Evaluation of a Prototype Air-Filtered Transport Trailer

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Summary

In response to the need by the industry for a livestock vehicle that addresses increased animal welfare and biosecurity during transport, a prototype air-filtered trailer was developed. Design parameters were gathered from a stakeholders' survey and initial design configuration options were narrowed down using computer simulation. The final design featured a trailer with two separate compartments: a front compartment that houses generator set, a bank of six air filters, ventilation controller, supplemental heater, and two axial fans; and a livestock compartment with solid aluminum walls, two decks with a hinged upper deck floor and a roof that can be lifted open, and a hydraulic loading platform.

Based on this design, the prototype trailer showed overall reduction of 96.9% in concentration of aerosolized model virus (bacteriophage Phi X174) inside the animal compartment relative to upstream of the filter (MERV-8 pre-filter and MERV-16 main filter). In addition, monitoring of two trips showed the mechanical ventilation system was able to maintain the desired thermal conditions within the animal compartment. A supplemental heating unit helped to ensure the temperature (animal compartment) did not go lower than 10°C during the trips under winter conditions. Events during the trip such as slowing down or full stops affected environmental conditions inside the trailer, although the desired conditions were quickly restored once the trip resumed.

Introduction

Pig production is a major industry in Canada (Dorjee et al., 2013) and its success over the years relied heavily on the availability of highly improved breeding stock. Breeding stock production is typically located in areas where disease pressure is low and biosecurity perimeters are wide. However, being able to take advantage of these biosecurity benefits also requires that breeding stock would need to be transported to other pig dense regions. While in transit, the potential exists where breeding stock may be exposed to airborne disease contamination. Several Canadian studies have provided evidence that introduction of infected animals, particularly gilts and sows into farms, was one of the common reasons for the spread of PRRSV in the country (Kwong et al., 2013; Rosendal et al., 2014; Thakur et al., 2015). Thus, it is imperative that measures be developed to prevent infection of these animals during transport and consequently close the biosecurity gap through which potential infection can be introduced to commercial herds. In addition, the livestock transport industry is also facing growing pressure to provide more herdsman-friendly and welfare-friendly vehicles (i.e., capable of providing stable, acceptable environmental conditions, reduced incidence of fatigued animals) in response to growing public awareness of animal welfare issues. Therefore, we need to re-visit the design of livestock trailers currently in use in the industry to address these issues by incorporating new design features that improve worker safety and animal welfare.

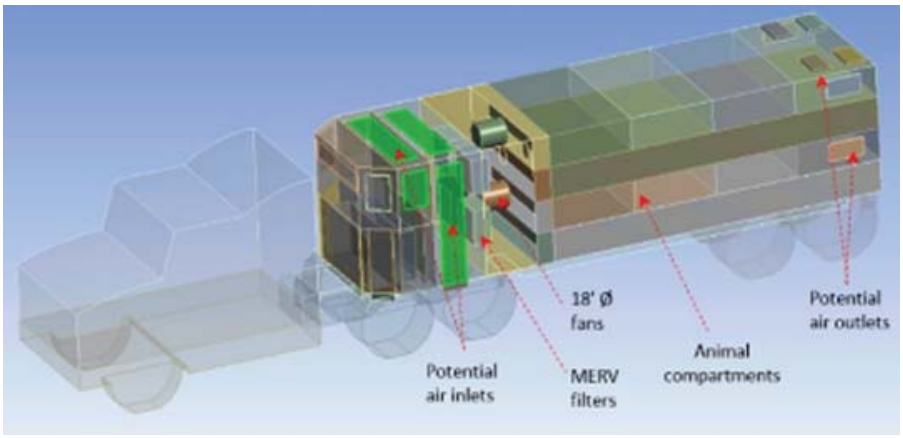

Figure 1. *Diagram of the model of the new trailer equipped with air filtration system*

Experimental Procedures

This project was carried out in four phases: survey of relevant stakeholders in livestock transport, computer simulation of various trailer design configurations to select the best design option, design and assembly of a new trailer prototype, and testing and evaluation of trailer performance.

A questionnaire which gathered inputs on the observed strengths and deficiencies of commercial swine transport trailers was distributed to a number of relevant stakeholders involved in pig transport. Responses gathered from the survey were summarized and formed the basis for the initial design of the new trailer, including desired features and preferences in the new trailer design.

The prototype trailer showed overall reduction of 96.9% in concentration of aerosolized model virus

Computer simulations were done using the commercially-available computational fluid dynamics (CFD) software ANSYS. To create a baseline case for latter comparisons with new trailer design, simulation was done on a conventional straight deck trailer (two decks and five compartments in the upper deck and six in the bottom deck). Six trailer design options based on alternative locations and different number of air inlets and air outlets, which are the main drivers of air movement in mechanical ventilation systems, were evaluated in summer and winter conditions.

Top designs were selected based on (1) ventilation effectiveness, and (2) the capability to meet the environmental requirement of pigs during transport. Heat removal effectiveness (HRE) was used to evaluate the ventilation effectiveness of each design option. The best design configuration for the air-filtered trailer from simulations was implemented in the construction of the prototype trailer.

The performance of the air-filtered trailer was evaluated during stationary and road tests. Specifically, its ability in preventing airborne pathogen introduction, and the effectiveness of the ventilation system in providing an acceptable micro-climate to pigs during transport were examined.

Figure 2. *Photos of the animal compartment showing (A) its lower and upper decks, (B) hinged roof, (C) gate that partitions each deck into two compartments, (D) air exhaust damper, (E) hydraulic loading platform, (F) hydraulic system showing motor, pump, controller and power supply, and (G) exterior of the assembled compartment.*

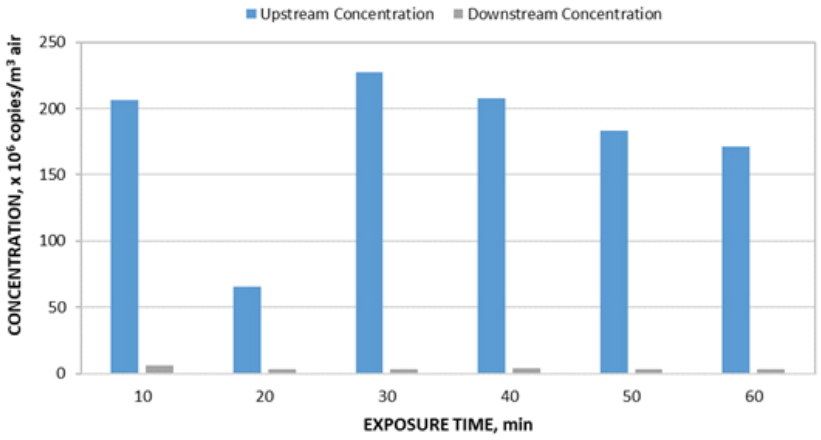

Figure 3. *Total bacteriophage Phi X174 (in genome copies/m3 of air) detected by qPCR. Each bar represents average concentration of the surrogate virus in the air sampled at different time points using 37-mm cassettes located outside (upstream) and inside (downstream) the trailer animal compartment from four replicate trials.*

Results and Discussion

Among the issues raised on the existing commercial livestock trailers were potential for disease infection via air due to the open configuration of the trailer, difficulty in loading and cleaning, and variable thermal conditions, among others. To address these concerns, the initial plan for the prototype trailer included design features such as incorporating mechanical ventilation and air filtration systems, reduced internal ramps and partitions, and having hinged floor panels to allow ease of loading/unloading pigs, and to facilitate cleaning.

Five of the six design options showed comparable range and mean values for heat removal effectiveness (HRE), temperature, moisture and air velocity at designated monitoring points in summer conditions. Taking into account both summer and winter simulation results, the trailer design which included one inlet opening on each side at the front area of the trailer and two air outlets on each side near the back of the trailer was selected as the best design option for subsequent sensitivity analysis (Figure 1).

The front compartment holds components of the trailer air filtration and ventilation systems where a 10-kW, single-phase generator set and air filter wall was installed. Two 18-inch diameter fans were installed at the downstream side of the filters to pull fresh air through the bank of air filters and into the animal compartment. The flow rates for each fan were controlled using a commercially-available centralized ventilation control system.

The animal compartment included solid walls, two straight decks (divided by a gate into two compartments) both being 3'5" in height. The middle portion of the floor of the upper deck and trailer roof are hinged and can be lifted up to allow easier loading, unloading or other activities (i.e., trailer cleaning, washing, inspection, etc.) (Figures 2A and 2B). To address animal handling and welfare issues arising from loading and unloading in the conventional livestock trailer, a 1000-kg capacity hydraulic loading platform was added in the prototype trailer

Overall, the air filtration system installed in the trailer yielded an approximately 96.9% reduction in the concentration of bacterial virus Phi X174 measured in the animal compartment of the trailer relative to upstream concentration (Figure 3). Monitoring of the trailer thermal condition during actual trips with the prototype trailer loaded with pigs under winter condition showed the need for supplemental heating to avoid temperatures in the animal compartment lower than 10°C. In addition, moisture (RH) level and air quality (CO2) inside the trailer during the monitored trips were maintained at levels comparable to conditions found inside swine barns.

Implications

Cost analysis of the air-filtered trailer prototype which considered total equipment and installation cost as well as annual operational and filter maintenance costs, yielded a payback period of 2.10 years if a modest premium of $5 per pig is realized for transporting pigs using an air-filtered trailer. From this first effort on design and development of major equipment, various points for optimization of the prototype have been identified to facilitate continuing work to further improve the efficiency of the trailer and to bring the overall trailer design closer to commercialization.

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