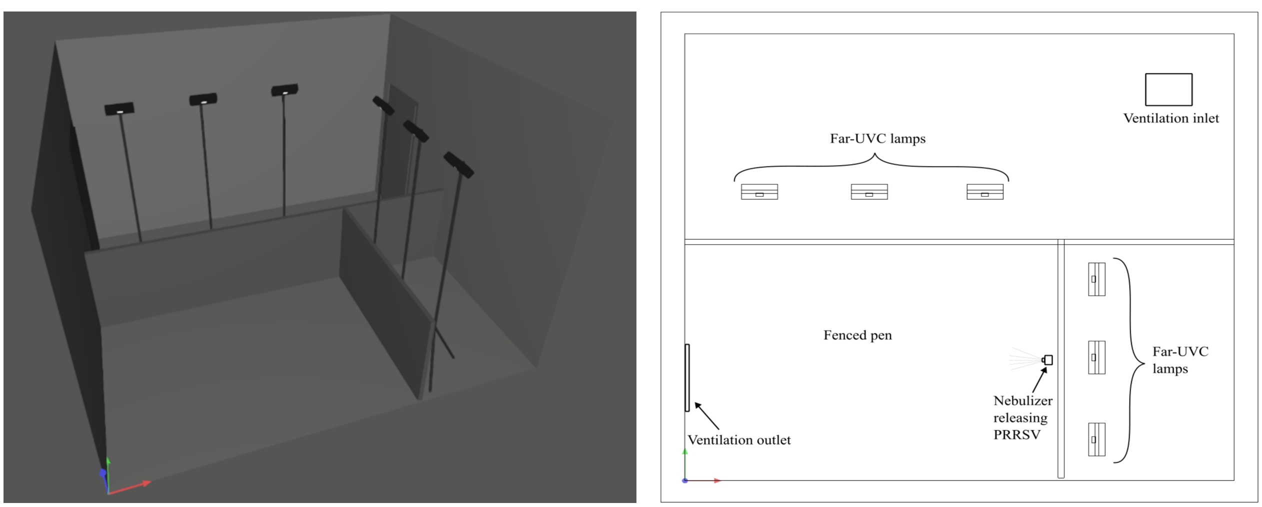

Figure 1: Experimental setup. A 3D model of the fenced pen with six far-UVC lamps placed around it. The lamps are mounted at a height of 2.3 meters and directed downwards toward the floor in the pen (A). A schematic representation of the room is shown from an overhead view, indicating the location of the far-UVC lamps, ventilation inlet and outlet, and the nebulizer releasing PRRSV into the room (B). The control is identical but without the far-UVC lamps.

To simulate airborne PRRSV contamination, nebulizers filled with a PRRSV solution were placed below the ceiling in each room. The nebulizers generated both small airborne particles and larger particles that quickly settled. To ensure retention of only airborne particles, a tarp was placed over the pen for the first 10 minutes post-nebulization. The larger particles settled on the tarp, which was then removed before introducing pigs into the pens—two per room. This setup was repeated in three independent experiments. Air and surface samples were collected from the pen prior and immediately after virus dispersal by the nebulizer and at 30 and 60 minutes subsequently, to confirm presence of PRRSV in all rooms. PRRS infection monitoring was conducted through blood samples taken from the pigs immediately before the experiment began and again over the following two days. A pig was considered PRRS-positive if its blood sample showed infection within 48 hours.

Results

In this study, we evaluated the efficacy of far-UVC in preventing airborne transmission of PRRSV to pigs. We conducted the experiment in identical rooms, with and without far-UVC lamps. Air and surface samples confirmed the presence of PRRSV in all rooms. In the non-irradiated control rooms, airborne PRRS infected the pigs during two out of three trials, with incidences of two and one infected pigs, respectively. This confirms that our experimental setup is effective and capable of facilitating PRRS infection in pigs through airborne transmission. Conversely, in the rooms with far-UVC lamps, no pigs contracted PRRS, demonstrating the effectiveness of far-UVC in inactivating the virus and reducing the risk of airborne transmission (Figure 2).

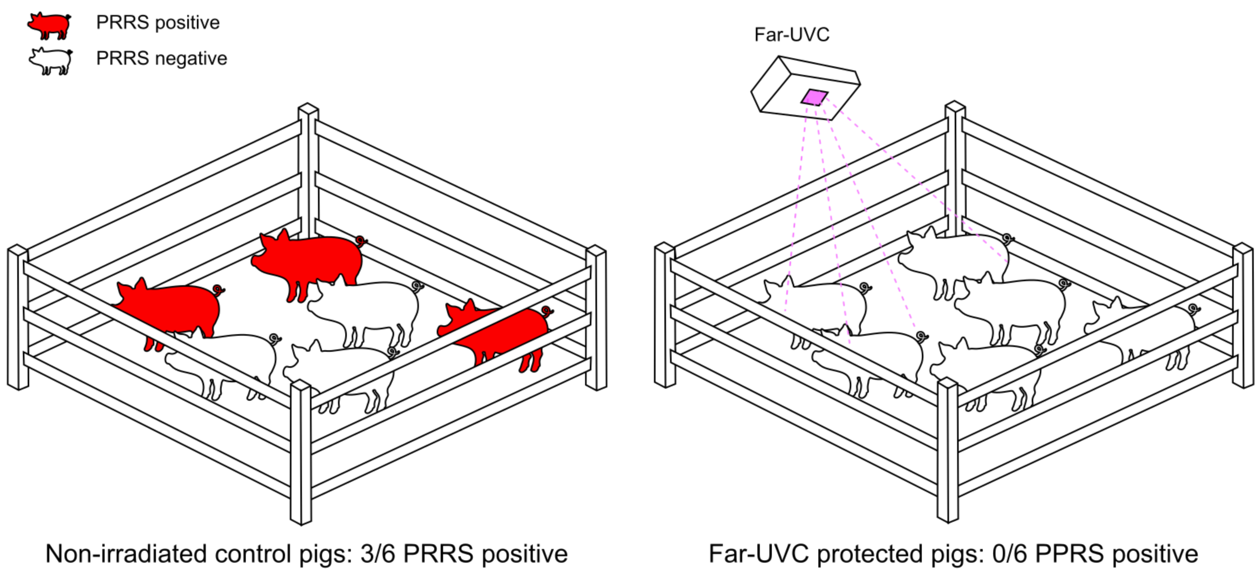

Figure 2: Far-UVC protects pigs against airborne transmission of PRRS. The pen on the left illustrates the results for the non-irradiated control pigs, in which half of the pigs contracted PRRS from the air. Red pigs denote PRRS-positive, and white pigs denotes PPRS-negative. In contrast, when far-UVC was applied, none of the pigs contracted PRRS, as shown in the pen on the right.

Conclusion

In this experimental setup, far-UVC provided 100% protection against airborne transmission of PRRS. In three independent experiments, 50% of the pigs in the non-irradiated control rooms contracted PRRS infection. In contrast, 0% of the pigs contracted PRRS when far-UVC was applied.

This demonstrates the effectiveness of far-UVC in preventing airborne transmission of PRRS and highlights its potential in preventing transmission between neighboring herds in real-world pig farms. The application of far-UVC is not limited to pig farms and PRRS; it extends to mitigating any airborne disease in livestock farms. Specifically, it can effectively inactivate swine influenza, reducing the risk of intra- and inter-farm airborne transmission, as well as inactivate avian influenza, lowering the risk of poultry farms being affected by airborne transmission from wild birds.

References

[1] Strategy for the Reduction of Porcine Reproductive and Respiratory Syndrome (PRRS) in Pigs in Denmark; 2022. Available from: https://svineproduktion.dk/Aktuelt/Temaer/PRRS.

[2] Dee S, Otake S, Oliveira S, Deen J. Evidence of long distance airborne transport of porcine reproductive and respiratory syndrome virus and Mycoplasma hyopneumoniae [Journal Article]. Vet Res. 2009;40(4):39.

[3] Otake S, Dee S, Corzo C, Oliveira S, Deen J. Long-distance airborne transport of infectious PRRSV and Mycoplasma hyopneumoniae from a swine population infected with multiple viral variants [Journal Article]. Vet Microbiol. 2010;145(3-4):198-208.

[4] Milonova S, Rudnick S, McDevitt J, Nardell E. Occupant UV exposure measurements for upper-room ultraviolet germicidal irradiation [Journal Article]. J Photochem Photobiol B. 2016;159:88-92.

[5] Görlitz M, Justen L, Rochette PJ, Buonanno M, Welch D, Kleiman NJ, et al.. Assessing the safety of new germicidal far-UVC technologies [Journal Article]; 2023.

[6] Hessling M, Haag R, Sieber N, Vatter P. The impact of far-UVC radiation (200-230 nm) on pathogens, cells, skin, and eyes - a collection and analysis of a hundred years of data [Journal Article]. GMS Hyg Infect Control. 2021;16:Doc07.

[7] Buonanno M, Ponnaiya B, Welch D, Stanislauskas M, Randers-Pehrson G, Smilenov L, et al. Germicidal Efficacy and Mammalian Skin Safety of 222-nm UV Light [Journal Article]. Radiat Res. 2017;187(4):483-91.

[8] Eadie E, Barnard IMR, Ibbotson SH, Wood K. Extreme Exposure to Filtered Far-UVC: A Case Study(†) [Journal Article]. Photochem Photobiol. 2021;97(3):527-31.

[9] Narita K, Asano K, Morimoto Y, Igarashi T, Nakane A. Chronic irradiation with 222-nm UVC light induces neither DNA damage nor epidermal lesions in mouse skin, even at high doses [Journal Article]. PLoS One. 2018;13(7):e0201259.

[10] Kaidzu S, Sugihara K, Sasaki M, Nishiaki A, Ohashi H, Igarashi T, et al. Re-Evaluation of Rat Corneal Damage by Short-Wavelength UV Revealed Extremely Less Hazardous Property of Far-UV-C(†) [Journal Article]. Photochem Photobiol. 2021;97(3):505-16.

[11] Sugihara K, Kaidzu S, Sasaki M, Ichioka S, Takayanagi Y, Shimizu H, et al. One-year Ocular Safety Observation of Workers and Estimations of Microorganism Inactivation Efficacy in the Room Irradiated with 222-nm Far Ultraviolet-C Lamps [Journal Article]. Photochem Photobiol. 2022.

[12] Narita K, Asano K, Naito K, Ohashi H, Sasaki M, Morimoto Y, et al. 222-nm UVC inactivates a wide spectrum of microbial pathogens [Journal Article]. J Hosp Infect. 2020.

[13] Welch D, Buonanno M, Grilj V, Shuryak I, Crickmore C, Bigelow AW, et al. Far-UVC light: A new tool to control the spread of airborne-mediated microbial diseases [Journal Article]. Sci Rep. 2018;8(1):2752.

[14] Li P, Koziel J, Zimmerman J, Zhang J, Cheng TY, Yim-Im W, et al. Mitigation of Airborne PRRSV Transmission with UV Light Treatment: Proof-of-Concept [Journal Article]. Agriculture. 2021;11(3):259. Available from: https://dx.doi.org/10.3390/agriculture11030259.

[15] Li P, Koziel JA, Zimmerman JJ, Zhang J, Cheng TY, Yim-Im W, et al. Correction: Li et al. Mitigation of Airborne PRRSV Transmission with UV Light Treatment: Proof-of-Concept. Agriculture 2021, 11, 259 [Journal Article]. Agriculture. 2022;12(5):680. Available from: https://dx.doi.org/10.3390/agriculture12050680.

[16] Buonanno M, Kleiman NJ, Welch D, Hashmi R, Shuryak I, Brenner DJ. 222 nm far-UVC light markedly reduces the level of infectious airborne virus in an occupied room [Journal Article]. Sci Rep. 2024;14(1):6722.

[17] Eadie E, Hiwar W, Fletcher L, Tidswell E, O'Mahoney P, Buonanno M, et al. Far-UVC (222 nm) efficiently inactivates an airborne pathogen in a room-sized chamber [Journal Article]. Sci Rep. 2022;12(1):4373.