Air filtration to prevent porcine reproductive and respiratory syndrome virus infection

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Summary

This commentary reviews results obtained in France and North America with different air filtration systems to prevent porcine reproductive and respiratory syndrome virus (PRRSV) infection. Most systems installed in France use high-efficiency particulate air (HEPA) filters and positive-pressure ventilation systems, while those in North America initially used mainly negative-pressure ventilation systems and filters with minimum efficiency rating values of 14 to 16. Major reductions in PRRSV cases were observed in most studies where the latter were used. Installing HEPA filters resulted in an almost complete elimination of PRRSV cases. No cases were recorded in 95% of farms where they were used.

Keywords: swine, air filtration, porcine reproductive and respiratory syndrome, prevention

Received: February 3, 2022
Accepted: August 5, 2022

Resumen - La filtración de aire para prevenir la infección por el virus del síndrome reproductivo y respiratorio porcino

Este comentario revisa los resultados obtenidos en Francia y América del Norte con diferentes sistemas de filtración de aire para prevenir la infección por el virus del síndrome reproductivo y respiratorio porcino (PRRSV). La mayoría de los sistemas instalados en Francia usan filtros de partículas de aire de alta eficiencia (HEPA) y sistemas de ventilación de presión positiva, mientras que los de América del Norte inicialmente principalmente usaban sistemas de ventilación de presión negativa y filtros con valores mínimos de clasificación de eficiencia de 14 a 16. Se observaron reducciones importantes en los casos del PRRSV en la mayoría de los estudios en los que se utilizó este último. La instalación de filtros HEPA dio como resultado una eliminación casi completa de los casos de PRRSV. No se registraron casos en el 95% de las granjas donde se utilizaron.

Résumé - Filtration de l'air pour prévenir l'infection par le virus du syndrome reproducteur et respiratoire porcin

Le présent commentaire fait une revue des résultats obtenus en France et en Amérique du Nord avec différents systèmes de filtration d'air afin de prévenir l'infection par le virus du syndrome reproducteur et respiratoire porcin (VSRRP). La majorité des systèmes installés en France utilise des filtres particulaires à haute efficacité (HEPA) et des systèmes de ventilation à pression positive, alors que ceux en Amérique du Nord utilisaient initialement principalement des systèmes de ventilation à pression négative et des filtres avec des valeurs d'efficacité minimales de 14 à 16. Des réductions marquées des cas de VSRRP ont été observées dans la plupart des études où ces derniers étaient utilisés. L'installation de filtres HEPA a résulté en une élimination presque complète des cas de VSRRP. Aucun cas n'a été enregistré dans 95% des fermes où ils étaient utilisés.

Results of air filtration to prevent porcine reproductive and respiratory syndrome virus (PRRSV) infection can be of interest for 2 reasons. First, positive results indicate a way to reduce losses and suffering associated with this disease. Second, the results allow for indirect assessment of the relative importance of aerosol transmission in the epidemiology of the disease. If after air filtration the number of cases was reduced by a large percentage in the absence of significant improvements in other biosecurity measures, it would mean that aerosol transmission is responsible for a large percentage of PRRSV cases. This commentary will summarize results obtained with different air filtration systems in France and North America. Studies published within the last 10 years were selected so that relatively recent data were considered.

High-efficiency particulate air filters

High-efficiency particulate air (HEPA) filters are expensive, but they can prevent the passage of at least 99.97% of particles of any size.[1] Their use is often limited to herds that are particularly important, like boar studs, nucleus, or multiplier herds. These filters have been used mostly in France, normally coupled with positive-pressure ventilation. The site in France where this system was first used for swine was the Outil expérimental de l'ANSES, laboratoire de Ploufragan (formerly called Station de Pathologie Porcine de Ploufragan). This experimental unit is where many of the French studies on swine infectious

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Desrosiers R, Cousin V. Air filtration to prevent porcine reproductive and respiratory syndrome virus infection. *J Swine Health Prod*. 2023;31(2):77-81. **https://doi.org/10.54846/jshap/1303**

diseases have been conducted.[2] This site includes a small specific-pathogen-free herd protected by air filtration since its installment in 1979. The site is in Brittany, the area of France where swine production is the most intensified. After 42 years in operation, the herd has remained negative for pathogens like PRRSV, influenza A virus-swine, pseudorabies virus, porcine respiratory coronavirus, and *Mycoplasma hyopneumoniae*, all of which are known to be transmissible by aerosol.[3,4]

This filtration technology was later used in farms of importance for different companies. Table 1 shows the number of farms that were equipped with this technology since 1995, the number of years prior to 2022 that the farm was at risk, and the number of PRRSV cases over the years.

Fifty-three farms were equipped with a HEPA filtration system since 1995, with an average filtration duration of 14.2 years. Thirty-seven of the farms were sow sites of which 32 were farrow-to-finish operations on the same site, 12 were boar studs, and 4 were finishing sites. Sow sites had between 150 and 1000 sows and boar studs had between 32 and 300 boars. Over the years, 2 farms originally filtered in 1998 broke with PRRSV, one farm in 2006 and the other in 2012. In both cases the epidemiological investigation concluded that a biosecurity breach was likely responsible for the infections. All farms have remained negative for *Mycoplasma hyopneumoniae*, another significant pathogen present in most countries including France.

A French company with a swine farm in China equipped with this type of system has remained negative for PRRSV since it was populated in 2016 (V. Cousin, unpublished data). Quebec, Canada has 5 sites that are equipped with a HEPA filtration system, 4 boar studs and 1 farrow-to-finish operation. The first systems were installed in 2003, and none have yet to become infected with PRRSV (R. Desrosiers, unpublished data). When considering the proportional size of its swine industry, few farms are equipped with a HEPA filtration system in the United States. One veterinary practitioner consults with 6 boar studs that are equipped with HEPA filters, the first installed in 2008. One farm broke with PRRSV twice. The investigation revealed that the filtration system had a bypass on a hand-made duct that allowed unfiltered air to be introduced into the barn.

Table 1: Number of farms equipped with HEPA filtration, years of installation, farm years at risk, and number of PRRS cases

Installation year	No. of farms	Farm years at risk	PRRSV cases
1995	1	27	0
1996	2	52	0
1997	1	25	0
1998	4	96	2
1999	3	69	0
2000	2	44	0
2001	2	42	0
2002	2	40	0
2003	3	57	0
2005	2	34	0
2007	2	30	0
2009	3	39	0
2010	1	12	0
2011	3	33	0
2012	3	30	0
2013	2	18	0
2014	2	16	0
2015	7	49	0
2016	4	24	0
2017	1	5	0
2018	1	4	0
2019	2	6	0
Total	**53**	**752**	**2**
	Cases per farm year at risk		**0.0027**
	Mean number of filtration years per farm: 14.2		

HEPA = high-efficiency particulate air; PRRSV = porcine reproductive and respiratory syndrome virus.

The farm has remained PRRSV negative since the problem was fixed in 2019, and none of the other 5 boar studs have broken with the disease. (D. Reicks, DVM, email, July 2021). Considering the results obtained in France, China, Quebec, and the United States, 95.4% (62 of 65) of the farms where this system was used have remained PRRSV negative. If the boar stud with the faulty system is removed from the list, then none of the remaining 64 farms have broken with PRRSV since 2012.

Other filtration systems

Most of the air filtration systems installed in the United States use filters with minimum efficiency rating values (MERV) of 14, 15, or 16. These systems are predicted to respectively prevent introduction of 75%, 85%, and 95% or more of particles between 0.3 and 1.0 micron.[5] Also, some farms are only filtering air during the cooler times of the year when PRRSV outbreaks are more frequent. Most farms initially used a negative-pressure ventilation system, but positive-pressure ventilation has gained popularity in recent years.[6] An advantage of positive-pressure ventilation is that, if functioning properly, unfiltered air is not likely to be introduced into the barn through various openings. Many studies have evaluated the results obtained with air filtration, but often without specifying the type of ventilation system, the MERVs of the filters used, and whether they were filtered all year long. Table 2 summarizes the results obtained in studies conducted over the last 10 years.

Only one study did not report a major beneficial impact from filtration. Silva et al[10] used machine learning algorithms to identify key biosecurity practices and factors associated with breeding herds reporting PPRSV outbreaks. They concluded that air filtration was not ranked among the top predictors for PRRSV outbreaks and suggested this could be due to the percentage of farms that reported air filtration between groups (11 of 50 farms that became PRRSV positive and 11 of 34 that remained uncontaminated). The Tousignant[12] study evaluated the results obtained with filtered farms, which had an average PRRSV incidence of 6% per year but did not evaluate results from unfiltered farms. The Morrison Swine Health Monitoring Project (MSHMP) tracks disease occurrence on a subset of US sow herds. The number of herds in the subset has changed over time and in recent years represented approximately 50% of the US sow inventory. Data from this project showed that 20.8% to 39.2% of sow herds reported a PRRSV break each year between 2009 and 2021 (MSHMP, email, December 2021). That is 3.5 to 6.5 times more than was observed in filtered farms of the Tousignant study.[12]

In the other 9 studies, the number of PRRSV breaks was reduced 2- to 14.4-fold with filtration. The Havas et al[7] study did not compare herds in terms of breaks, but in terms of being infected with PRRSV or not. The odds of being positive for PRRSV were reduced by 95% with filtration.

Discussion

The possibility for PRRSV to be transmitted between farms by aerosol has been a controversial topic for many years. In 1999, it was proposed in a popular newsletter that more and more epidemiological evidence suggested that PRRSV could be transmitted between farms by aerosol.[17] This created some turmoil because up until then, and for years to come, it was not shown to be possible to infect pigs with PRRSV by aerosol over a distance greater than 2.5 m.[18-20] Different researchers expressed opposite views in what was sometimes referred to as the aerosol debate.[3] In 2004 and 2005, published studies from different countries and local field observations strongly supporting aerosol transmission of different swine pathogens, including PRRSV, were reviewed.[3,4] Among others, these reviews mentioned the impressive results obtained with air filtration in France. In 2009, Pitkin et al[21] proved using a regional production model that aerosol transmission of the virus over 120 m could occur repeatedly and confirmed that air filtration was effective at preventing this type of contamination. Since then, different studies have suggested that not only is aerosol transmission possible between farms, but it could even be among the main modes by which the virus is introduced into breeding herds.

The results included in Table 2 would support that there are situations where air filtration makes a large difference in the incidence of PRRSV outbreaks. A frequent and sensible argument to explain the positive results obtained with air filtration is that when installed, other biosecurity measures may also be improved

Table 2: Studies between 2012 and 2021 where the impact of air filtration on PRRSV was evaluated

Reference	No. Farms; period involved	Results
Havas et al,[7] 2021	Not specified; not specified	95% lesser odds of being PRRSV infected if filtered
Feder,[8] 2021	85 farms; not specified	More than 3 times less PRRSV cases after filtration
Moeller et al,[9] 2020	208 farms; not specified	Odds of PRRSV cases at 0.0992 if filtered vs unfiltered
Silva et al,[10] 2019	11 farms in case & control groups; 2012-2017	Air filtration not ranked among top predictors for PRRSV breaks
Vilalta et al,[11] 2018	58 farms; 2009-2018	Risk of breaking with PRRSV decreased by half after filtration
Thomas,[6] 2018	27 farms; 18 months	PRRSV risk reduced 4.3 times after filtration
Tousignant,[12] 2015	10 in 2005 up to 119 in 2014; 2005-2014	Incidence of PRRSV cases across all farms in the data set averaged 6% per year
Reicks,[13] 2015	25 boar studs; 4.1 years before and 7.7 years after	Incidence per year went from 14.4% to 1.0% after filtration
Reicks,[14] 2014	93 farms; 4.2 years before and 4.8 years after	New infections per year went from 52.5% to 11.3% after filtration
Alonso et al,[15] 2013	37 farms; 7 years	Filtration reduced risk of infection by 80%
Dee et al,[16] 2012	24 farms; 2005-2012	From 1.23 cases per herd year before to 0.17 cases per herd year after filtration

PRRSV = porcine reproductive and respiratory syndrome virus.

contributing to the apparent positive filtration impact. While this is a possibility, the importance of that beneficial impact is unknown. Given the losses often associated with PRRSV, major efforts to improve biosecurity measures have already been made for many years, whether farms were filtered or not. Furthermore, in a comparison of 25 boar studs, Reicks[13,22] stated that the percentage of breaks per year went from 14.4% before filtration to 1.0% after it was implemented with no changes in biosecurity. Thus, the improvement in PRRSV incidence in that case could be attributed solely to filtration, which suggests that most of the breaks prior to filtration were associated with aerosol transmission. Similarly in another US study, Alonso et al[15] concluded that air filtration led to an approximately 80% reduction in risk of novel PRRSV introduction indicating that approximately four-fifths of PRRSV outbreaks may be attributable to aerosol transmission on large sow farms with good biosecurity in swine-dense regions. The authors reported that while unable to assess standards of external biosecurity in their study farms, this concern was mitigated by the relatively uniform veterinary oversight across all of them. Finally, Dee et al[16] reported in one part of their study that the odds for a new PRRSV infection in a nonfiltered breeding herd was 8.03 times higher than in a filtered breeding herd. The authors mentioned that the selected herds used industry standard biosecurity practices and were exposed to comparable conditions suggesting that filtration was the most important difference between the groups.

The results obtained with air filtration in France were and have remained impressive. In one of the first reports on its efficacy, Lecarpentier et al[23] described 11 farms equipped with such a system that were owned by the same company. The first filtration was installed in 1996, two were installed in 2002, and the others installed between 1998 and 2000. Seven of the 11 farms had been contaminated with PRRSV prior to filtration. None of them became infected prior to 2004, when the study was reported. Ten of these 11 herds were in Brittany, the area in France with the highest pig density. However, as previously mentioned, the main system used in France is different than those used in most cases in the United States.

Dee et al[24] showed that the efficacy of various systems could vary. When comparing HEPA filters to a MERV 15 system, only the former prevented infection of pigs in all replicates (76 of 76) while the latter did not in 2 of them (74 of 76). More recently Batista[25] evaluated the efficacy of different filters (MERV 14, MERV 16, and antimicrobial filters) to block the passage of PRRSV, influenza A virus-swine, and *Streptococcus thermophilus* (as a model for *Streptococcus suis*). The author concluded that the MERV 16 filters had the highest capture efficiencies. When considering their ability to prevent airborne PRRSV transport, Dee et al[26] showed that efficacy differences may be found with systems from different companies having the same theoretical MERV values. Finally, it was also suggested that some filtration systems do not maintain their efficacy over time as well as others.[6] Thus, it is important when evaluating results obtained with air filtration to consider the specifics of each filtration system used.

Dee et al[16] reported that 24 farms had an average of 1.23 cases per farm year at risk before filtration. It greatly improved to 0.17 cases per farm year at risk following filtration with MERV 14 or 16 filters. The 53 farms equipped with HEPA filters in France had 0.0027 cases per farm year at risk, or 63 times less. More information would be needed to determine to what level comparison between the US and French results can be made. Different factors would need to be evaluated, including the respective biosecurity measures observed on farms, the size of the farms, the infection pressure from the neighboring herds, the aerosol transmissibility of the strains, and the climatic conditions. Nevertheless, the magnitude of difference in the results obtained as well as the theoretical superiority of HEPA filters seem to leave little doubt on the fact that better results can be obtained with these filters.

There is no more debate over the possibility for PRRSV to be transmitted between farms by aerosol. Today the question is how frequently and over what possible distances aerosol transmission occurs. The results obtained with air filtration in different countries suggest that there are situations, particularly in hog-dense areas, where viral aerosol transmission could be the most important way of introduction into breeding herds. This would align with the relative inefficacy of other significant biosecurity efforts that have been applied to control it.[27]

Nevertheless, there are clearly other ways by which the PRRSV can be introduced into swine herds, and not all studies have shown that aerosol or local transmission had an important role in the epidemiology of PRRSV.[28-32] Looking at spatial and temporal patterns of PRRSV genotypes, Rosendal et al[28] concluded that there was no strong evidence that aerosol transmission was occurring in Ontario. Similarly, Kwong et al[32] reported that the 3 relatively most important factors for the spread of a specific genotype in that province were sharing the same herd ownership, gilt source, and market trucks. Spatial proximity could not be identified as an important contributor to spread. In a review on the topic, Arruda et al[31] reported that aerosol transmission of the PRRSV was possible, but further studies were needed to determine if it was a frequent event or not. While most studies where air filtration was evaluated suggest that aerosol contamination is frequent, the relative importance of that transmission route is still debated.

Because air filtration systems currently used are expensive, another question remaining is the distance over which the virus can travel by aerosol to infect herds. Quantifying that distance would help to determine at what point investment in filtration or in future methods found to prevent aerosol contamination may be justified.

Finally, not all air filtration systems are created equal as some are more effective than others. Efficient prevention of aerosol contamination can allow a farm to remain negative for PRRSV and other airborne pathogens on a long-term basis.

Implications

- Not all air filtration systems are created equal.
- Being PRRSV negative long-term is possible, even in hog-dense areas.
- There are situations where aerosol is the most frequent contamination source.

Acknowledgments

The authors would like to acknowledge Dr Darwin Reicks for providing supplementary information on his research and results with HEPA filters used on farms he consults with.

Conflict of interest

None

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