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An evaluation of ultraviolet light (UV_{254}) as a means to inactivate porcine reproductive and respiratory syndrome virus on common farm surfaces and materials

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ABSTRACT

A study was conducted to assess the effect of UV_{254} on the concentration and viability of PRRSV on surfaces and materials commonly encountered on swine farms. A standard quantity (5×10^6 $TCID_{50}$, total dose) of a PRRSV modified live vaccine virus was inoculated onto 2 matched sets of surfaces/materials including wood, plastic, latex, rubber, styrofoam, metal, leather, cloth, concrete, cardboard, glass and paper. One set was exposed to UV_{254} radiation (treatments) and the other to incandescent light (controls) for a 24 h period. During this time, treatments and controls were swabbed at 10 min intervals from 0 to 60 min post-inoculation (PI) and again at 24 h PI. The quantity of PRRSV RNA on each item at each sampling time was calculated by RT-PCR and the presence of viable PRRSV in each sample was determined by swine bioassay. A significant reduction ($p < 0.0001$) in the quantity of PRRSV RNA was demonstrated at 24 h PI independent of treatment. In addition, a significant reduction ($p = 0.012$) in the number of UV_{254}-treated surfaces which harbored viable virus was observed at 60 min (0/12 positive) when compared to control surfaces (5/12 positive). In addition, all UV_{254} treated samples collected between 10 and 50 min PI were bioassay negative. These results suggest that UV_{254} is an effective means to inactivate PRRSV on commonly encountered farm surfaces and materials and inactivation can be accomplished following 10 min of exposure.

The germicidal effects of short wave ultraviolet light (UVC_{254}) have been well documented (Hijnen et al., 2006; Keklik et al., 2010). Through the formation of thymidine dimers, UV_{254} functions as a mutagen and prevents pathogen replication (Rolfsmeier et al., 2010). Recent data have demonstrated the ability of UVC_{254} to inactivate porcine reproductive and respiratory syndrome virus (PRRSV) (Cutler et al., in press). These data are important as PRRSV is an economically significant pathogen of pigs, whose cost to the US swine industry has been estimated to meet or exceed 560 million dollars per year (Neumann et al., 2005). The inability to control PRRSV transmission and clinical impact using conventional methods such as animal flow or vaccination has forced producers to elevate the level of biosecurity in order to reduce the risk of spread between herds (Pitkin et al., 2009). A well-established means of PRRSV transmission between herds is the mechanical spread of virus via contaminated articles, such as fomites, transport vehicles and containers (Otake et al., 2002; Dee et al., 2002, 2004). An integral component of the mechanical spread of PRRSV is its ability to survive outside of the pig on environmental surfaces commonly encountered on swine farms (Pirtle and Beran, 1996). In an effort to reduce this risk, strategies to sanitize high-risk surfaces and materials such as livestock transport vehicles, incoming supply containers and the hard surfaces of facilities have become an important component of farm-based biosecurity (Dee et al., 2005a). While the use of

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disinfectants to treat surfaces has been the standard approach (Dee et al., 2005b), UV_{254} inactivation of PRRSV may be another option for on-farm sanitation. Therefore, the objective of this study was to evaluate the ability of UV_{254} to inactivate PRRSV under controlled field conditions. Specifically, we wished to determine the effects of UV_{254} on the quantity and viability of PRRSV on surfaces and materials commonly encountered in commercial swine farms and to calculate the time required to inactivate virus. Based on its mode of action, we hypothesized that the application of UV_{254} to contaminated surfaces and materials would result in a significant reduction in virus viability but not concentration.

1. Methods

1.1. Description of surfaces, materials inoculated and UV_{254} source

The study was conducted in 2 separate rooms of the residence facility at the University of Minnesota Swine Disease Eradication Center (SDEC) research site in west-central Minnesota during the month of August 2010. The temperature and humidity of both rooms were controlled by the central air conditioning system present in the residence. Prior to initiation of the study, 12 different surfaces and materials commonly found on commercial swine farms were selected for the study, including wood, plastic, latex, rubber, styrofoam, metal, leather, cloth, concrete, cardboard, glass and paper. A list of the surfaces and materials is provided in Table 1 along with a description of the specific item selected for analysis. Two matching sets of these 12 items were placed on the floors of the treatment and control rooms in the test facility and were arranged in 2 rows with 6 surfaces per row. Each item was placed 2.54 cm from one another in the following order:

Row 1: rubber, concrete, paper, styrofoam, plastic, wood.
Row 2: metal, cloth, latex, leather, glass, cardboard.

The temperature and relative humidity of each room were fixed at 20 °C and 60%, respectively. In the control room, an incandescent light (Sylvania Double Life Flood light, 120 V, 65 W, St. Mary's, PA) was located at ceiling height (2.4 m above the floor). The 2 rows of items were placed flat on the floor to maximize exposure to the light source. In the treatment room, an ultraviolet light (model number D 36-1CC) consisting of 1 lamp (91.4 cm in length 120 V, 13.8 W output) (SaniLIGHT, Atlantic Ultraviolet Corporation, Hauppauge, NY) was installed in the ceiling at the same height. This instrument was fitted with one mercury vapor germicidal lamp, capable of emitting ultraviolet C radiation at a wavelength of 254 nm. Samples were arranged in an identical manner as in the control rooms. To initiate the study, a 5 cm × 5 cm area on the upper surface each of the 12 items in the treatment and control rooms was inoculated with 5 mL of PRRSV (5×10^6 $TCID_{50}$, total dose) using a commercially available modified live vaccine virus (Ingel Vac MLV, Boehringer-Ingelheim Vetmedica, St. Joseph, MO). Following inoculation, the lights in each room were turned on and sampling was initiated.

1.2. Procedure of sampling and testing

The sampling procedure involved swabbing the inoculation points on each item using sterile cotton swabs stored in 10 mL plastic tubes containing 6 mL of phosphate buffered saline. Samples were collected at 10 min intervals from 0 to 60 min PI and at 24 h PI. During the sampling period, the UV_{254} light and the incandescent light remained on at all times and separate personnel collected samples from the 2 rooms. Following completion of the treatment and control sampling, 2 matching sets of negative control surfaces/materials were sham inoculated with 5 mL of saline, exposed to either UVC_{254} or incandescent light for 24 h, and sampled in an identical manner.

Following collection, samples were submitted to the Minnesota Veterinary Diagnostic Laboratory for testing. To determine the effect of UV_{254} on the quantity of PRRSV RNA present on each item at 0, 1 and 24 h PI, a 2 mL aliquot of each sample was tested using quantitative PCR (TaqMan, Applied Biosystems, Foster City, CA) (Egli et al., 2001). To determine the effect of UV_{254} on virus viability, a 2 mL aliquot of each sample collected at 0 h, 1 h and 24 h PI was inoculated IM into PRRSV-naïve pigs (swine bioassay) (Swenson et al., 1994). To determine the length of time of UV_{254} exposure required to inactivate PRRSV independent

Table 1
Summary of surface and material type selected for analysis and its corresponding item on farm.

Surface/material tested	Surface characteristics	Representative farm item
Rubber	Smooth, non-absorbent	Work boot
Concrete	Rough, non-absorbent	Slotted flooring
Paper	Rough, absorbent	Paper towels
Styrofoam	Rough, non-absorbent	Semen cooler
Plastic	Smooth, non-absorbent	Disposable plastic bag
Wood	Rough, non-absorbent	Surface of loading chute
Metal	Smooth, non-absorbent	Electric drill
Cloth	Rough, absorbent	Work glove
Latex	Smooth, non-absorbent	Laboratory glove
Leather	Rough, absorbent	Work glove
Glass	Smooth, non-absorbent	Vaccine bottle
Cardboard	Smooth, non-absorbent	Shipping container