ORIGINAL RESEARCH PEER REVIEWED

A qualitative study to identify potential biosecurity risks associated with feed delivery

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Summary

Objectives: To identify management and operational functions, recommended by feed-company personnel and swine producers, that have the potential to decrease the risk of pathogens being transmitted among swine farms through movement of feed trucks.

Materials and methods: Focus groups and key-informant interviews were conducted with feed company representatives (21), including managers, dispatchers, and truck drivers, and also with swine producers (15). Questions explored biosecurity measures that would reduce risk of pathogen transmission at the farm, feed-company, and feed-truck levels. Participants were asked to rate these biosecurity management changes by economic and logistic feasibility and likelihood of reducing pathogen transmission.

Results: The results provide an understanding of the roles of the farm, feed truck, and feed company in biosecurity management surrounding delivery of feed to swine farms and the need for education about how pathogens move among farms. Examples include pest control and truck washing, dispatching trucks according to farm disease status, drivers not entering the barn, reducing exposure of trucks to deadstock and manure, and educating all industry personnel.

Implications: All swine industry personnel must think about their roles in pathogen transmission associated with feed delivery and consider implementing changes and developing an industry standard that could reduce this risk. Veterinarians may take the responsibility of educating others in the industry about risks identified in the scientific literature that are associated with pathogen transmission. Biosecurity is everyone's concern: everyone has a role to play in reducing the potential risk.

Keywords: swine, biosecurity, feed delivery, qualitative research, focus groups

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Resumen - Un estudio cualitativo para identificar los riesgos de bioseguridad potenciales asociados con la entrega de alimento

Objetivos: Identificar las funciones de manejo y operacionales identificadas por el personal de compañías de alimento y productores porcinos, que tienen el potencial de reducir el riesgo de transmisión de patógenos entre granjas porcinas a través del movimiento de camiones de alimento.

Materiales y métodos: Se realizaron entrevistas a informantes clave y grupos de enfoque con representantes de las compañías de alimento (21), incluyendo gerentes, despachadores, y conductores de camión, y también productores porcinos (15). Las preguntas exploraron medidas de bioseguridad que redujeran riesgos de transmisión de patógenos en la granja, la compañía de alimento, y a nivel de camión de alimento. A los participantes se les pidió que calificaran estos cambios de manejo de bioseguridad por la vialidad económica y logística y la posibilidad de reducir la transmisión de patógenos.

Resultados: Los resultados proveen un entendimiento del papel que juegan la granja, el camión de alimento, y la compañía de alimento en el manejo de la bioseguridad alrededor de la entrega de alimento a granjas porcinas y la necesidad de educación sobre la manera como los patógenos se mueven entre las granjas. Algunos ejemplos incluyen el control de pestes y lavado de camión, despacho de camiones de acuerdo al estatus de enfermedad de la granja, conductores que no entran al granero, reducción de exposición de camiones a animales muertos y excretas, y la educación de todo el personal de la industria.

Implicaciones: Todo el personal de la industria porcina deben pensar en su papel en la transmisión de patógenos asociados con la entrega de piensos y considerar la implementación de los cambios y el desarrollo de un estándar del sector que podrían reducir este riesgo. Los veterinarios pueden tomar la responsabilidad de educar a otros en la industria sobre los riesgos identificados en la literatura científica que están relacionados con la transmisión de patógenos. La bioseguridad es asunto de todos: todos tienen un papel que jugar en la reducción del riesgo potencial.

Résumé - Étude qualitative pour identifier les risques potentiels de biosécurité associés à la livraison d'aliments

Objectifs: Identifier les activités opérationnelles et de gestion mentionnées par le personnel de compagnies d'alimentation et les producteurs de porcs qui ont le potentiel de diminuer le risque de transmission d'agents pathogènes entre les fermes porcines via les déplacements des camions de moulée.

Matériels et méthodes: Des groupes d'intérêt et des entrevues des intervenants clés ont été menés auprès de représentants de compagnie d'aliments (21), incluant des gérants, des répartiteurs, et des conducteurs

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de camion, de même que des producteurs de porcs (15). Les questions portaient sur les mesures de biosécurité qui réduiraient le risque de transmission d'agents pathogènes à la ferme, à la meunerie, et par les camions. On demandait aux participants de classer ces changements aux mesures de biosécurité en fonction de leur faisabilité logistique et financière et leur probabilité à réduire la transmission d'agents pathogènes.

Résultats: Les résultats fournissent une compréhension des rôles de la ferme, du camion de moulée, et de la meunerie dans la gestion de la biosécurité entourant la livraison de nourriture aux fermes porcines et le besoin d'éducation sur les modes de transmission des agents pathogènes entre les fermes. Citons par exemple, le contrôle de la vermine et le lavage des camions, la répartition des camions en fonction du statut sanitaire de la ferme, le conducteur de camion n'entrant pas dans les bâtiments, diminuer l'exposition des camions aux animaux morts et au fumier, et éduquer tout le personnel de la compagnie.

Implications: Tout le personnel de l'industrie porcine doit réfléchir à son rôle dans la transmission des agents pathogènes associée à la livraison de nourriture et considérer mettre en place des changements et développer des standards qui pourraient réduire ce risque. Les vétérinaires pourraient prendre la responsabilité d'éduquer les autres membres de l'industrie sur les risques identifiés dans la littérature scientifique qui sont associés avec la transmission des agents pathogènes. La biosécurité concerne tous les intervenants et tous ont un rôle à jouer dans la réduction des risques potentiels.

Biosecurity protocols are important in reducing the introduction and transmission of pathogens among swine farms.[1] In the North American swine industry, biosecurity protocols are essential to ensuring market stability, maintaining export opportunities, and minimizing public health concerns related to foodborne illness.[2] Some pathogens affecting swine can be transmitted by contaminated clothing, shoes, equipment, and vehicles, and in contaminated feed.[1,2] Previous research has shown that delivery of feed has the potential to be involved in the transmission of disease among swine farms.[3] Although we are unaware of literature directly linking an outbreak to feed delivery, research in other areas has shown there is a risk related to contaminated feed itself, as well as to contaminated trucks, tires, boots, clothing, and other fomites.

Salmonellosis, a common cause of foodborne illness in Canada, is the second most common cause of bacterial foodborne illness in the United States.[4-6] Infection causes gastrointestinal illness in humans, and severe illness and even death can occur in vulnerable individuals.[7] Swine can act as asymptomatic carriers.[8-13] Salmonellae have been isolated from pigs,[14,15] boots,[15] flies,[14,15] rodents,[14-17] bird feces,[15] feed,[3,17] and feed-ingredient samples[3,17] on swine farms. In one study, salmonellae were isolated from 2.8% of on-farm feed and feed-ingredient samples, and from 46.7% of swine farms.[17] In another study, salmonellae were present on 22.7% of feed trucks sampled, either in the grain box or in the feed itself.[3] The authors concluded that feed trucks could serve as a source of *Salmonella* organisms, and recommended that trucks be washed and disinfected between loads. Pigs fed a diet contaminated with *Salmonella* can become infected but remain clinically healthy.[9,18]

Porcine reproductive and respiratory syndrome (PRRS) is one of the most widespread and economically important diseases in the North American swine industry.[19,20] Infection causes reproductive failure in sows, morbidity and mortality at multiple production stages, and large production and economic losses.[20] Replacement animals and semen are the most common sources of PRRS virus (PRRSV) transmission, although vehicles, fomites, aerosols, and insects also play a role.[20] People act as mechanical vectors for PRRSV; viral RNA has been detected on coveralls, boots, and other fomites after contact with infected pigs.[21] Furthermore, workers who contact infected pigs can transmit the virus when they enter a population of susceptible pigs without changing boots and coveralls or washing their hands.[21,22] Basic sanitation protocols limit the transmission of PRRSV.[22] Additional research showed that PRRSV could be introduced to a swine facility after an inoculated carrier (snow and water or soil samples) was affixed to the vehicle's wheel well, and the virus was subsequently introduced at the barn's entrance.[23,24] Additionally, a PRRSV-positive herd status has been significantly associated with the feed truck visiting another herd without being washed prior to arrival.[25]

A variety of other pathogens can be moved from one farm to another on fomites such as boots, clothing, hands, and vehicles. These include *Brachyspira hyodysenteriae*,[26] transmissible gastroenteritis virus (TGEV),[27,28] *Lawsonia intracellularis*,[29] and *Escherichia coli*.[30,31] This information highlights the potential risk associated with feed delivery via contaminated fomites such as hands, boots, and coveralls, as well as the feed and feed trucks themselves.

In order to investigate these issues in more detail, a qualitative approach was used. Qualitative methods provide an added dimension to research because they allow investigators to identify and explore the issues important to the study population.[32] Qualitative research uses methods such as focus groups and key-informant interviews to gather participants' knowledge, lived experiences, and perspectives.[32-34] Qualitative methods also aid researchers in understanding the issues and context surrounding a subject.[32] Such methods produce relevant results applicable to the study population.[33] This study used focus groups and key-informant interviews to gather information about biosecurity best practices in the feed industry and to explore concerns surrounding delivery of feed to swine farms. In order to understand a variety of perspectives, discussions included feed-company managers, dispatchers, and truck drivers, and swine producers. The discussions were used to identify the biosecurity protocols currently in place regarding delivery of feed and to determine the changes participants thought could be implemented to further reduce the risk of disease transmission associated with feed delivery. The first objective of this study was to summarize the key management and operational functions identified by feed-company personnel and swine producers as having the potential to affect the risk of disease transmission among swine farms. The second objective was to have participants identify economically and logistically feasible operational approaches that are expected to reduce the potential risk of disease transmission.

Materials and methods

This study received approval from the University of Guelph Research Ethics Board.

Study participants

The study consisted of three focus groups and 18 key-informant interviews, and participants

included feed-company personnel and swine producers. Discussions were held during October through December, 2012.

Participants were recruited with assistance from the Ontario Agri Business Association (OABA) and Ontario Pork. Twelve feed companies were contacted through OABA, and managers from seven of these companies agreed to participate. Additionally, a representative from another feed company was recruited when a member of the research team made a presentation at a swine industry meeting. Managers from four of the eight feed companies were asked to participate further by allowing the researchers to contact some of their employees (drivers, dispatchers, sales personnel) and ask them to take part in key-informant interviews. Three of these four feed companies agreed and facilitated participation of their employees. Twenty-two swine producers were contacted through Ontario Pork and the University of Guelph: one did not respond, two declined to participate, three were not available during the proposed time frame, and one agreed to participate but did not attend their scheduled focus group.

The focus groups and key-informant interviews included a total of 21 feed-company personnel and 15 swine producers. The feed-company personnel represented eight Ontario feed companies and included eight managers, six feed-truck drivers, four dispatchers, one sales person, one production supervisor, and one customer-service representative. Each participant was provided with a letter that included background information about the importance of reducing pathogen transmission among swine farms, the reasons the research was focused on the feed industry, and the purpose and format of the study. Participants were informed that the discussions would be audio-taped (H2next Handy Recorder; Zoom, Japan) and professionally transcribed, and they agreed to keep the discussion confidential, signed a consent form, and received a $50 gift card in compensation for their participation. Additionally, each producer who took part in the study was asked to provide information about their farm – what type of operation it was, how many sites it included, how many pigs it had, and how often bulk or bagged feed or both were received.

Structure of focus groups and key-informant interviews

The focus groups and most of the key-informant interviews were facilitated by one of the authors and observed by a second author. The observer led five of the 18 key-informant interviews. All of the focus-group and face-to-face key-informant interviews were held within 2 hours of Guelph. Some key-informant interviews were by telephone. Each focus group met once. The facilitator welcomed the participants and described the purpose of the project and the consent form. Then a series of standardized, open-ended questions were asked that were then followed by questions that encouraged participants to clarify and elaborate on their comments. Specifically, these questions asked about diseases considered to be among the three most important in the swine industry, participant knowledge about how diseases are transmitted from farm-to-farm, current biosecurity protocols at feed-company and farm levels, and changes that could be implemented to further reduce the potential risk of pathogens being transmitted during the delivery of feed.

Rating of management ideas

The observer recorded management ideas that emerged during the discussion. After completion of all focus groups and key-informant interviews, the researchers collated the recommendations that emerged. This information was sent to all participants for whom e-mail addresses were available, including 18 feed-company personnel and 14 producers. Participants were asked to rate all recommendations on the basis of three criteria: their effectiveness for disease control, ease of implementation, and economic feasibility. On a scale of 1 to 5, a rating of 5 meant the idea was rated in a positive way (good for disease control, easy to implement, economically feasible) and a rating of 1 meant the idea was rated in a negative way (not good for disease control, hard to implement, not economically feasible). Responses were received from 25 of the possible 32 participants who were reached by e-mail. Not all 25 respondents ranked all of the management ideas, but 17 to 23 ratings were received for each idea.

Transcript analysis

Transcripts from the focus groups and key-informant interviews were examined in order to identify the ideas, themes, and opinions expressed by participants. The researchers identified the swine diseases that the participants considered most important and summarized participant understanding of how diseases are transmitted from farm to farm and whether diseases can be transmitted in the feed itself. Information was summarized to highlight current procedures at the feed-company, dispatcher, truck-driver, and farm or producer levels and the changes or improvements participants felt could be made. The researchers also noted the similarities and differences in the opinions and comments from feed-company personnel and producers.

Results

Producer information

The producers who participated in this study represented a variety of farm types and sizes. Eleven farms were farrow-to-finish and four were finisher only. Four producers had one-site operations, three had two-site operations, and seven had three-site operations. One producer did not indicate the number of sites. Eleven producers had sows, with a mean of 1355 (standard deviation [SD] = 1261), a minimum of 120, and a maximum of 4500 sows. Ten producers had nursery pigs, with a mean of 12,120 (SD = 15,310), a minimum of 300, and a maximum of 45,000 pigs. Fourteen producers had finisher pigs, with a mean of 16,282 (SD = 21,146), a minimum of 400, and a maximum of 75,000 pigs. All producers received bulk feed on a regular basis, and 10 received bagged feed on a regular basis.

Important diseases and knowledge about how diseases are transmitted

Table 1 shows the pathogens that cause the diseases identified by participants as being among the three most important in swine production. Some participants listed only one or two diseases. Four participants (two managers, one driver, and one producer) included pneumonia; four (one manager, two drivers, and one producer) included scours; and two drivers were not familiar with any specific pathogens or disease problems in pigs. Table 2 presents participant responses when asked how diseases spread from farm to farm. Mechanisms by which participants thought pathogens could be transmitted in the feed itself included birds, rodents, fomites, trucks, raw ingredients, bulk pipe hoses, and people. Personnel of all types indicated that salmonellae could be transmitted in the feed. Other pathogens mentioned included transmissible gastroenteritis virus, PRRSV, *E coli*, influenza A virus, and *B hyodysenteriae*. This study was conducted before porcine epidemic diarrhea was a clinical problem in US and Canadian swine herds.

Table 1: Pathogens that cause diseases identified during focus-group discussions and key-informant interviews as being among the three most important in swine production*

Pathogens that cause the diseases	Managers	Dispatchers, sales personnel, other employees	Drivers	Producers
Actinobacillus pleuropneumoniae	Yes	Yes	No	Yes
Brachyspira hyodysenteriae	Yes	No	No	Yes
Foot-and-mouth disease virus	Yes	No	Yes	No
Haemophilus parasuis	No	No	Yes	Yes
Influenza A virus	Yes	Yes	Yes	Yes
Lawsonia intracellularis	Yes	No	No	Yes
Mycoplasma hyopneumoniae	Yes	No	No	Yes
Porcine circovirus type 2	Yes	Yes	Yes	Yes
Porcine reproductive and respiratory syndrome virus	Yes	Yes	Yes	Yes
Salmonella enterica serovars	Yes	Yes	Yes	Yes
Streptococcus suis	Yes	No	No	Yes
Transmissible gastroenteritis virus	Yes	Yes	Yes	Yes

* Focus-group discussions and key-informant interviews with 15 swine producers and 21 feed-company employees (including managers, dispatchers, and truck drivers) were conducted to examine the potential risks of disease transmission associated with feed delivery. Participants were asked about the important diseases in swine production. "Yes" response indicates that at least one person in that category mentioned the disease. "No" response indicates that no one in the category mentioned the disease. However, "no" cannot be interpreted as participants being unaware of the disease.

Currently implemented protocols and related issues

The following information summarizes by topic the key points of discussion regarding biosecurity protocols.

Feed mill. All mills represented were certified under the Hazard Analysis and Critical Control Points system and follow a program that includes, among other things, regular testing of raw ingredients for *Salmonella*, collection of drag swabs from locations around the mill and testing for *Salmonella*, keeping the mill and the equipment clean, and pest control. However, rodent and bird control were identified as challenges for some mills.

Trucks delivering ingredients to the mill are inspected for cleanliness and asked to declare their previous load. Suppliers are asked what programs they have in place to ensure the quality of their product; incoming product is rejected if mill personnel feel it has been compromised.

Traffic control at the mill is a concern – the mill's own feed trucks, supplier trucks, and customer trucks all enter the mill yard. There is little control over traffic and little knowledge about where incoming vehicles have been; feed-mill personnel expressed concern that such vehicles could be bringing pathogens on-site.

At most mills, personnel ask visitors and contractors where they have been and take note of what visitors are wearing. Some people are allowed in the mill for tours, although producers and drivers are generally kept out of production areas. However, some producers felt there should be more control over where visitors are allowed to go. Some mills are quite strict regarding visitor traffic, whereas others are more relaxed and have few restrictions.

Employees are trained on basic hygiene and biosecurity. Drivers are encouraged to wash their hands when they come into the mill and to generally stay clean, although compliance is variable.

In the past, empty feed bags were returned to the mill and refilled; however, bags are no longer reused due to biosecurity concerns. Some mills do not accept returned feed at all, and some specifically do not accept returns from swine farms. Some companies have incorporated micro-bin systems to reduce handling of feed and feed ingredients.

Feed. Generally, incoming ingredients and some batches of finished feed are sampled and tested for *Salmonella* and mycotoxins. High temperature and steam during the pelleting process are thought to reduce pathogen loads in the finished product. However, mash feed is not heat treated and therefore presents a greater risk than pelleted feed. Some feed mills installed netting to try to keep birds out of the loading area, but that intervention has not worked well.

Dispatcher. It is difficult to manage scheduling when feed is ordered without sufficient notice. The dispatcher's best tool is advance orders, as last-minute deliveries are difficult to incorporate into an existing schedule. Thus, delivery of the feed, rather than biosecurity, may be the dispatcher's first priority. Feed mills designate certain farms and production systems as "high-biosecurity," but the criteria for defining farms as such are not entirely clear. The dispatcher tries to accommodate producers with a pyramid in mind. Sow breeders and multiplier herds are at the top of the pyramid and will receive feed at the beginning of the week. Next will be nursery barns, and finishers generally receive feed at the end of the week. Dispatchers also try to schedule deliveries to high-biosecurity, high-health farms first, and low-biosecurity, low-health farms last. Breeding sites generally have priority over commercial farms because of the way an outbreak would affect the industry as a whole. This pyramid structure occurs at most, but not all, feed companies. Delivery sequence for some mills is based primarily on location and convenience. Such routes are generally

Table 2: Participant knowledge of ways that diseases can be transmitted among farms*

Means of disease transmission	Managers	Dispatchers, sales personnel, other employees	Drivers	Producers
Aerosolization	Yes	Yes	Yes	Yes
Birds	Yes	Yes	Yes	Yes
Deadstock trucks	Yes	No	No	Yes
Delivery of bagged feed	Yes	No	Yes	Yes
Direct pig-to-pig contact	Yes	Yes	Yes	Yes
Equipment	Yes	No	No	Yes
Feed	Yes	Yes	Yes	Yes
Feed sales personnel	No	No	No	Yes
Feed trucks	Yes	Yes	Yes	Yes
Fomites	Yes	Yes	Yes	Yes
Hoses for delivery of bulk feed	No	No	Yes	Yes
Improper deadstock management	Yes	No	No	No
Livestock trucks	Yes	Yes	Yes	Yes
Manure and spreading equipment	Yes	No	Yes	Yes
People	Yes	Yes	Yes	Yes
Rodents	Yes	Yes	Yes	Yes
Service people (electricians)	No	Yes	No	Yes
Supplies (veterinary, semen)	Yes	No	No	Yes
Traffic routes	Yes	No	Yes	Yes
Veterinarians and the clinic	No	Yes	Yes	Yes

* Study described in Table 1. Questions were asked about the transmission of disease and whether it can be transmitted via the listed methods. "Yes" response indicates that at least one person in that category mentioned this route of disease transmission. "No" response indicates that no one in the category mentioned this route of disease transmission. However, "no" cannot be interpreted as participants being unaware that disease could be transmitted this way.

planned according to the most economical way for the feed to be delivered. The dispatcher's information about disease status sometimes comes from the producer, but also from sales personnel, the veterinarian, a neighbour, or from driver observations. One feed-company representative stated that producers tend to be open to sharing information if their farm is "clean," but less so if their farm has problems with disease. Feed-company personnel stated that such information is shared only when it is something really critical. The feed company may realize that there has been an outbreak on a particular farm only if the producer orders medicated feed or if the truck driver notices there is more deadstock than usual. In case of a known outbreak on a farm, the dispatcher schedules delivery to that farm for the end of the day, and the truck is washed immediately afterwards. The driver is advised to spray the truck tires with disinfectant on the way into the farm and on the way out. If feed is being delivered to a neighbour of a farm with a known outbreak, the route is changed to avoid having the truck pass the infected farm. Producers often request delivery of their feed first thing on Monday morning with a clean truck; however, mills have limited resources and it is not possible to provide this service for everyone.

Feed trucks. There is a general move towards using tanker trucks instead of box trucks, with augers being preferred over blowers. All participants agreed that box trucks present the highest biosecurity risk, followed by tanker trucks that blow feed into the bins, then by tanker trucks that auger the feed. Box trucks are considered the highest risk because the driver has to get in and out of the feed compartment in order to move dividers and sweep out feed. In this way, the inside of the compartment and even the feed itself could become contaminated. Tanker trucks allow the feed to be loaded and unloaded without being touched. Auger trucks in particular minimize the contact required between the feed bin and the truck. The whole fleet is generally washed every weekend using high-pressure hoses with hot water and soap. For some companies, the soap includes a disinfectant. Participants were aware that if a truck does not dry completely after being washed, moisture can promote the growth of some pathogens. Some companies have their own washing facilities, while others use a commercial truck wash. Trucks are often washed more

than once per week, for example, if a customer requests a clean truck, if a sow herd or other high-biosecurity herd needs feed mid-week, or if the driver visits a farm that is considered dirty and high-risk or that is positive for a specific pathogen. Generally, producers felt that drivers take pride in keeping their trucks clean, but that trucks should be washed more often. Feed-company personnel and producers acknowledged that it is not practical to wash the trucks between farms or even every day. Some trucks have onboard disinfectant sprayers. For the others, the driver has a hand-held disinfectant canister. It was once common practice for the driver to spray truck tires prior to entering every swine site. Generally, this is now done only at producer request, but some companies still spray regularly, especially at sow farms. Disinfecting tires was discussed at length. Most participants realized that the contact time is probably insufficient to kill pathogens, and that the disinfectant will not be effective if there is organic material on the tires. The practice of disinfecting tires is generally viewed as being cosmetic by both feed-company personnel and producers. Producers expressed concern that although trucks might be cleaned prior to being loaded, they then enter a high-traffic loading bay that is rarely washed or disinfected.

Driver. There is an important link between the driver and the dispatcher – the driver talks to producers, makes on-farm observations, and can relay this information to the dispatcher. Drivers usually receive biosecurity training. They are instructed on cleanliness of their hands and footwear and the inside of the truck's cab. Drivers try their best to keep a tidy truck and to keep themselves clean. At some feed mills, they are provided with disinfectant spray for the floor mats, pedals, and steering wheel, multiple sets of gloves, and disposable plastic boots. They are often instructed to stay away from the barn, to avoid going inside the barn, and to use a shovel if the feed needs to be moved, instead of using their hands or feet. Disposable plastic boots are worn by the drivers if the producer makes that request, or if the farm is considered high-risk. All participants seemed to understand the importance of such protection, but there was concern about the risk to the driver, expressed by both the feed-company personnel and producers, because these plastic boots are slippery, too big, and easily ripped. The boots are especially dangerous in the winter and have resulted in several workplace accidents. The general feeling was that disposable plastic boots don't work well and something different needs to be investigated. Drivers are provided with several pairs of rubber or leather gloves or both. They try to keep them clean and dry, but they are used at multiple farms. The producers felt that wearing the same pair of gloves at multiple farms is a biosecurity concern, and that the drivers should be provided with disposable gloves. This presents a challenge in the colder months, when drivers need warm gloves. Customer requests are listed electronically on the bill of lading. Generally, the driver complies with the producer's requests, even if that means going inside the barn.

Bulk feed. The biggest concern with delivery of bulk feed relates to the use of blow pipes, which are moved from farm to farm. Truck drivers are generally careful about placement of the pipe and attempt to avoid dragging it through mud or manure, but it can be challenging to keep clean.

Bagged feed. Bagged feed is considered a higher biosecurity risk than bulk because there is more personal contact with bagged feed. A bag could get stepped on or dropped on the ground by accident. Often, the driver is asked to enter a farm building in order to deliver bags. Producers do realize that bagged feed is a risk and try to limit the amount they order. Feed-company personnel expressed concern that many producers ask that bags be delivered right into the feed room. The producers we spoke with knew that having bags delivered to the feed room is a risk and were surprised to hear that some producers still asked drivers to deliver the bags into the barn. Alternatively, some producers ask that the bags be left on the loading chute from which pigs are shipped. This is a concern for the driver with respect to manure contamination. The ideal situation, according to feed-company personnel and producers, would be for bagged feed to be delivered to a separate building (a shed or garage). Then the producer would be responsible for taking the bags to the barn at a later time. Alternatively, bags could be unloaded truck-to-truck at the end of the laneway.

Producer. Biosecurity protocols vary extensively between farms. Producers often ask to be the first feed delivery of the day, not necessarily asking for a clean truck, but making the assumption that because it is first thing in the morning, the truck is clean. Producers need to communicate to the mill exactly what they want. Deadstock management was a real concern. Recently, marked improvements have been made in the management of deadstock, and producers tend to locate the bins on the edge of the property. In some cases, however, the deadstock bin is located right next to the feed bin or the laneway. In this case, run-off from the bin has been observed draining across areas where the driver of the truck has to drive or walk. There is also concern about how deadstock are moved from the farm to the bin; deadstock may be dragged across high-traffic areas. Some of the drivers we spoke with complained of deadstock being left in inappropriate areas (such as near the feed bin or on the laneway). Producers are aware of these issues and feel that the ideal situation is for deadstock to be composted or incinerated on-site. The cleanliness of the feed bin area is important. Some producers have their feed bins fenced in, with the pipes extending outside the fence. This prevents the driver from getting close to the bin and crossing paths with the producer. Feed-company personnel expressed concern that last-minute feed orders disrupt the dispatcher's plan for the day and make sequencing, with respect to biosecurity, more challenging. Ideally, producers should plan their orders to decrease the frequency with which the feed company must deliver to the farm: less interaction means less risk for the producer. Bigger bins would mean less frequent deliveries. Occasionally, producers order more feed than there is room for in the bin and the driver needs to decide what to do with the extra feed. Producers were aware of these issues, but stated that unforeseen circumstances make inventory management challenging. Producers need to maintain clean, dry yards – this concern was expressed by both feed-company personnel and producers. The lane needs to be well drained so that trucks are not driving through mud, manure, or puddles. Some producers we spoke with were aware of this issue and make an effort to maintain a clean, dry yard without deadstock, straw, manure, or other debris. If producers are able to maintain a clean yard, people will respect it more. A cluttered or dirty yard may give the impression that the producer does not think biosecurity is important. Producers could try to schedule delivery of feed so that other traffic, such as livestock trucks, are not at the farm at the same time and that equipment used to spread manure is not being used at the same time feed is being delivered. In particular, drivers did not want to drive over manure that was spilled in the laneway or the yard.

New management ideas

Management ideas discussed in the focus groups and key-informant interviews are summarized in tables 3 through 6. They are categorized according to the level of implementation: feed company (Table 3), dispatcher (Table 4), driver (Table 5), or producer (Table 6). Ideas are organized in descending order of average overall rating, and the average rankings for disease control, ease of implementation, and economic feasibility are provided.

Discussion

The focus groups and key-informant interviews revealed that swine producers and feed-company personnel recognize the importance of biosecurity in ensuring a sustainable swine industry. Not only is biosecurity fundamental to economic sustainability, it is also important in maintaining freedom from disease that is key to swine productivity and to maintaining both local and export markets. Participants in this study discussed the many protocols they already have in place to reduce the potential biosecurity risk associated with delivery of feed. They stressed that biosecurity is a responsibility shared across all levels, and that everyone has a role to play in ensuring these protocols are carried out effectively.

Participants were first asked how diseases are transmitted from farm to farm. Managers and producers seemed to have the most knowledge about the different ways diseases can be transmitted. Participants from all groups were aware that contact between an infected animal and one that is susceptible to a pathogen is the most important route of transmission, but a variety of other means were mentioned (Table 2).[1,35,36] Participants were also asked to list specific diseases that could be transmitted in the feed, if they thought that was a possibility. A previous study showed that *Salmonella* can be transmitted in the feed,[3] and at least one person from management, drivers, and producers identified this as a possibility. Some participants also thought that PRRSV and TGEV could be transmitted in the feed itself; however, this is not supported by scientific evidence. This opinion highlights the importance of increased education for people in the industry so that feed-company personnel and swine producers understand which pathogens can be found in feed and which are not expected to be found in feed.

Participants in this study generated a large number of recommendations for protocols that could further reduce the risk of disease transmission associated with delivery of feed. Some ideas that were highly rated in terms of disease control and economic and logistic feasibility are discussed here. One recurring theme was that visitor access should be restricted, both at the feed mill and at the farm. Studies have shown that boots can become contaminated with *Salmonella*,[15] and that boots, coveralls, and hands can become contaminated with PRRSV.[21] When they do not change their clothing or footwear after contacting infected pigs, people can act as mechanical vectors for a variety of pathogens, including *B hyodysenteriae*,[26] *E coli*,[30] TGEV,[27] and PRRSV.[21] These studies highlight the importance of restricting visitor access whenever possible. Specific recommendations from previous studies include the following: do not allow visitors to enter the bagged-feed storage area at the feed mill; ensure sales personnel visiting farms follow good biosecurity protocols (including showering in and changing coveralls); have producers provide a container so the driver can leave the bill of lading at the feed bin; and never ask or allow feed-company personnel to enter the barn.

Ensuring adequate pest control at the feed company was also rated highly by participants, and several studies have shown there is

Table 3: Average ratings for feed-company-level management changes to enhance biosecurity on a scale of 1 to 5*

Recommendation	Rating category		
	Disease control	Ease of implementation	Economic feasibility
Pest control (rodents and birds)	4.44	4.67	4.44
Truck-washing facilities dedicated to feed trucks (not shared with livestock trucks)	4.67	3.89	3.76
Exclude visitors from the area where bagged feed is stored	4.00	4.09	4.22
Visitor sign-in book recording recent contact with livestock	3.71	3.94	4.41
Do not return skids or pallets to the mill	4.00	4.09	3.57
Maintain a central database for disease status on farms	4.26	3.48	3.83
Wash feed trucks more often (more than once per week)	4.35	3.61	3.39
Scoring system for farms based on production type and biosecurity measures to plan the sequencing of deliveries	4.06	3.29	4.00
Do not allow bulk or bagged product to be returned to the mill	4.22	3.57	3.39
Returned skids or pallets are washed, disinfected, and dried at the mill	4.22	3.04	3.13
Use preferred truck types: auger > blower > box	3.67	3.06	2.39
Purchase tankers with a side compartment dedicated to bagged feed	3.00	2.94	2.82
Wash and dry feed trucks daily in a heated bay located at the feed mill	4.32	2.09	1.82
Have one feed truck dedicated to high-health herds	4.04	2.17	1.74

* Study described in Table 1. For each recommendation, each column represents the average rating of one of the three categories on a scale of 1 to 5, with 5 the most positive rating and 1 the least positive rating.

Table 4: Average rating for dispatcher-level management recommendations to enhance biosecurity on a scale of 1 to 5*

Recommendation	Rating category		
	Disease control	Ease of implementation	Economic feasibility
Plan delivery route to visit high-health, high-biosecurity herds first and low-health, low-biosecurity herds last	4.65	3.74	4.00
Plan sequence of delivery for bagged feed, with high-health, high-biosecurity herds visited first	4.06	3.67	3.39
Sequence deliveries in the absence of disease, eg, sow herds first and finisher herds last; all-in, all-out first and continuous flow last	4.28	3.50	3.17
Give producer 45 minutes advance warning before the truck is scheduled to arrive; producer can then arrange to meet the driver on arrival	3.26	3.16	3.74
Plan deliveries within production systems so that one system can have a feed truck for the day	3.95	2.50	2.45

* Study described in Table 1. For each recommendation, each column represents the average rating of one of the three categories on a scale of 1 to 5, with 5 the most positive rating and 1 the least positive rating.

a risk of rodents and birds transmitting disease. *Salmonella* serovars have been isolated from bird feces on swine farms.[15] Rodents have tested positive for a variety of pathogens that infect swine, including *Salmonella,*[14,15] *Bordetella bronchiseptica*,[16] *Pasteurella* species,[16] *E coli*,[16] *Campylobacter jejuni*,[16] *B hyodysenteriae*,[16,37] and rotavirus.[16] Rodents are not carriers of PRRSV.[38,39]

Throughout discussions with feed-company personnel and swine producers, the subject of deadstock management came up frequently, and the recommendation that producers keep deadstock properly contained was highly rated. Deadstock and run-off from carcasses may act as reservoirs for pathogens.[40] The use of truck-washing facilities dedicated to feed trucks and not shared with livestock trucks was rated highly among participants. Since livestock trucks have direct contact with animals, they are considered to be a bigger risk than feed trucks.

Participants also stressed the importance of planning the route for feed delivery so that high-health, high-biosecurity herds are visited first, and low-health, low-biosecurity herds are visited last. This aligns with recommendations made by the Food and Agriculture Organization (FAO) and the Canadian Swine Health Board, who advise that feed deliveries be made in the order of health status, with high-health farms being visited early in the week, and contaminated facilities being visited later in the week.[1,41] Additionally, the FAO recommends that nucleus herds receive deliveries after the truck has been properly decontaminated and has had 2 days of down time.[1]

Some ideas were rated highly in terms of disease control, but were generally considered difficult to implement because of their poor economic and logistic feasibility. These include washing and drying feed trucks daily, washing and disinfecting the blow pipe between farms, and having bagged feed delivered to a separate room so that it can be fumigated before entering the barn. Although these ideas may have a measurable impact on disease control, participants considered them too costly, too challenging, or both to implement in the current system.

Several management ideas were related to infrastructure challenges or more global-industry ideas that cannot be addressed on existing farms or in a short time-frame. Farm layout in particular was identified as an issue: farms that have not been designed to enhance biosecurity would require infrastructure changes. Several identified issues are important considerations when designing new farms. Firstly, a variety of traffic uses the same lane – manure equipment, livestock trucks, deadstock trucks, feed trucks, and service vehicles. Both feed-company personnel and producers expressed concern that the feed-truck driver does not know when other types of traffic were last on-farm or exactly where they drove. Ideally, there would be separate lanes for different types of traffic, but in many cases there is only one lane at each farm. This highlights the importance of scheduling pigs and manure movement separately from feed delivery. Secondly, the location of the feed bin is a concern. There were reports of feed bins located next to the deadstock bin or compost pile, the load-out chute, the manure pit, or directly underneath exhaust fans. Producers realize that bin placement can be a biosecurity issue, but it would be challenging to relocate existing bins. Ideally, the bin would be located on the perimeter of the property and away from high-traffic areas.

Some broader themes identified include the need for increased communication, collaboration, education, and research. There is a need for increased communication between feed companies and producers, especially in terms of disease status. The feed company needs this information in order to make the best decisions regarding the sequence of deliveries. The producers we spoke with are aware of the importance of informing the feed company of an outbreak so that feed deliveries can be sequenced properly. Throughout our discussions, there was concern that government, academic, and industry organizations are approaching these issues independently. The industry would like to see more collaboration among the different sectors. Feed-company personnel also felt there should be more collaboration among commodity groups (swine, poultry, and cattle), since feed companies do not necessarily make that distinction in the delivery of feed. Both feed-company personnel and swine producers expressed interest in development of a set of minimum standards that everyone adheres to, with additional precautions to be taken in case of a disease outbreak. Finally, there is a need for science-based recommendations. Some participants felt

Table 5: Average rating for driver- or sales-personnel-level management recommendations to enhance biosecurity on a scale of 1 to 5*

Recommendation	Rating category		
	Disease control	Ease of implementation	Economic feasibility
Ensure sales personnel follow good biosecurity protocols when calibrating the mill	4.48	4.83	4.87
Feed company personnel do not enter the barn	4.52	4.70	4.83
Increase driver education to understand why certain protocols must be followed	4.26	4.37	4.47
On tanker trucks, keep bagged feed compartment clean	4.11	4.47	4.26
Wash and disinfect floor mats regularly	4.09	4.23	4.27
Drivers report biosecurity incidents or observations to the feed company	3.71	4.00	4.29
Drivers wear disposable boots or clean reusable over-boots when leaving the cab of the vehicle	3.86	3.96	4.17
Multiple pairs of reusable boots available for drivers; clean, disinfect, and dry boots after on-farm use	3.86	2.83	3.09
Checklist of farm-specific biosecurity protocols for the driver, who signs off on all protocols	3.53	3.63	4.05
Bulk delivery trucks completely cleaned out before leaving a farm	3.56	3.79	3.72
Drivers wear a new pair of disposable gloves at each farm	3.45	3.48	3.67
Disinfect bag carts, trolleys, and loading ramps between loads	3.83	3.13	3.30
Ensure the blow pipe doesn't touch the ground or mud	3.61	2.78	3.48
Wash and disinfect the blow pipe between farms	3.64	2.13	2.65
For tanker and box trucks: install a coarse mesh so that the driver cannot enter the feed compartment	3.18	2.17	2.50
Wash sales-personnel vehicles between farms	3.45	2.09	2.00
Removable slatted plastic floor inserts for box trucks that can be cleaned and disinfected	3.17	2.33	1.94

* Study described in Table 1. For each recommendation, each column represents the average rating of one of the three categories on a scale of 1 to 5, with 5 the most positive rating and 1 the least positive rating.

that certain recommendations are based on marketing and are not necessarily backed by scientific evidence. The people we spoke with are generally happy to implement biosecurity protocols as necessary, but they need to know that scientific evidence supports these decisions. Additionally, education is important in ensuring that feed-truck drivers and producers understand the science behind biosecurity recommendations. If they understand the reasoning behind specific recommendations, they may be more likely to comply. Some of the drivers we spoke with expressed interest in having fact sheets outlining the diseases that are important in swine production, how they affect pigs, and how they are transmitted.

This work has provided valuable insight into participant knowledge and application of biosecurity protocols related to delivery of feed. It has increased awareness of this issue among feed-industry personnel and swine producers. The qualitative, participatory approach utilized here was well received by participants. They appreciated that we wanted to know their thoughts and ideas about the issues and to obtain their input about what is important and what improvements might be feasible. The researchers have gained a much better understanding of the issues and the complexity involved with delivery of feed. Additionally, the focus-group approach facilitated sharing ideas and knowledge among participants and allowed them to learn from others in their field. An added benefit of the approach was that some producers had not thought about what they can do to prevent diseases from being picked up on their farm and moved elsewhere by a feed truck. Generally, their focus is to prevent pathogens from coming into their own farms. However, this expanded thinking is very important to the swine industry as a whole.

This study has some limitations, the biggest of which is selection bias – participants were recruited through a convenience sample selected by OABA and Ontario Pork. Feed-company personnel and producers who chose to participate may have done so because they already understood the importance of biosecurity. As a result, our sample may represent those who are already doing well in this area and may not include feed companies or producers who have fewer protocols in place.

This study has identified many important factors related to biosecurity and the surrounding issues. The next step is to determine the frequency with which certain practices are being implemented.

Implications

- Biosecurity is a responsibility shared among all members of the industry, and

Table 6: Average rating for producer-level (farm-level) management recommendations to enhance biosecurity on a scale of 1 to 5*

Recommendation	Rating category		
	Disease control	Ease of implementation	Economic feasibility
Provide a container where the driver can leave the mill order without going near the barn	4.32	4.95	5.00
Don't allow feed-company personnel to enter the barn for any reason	4.48	4.74	4.91
Contain deadstock in proper bins with lids	4.70	4.68	4.55
The producer shares the disease status of the farm, informing the feed company when the herd has a new outbreak	4.70	4.30	4.83
The driver never enters the barn to deliver bagged feed	4.52	4.30	4.83
1. Driver leaves the bags in a shed	4.26	4.26	4.21
2. Driver leaves the bags on a cart that staff pull inside the barn or feed room	3.41	3.94	4.22
3. Feed loaded into the barn from the outside via a chute	4.28	3.33	3.11
4. Bags off-loaded truck-to-truck at the end of the laneway	3.94	3.06	3.28
Area around the bottom of the feed bin is kept clean and tidy	4.00	4.57	4.83
Producer orders an appropriate amount of feed; no leftovers go back to the mill	3.95	4.41	4.77
Storage area for bagged feed is kept clean and tidy	3.84	4.47	4.74
Rodent control	4.25	4.15	4.30
Producers report biosecurity breeches to the mill; driver can be reminded of protocols	3.89	4.26	4.53
Signs indicate controlled access and restricted access zones (where to park, where not to go) and ensure compliance	4.00	4.21	4.42
Keep farm lane clean, dry, well drained; driver need not drive or walk through manure, mud, or run-off from the deadstock bin	4.65	3.91	4.00
Garbage (eg, gloves, disposable plastic boots) disposed of on-farm	4.13	4.13	4.17
Producer always washes hands prior to handling feed	3.47	4.26	4.42
Bagged feed stored off the floor	3.32	4.32	4.26
Producer plans timing of feed delivery; manure not being spread when feed truck arrives	4.22	3.35	4.27
Checklist of farm-specific biosecurity protocols for driver to sign to confirm they followed all protocols	3.26	3.79	4.42
Chain and a sign at the end of the laneway to remind driver about biosecurity	3.20	4.05	4.00
Pipes for delivery of feed are producer-owned and stay at each farm	3.68	4.11	3.37
Producer requests specific biosecurity protocols from feed company	3.78	3.43	3.70
Producers order bulk feed instead of bagged feed	3.67	3.61	3.44
Producer provides farm boots for the driver	3.27	3.36	4.00
Appropriate feed-bin placement (not near exhaust fans, deadstock, loading chute, manure pump-out, main barn entrance)	4.25	2.95	2.95
Use blow pipe extensions so driver need not get close to the feed bin or barn	3.17	3.33	3.28
Bagged feed delivered to a separate room or building so that it can be fumigated before being carried into the feed room	4.05	2.89	2.79
Locate feed bins at the edge of the property	3.94	1.72	1.61
Retrofit bins so that when feed is being delivered via an auger truck, the driver can open the bin remotely without leaving the cab	3.28	1.33	1.39

* Study described in Table 1. For each recommendation, each column represents the average rating on a scale of 1 to 5, with 5 the most positive rating and 1 the least positive rating.

individuals of each sector need to work together to enhance biosecurity for the industry as a whole.
- There is diversity of opinion regarding the issues that are most important and the interventions that could be implemented in order to further decrease the risk of pathogen transmission associated with delivery of feed.
- The swine industry is willing to implement changes, but wants to know there is scientific evidence to support these changes.
- There is great interest in development of an industry standard for best practices related to the delivery of feed.
- There is a need for education concerning biosecurity issues, and veterinarians can play a role in this.

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Conflict of interest

None reported

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*Non-refereed references.

Conversion tables

Weights and measures conversions

Weights and measures

Common (US)	Metric	To convert	Multiply by
1 oz	28.35 g	oz to g	28.4
1 lb (16 oz)	453.59 g	lb to kg	0.45
2.2 lb	1 kg	kg to lb	2.2
1 in	2.54 cm	in to cm	2.54
0.39 in	1 cm	cm to in	0.39
1 ft (12 in)	0.31 m	ft to m	0.3
3.28 ft	1 m	m to ft	3.28
1 mi	1.6 km	mi to km	1.6
0.62 mi	1 km	km to mi	0.62
1 in^2	6.45 cm^2	in^2 to cm^2	6.45
0.16 in^2	1 cm^2	cm^2 to in^2	0.16
1 ft^2	0.09 m^2	ft^2 to m^2	0.09
10.76 ft^2	1 m^2	m^2 to ft^2	10.8
1 ft^3	0.03 m^3	ft^3 to m^3	0.03
35.3 ft^3	1 m^3	m^3 to ft^3	35
1 gal (128 fl oz)	3.8 L	gal to L	3.8
0.264 gal	1 L	L to gal	0.26
1 qt (32 fl oz)	946.36 mL	qt to L	0.95
33.815 fl oz	1 L	L to qt	1.1

Temperature equivalents (approx)

°C	°F
0	32
10	50
15.5	60
16	61
18.3	65
21.1	70
23.8	75
26.6	80
28	82
29.4	85
32.2	90
38.8	102
39.4	103
40.0	104
40.5	105
41.1	106
100	212

$°F = (°C \times 9/5) + 32$

$°C = (°F - 32) \times 5/9$

Conversion chart, kg to lb (approx)

Pig size	Kg	Lb
Birth	1.5-2.0	3.3-4.4
Weaning	3.5	7.7
	5	11
	10	22
Nursery	15	33
	20	44
	25	55
	30	66
Grower	45	99
	50	110
	60	132
Finisher	90	198
	100	220
	105	231
	110	242
	115	253
Sow	135	300
	300	661
Boar	360	794
	363	800

1 tonne = 1000 kg
1 ppm = 0.0001% = 1 mg/kg = 1 g/tonne
1 ppm = 1 mg/L