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Swine producer survey of influenza A virus awareness and risk mitigation practices in the United States

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Abstract

Influenza A virus (IAV) is a zoonotic pathogen that causes widespread infection in swine populations and can result in severe economic losses. Implementation of biosecurity practices and surveillance programs can help prevent within-herd transmission, zoonosis, and reverse zoonosis of IAV. A survey was conducted by mail to evaluate the general knowledge and perceptions of IAV from individuals involved in the swine industry focusing on pork producers and to determine how these factors influence on-farm and employee biosecurity practices. Most participants expressed some level of concern related to the presence (77.5%), and economic impact of IAV in their swine operation (85%) and potential zoonotic transmission (73%). Although respondents reported implementation of specific on-farm biosecurity practices such as facility entry procedures for employees (67.8%) and use of boots dedicated to a farm or building (84.5%), they did not require practices such as gloves (40.8%) and respirator/dust mask use (32.4%). Moreover, few participants reported enforcing employee influenza prevention strategies such as employee vaccination (20.6%) and sick leave policies (26.1%). Similarly, a low percentage of participants stated using IAV vaccines in their breeding herds (16%). These data suggest that although participants are generally aware and concerned about IAV, they could become more informed about the ecology of the virus in order to help mitigate its impact on swine operations. This study provides evidence that producers and individuals involved in swine production may need to become better informed of the consequences of IAV-S infections among swine production systems as well as the long-term benefits of implementing recommended biosecurity practices that are necessary to prevent transmission.

1. Introduction

Influenza A virus (IAV) causes an acute respiratory disease in swine associated with widespread infection in pig populations with public health implications (Brown, 2000). In the United States (US), IAV has evolved from a disease causing seasonal outbreaks to what are considered endemic infections in swine production systems (USDA-APHIS, 2020). Pigs are susceptible to infection with both avian and 'human-like' subtypes, which makes them a reservoir of IAV (Brown, 2000). Pigs are also considered intermediate hosts or 'mixing vessels' for viral reassortment of gene segments from swine, avian and human hosts (Ma, 2008). This may result in the generation of novel progeny viruses that could potentially infect other species or cause future pandemics (Myers et al., 2005; Brown, 2000). The USDA IAV in swine (IAV-S) Surveillance Program has detected over 10,000 positive cases with available virus isolates since its inception in 2010 (USDA-APHIS, 2020). Despite low mortality, the prevalence of IAV-S is a global problem and can result in significant economic losses (Ma et al., 2010; Vincent et al., 2016). High morbidity in swine herds affects performance of breeding sows, productivity of growing pigs and causes longer delays to slaughter (Salvensen, 2021).

IAV is a zoonotic pathogen, but it can also be transmitted from humans to animals (reverse zoonosis) (Arunorat, et al., 2017). Bidirectional transmission of IAV and the potential public health consequences demand implementation of biosecurity measures and surveillance programs at farm and national levels to monitor the genetic ecology of the virus. Nonetheless, the awareness of IAV-S public health significance and zoonotic potential is lacking and suggests the need for enhanced biosecurity practices in swine production systems. This may be attributed to the fact that adoption of these methods in the US has been expensive yet precautionary and not mandatory (Pudenz, et al., 2019). It was not until recently that policies such as the Veterinary Feed Directive were adopted by the US, or that producers had to provide evidence of biosecurity use to receive indemnity payments during an outbreak (Pudenz et al., 2019). The use of biosecurity practices varies across swine operations depending on previous experiences of producers with IAV-S and general knowledge regarding disease incidence and potential risks (Pudenz, et al. 2019). The aim of this study was to examine pig producers' knowledge, perceptions and methods of control of IAV and how these factors influence on-farm and employee biosecurity systems.

2. Materials and methods

2.1. Survey design

A survey was developed to collect data from pork producers and individuals involved in swine production regarding their knowledge and perceptions about IAV-S in swine. The survey consisted of four pages with 1 open and 22 closed questions. The survey included general questions concerning respondents' role in swine production, size of their breeding herd, number of swine marketed, geographic region of where the swine operation was located and presence of IAV-S in their swine production system. The survey also inquired about the level of concern regarding IAV in swine and humans, facility entry policies, implementation of on-farm biosecurity procedures and use of personal protective equipment (PPE). In addition, it inquired about employee biosecurity procedures, vaccine use in breeding herds and perceptions regarding the economic impact associated with the presence of IAV-S. The survey also included questions related to level of concern regarding transmission, sources for introduction of new IAV-S strains into a production system, and opinions about continued funding the USDA surveillance program in the US. Participants were offered the option to select 'other' when the available choices of a survey question were not applicable to their specific operation or association with swine production.

2.2. Distribution of surveys

The sampling frame consisted of a list of members of the Iowa Pork Producers Association (IPPA) who were targeted for the survey. The list included names and mailing addresses, but it did not include email addresses. The survey was produced exclusively in hard copy and not offered in an online format, considering email addresses were not provided. The Center for Survey Statistics and Methodology – Survey Research Services (CSSM-SRS) at Iowa State University helped prepare and administer the survey, arranged for printing materials, and were responsible for data collection. Survey packets with a cover letter, paper survey, and a postage paid return envelope were mailed to targeted producers on May 24, 2017. A reminder postcard was sent six days later. A second packet was mailed to non-respondents three weeks following the reminder. A third packet was sent to non-respondents approximately one month after the second packet was mailed.

2.3. Data management

The CSSM-SRS staff monitored the data collection process and recorded the receipt of completed surveys. In addition, the survey center responded to questions received on the toll-free number provided in the survey cover letter as well as managed results and de-identified the data. Furthermore, the CSSM-SRS staff edited, key entered coded surveys using a double entry verification system and checked the data for errors. The final data and text files were prepared and delivered in September 2017.

2.4. Statistical analysis

Two analyses were performed to examine the effects of the explanatory variables on the variables of interest (response variables). In the first part, a Pearson's Chi-squared Test was used to check if the distribution of a response variable depended on the values of an explanatory variable. The results were summarized in a table where "1" represents that the relationship between one response variable and one explanatory variable is not independent, and "0" represents variables that are independent. The option "don't know" was not included in the data analysis. In the second part, regression models were fitted to analyze the relationship between the response variable and the explanatory variables. For binary response variables, logistic regression models with group regularization methods were applied to find important explanatory variables. For categorical response variables, multinomial regression models with group regularization methods were applied to find important explanatory variables.

3. Results

3.1. Survey distribution

The original sampling frame consisted of 3000 IPPA members. However, in instances where two members shared the same address (e.g., married couples), one individual was removed from the survey population. A total of 73 duplicate listings were removed prior to data collection. The final sample contained 2927 swine producers. During data collection, 92 (3.1%) of respondents who were not actively involved in swine production were classified as ineligible. The final sample of eligible participants included 2835 producers. A total of 879 (31.0%; 879/2835) completed surveys were received from 737 (83.8%; 737/879) active swine producers and 142 (16.2%; 142/879) from IPPA members who were involved in research, allied industries, or who were previously involved in swine production.

3.2. Study population demographics

Characteristics of respondents based on role in swine production, size of breeding herd, number of swine marketed, and geographic region of the swine operation are shown in Table 1. The 142 IPPA members involved in research, allied industries, or previous swine production, were instructed to answer questions 18 through 23 only (Appendix A; Supplementary data). All completed surveys from active swine producers were reported from Region 2/Midwest, excluding one respondent from Region 4 and three from Region 3.

Table 1: Demographics and characteristics of respondents to the influenza A virus swine producer survey.

Variables	Frequency (*N*)	Percent (%)
Role in Swine Production		
Owner/Co-owner - Commercial Operation	304	34.6
Contract Grower - Commercial Operation	286	32.5
Not Directly Involved in Swine Production	98	11.2
Owner/Manager/Herdsperson - Non-Commercial Operation	80	9.1
Manager/Herdsperson - Commercial Operation	46	5.2
Allied Industry or Technical Service	26	3.0
Missing Q18 - 23 Completed	12	1.4
Missing, Whole Survey Completed	10	1.1
Both Owner and Contract Grower	8	0.9
University or Researcher	6	0.7
Both Contract Grower and Manager/Herdsperson	3	0.3
TOTAL	**879**	**100**
Size of breeding herd		
More than 25000 sows	19	2.6
5001 - 25000	21	2.9
1000-5000	85	11.8
Less than 1000 sows	160	22.2
Not applicable (no breeding herd)	437	60.5
TOTAL	**722**	**100**
Number of swine marketed		
More than 100000	44	6.0
25000 - 100000	108	14.7
5001 - 25000	327	44.6
1000 - 5000	185	25.2

Less than 1000 swine	70	9.5
TOTAL	**734**	**100**
Geographic region of swine operation		
Region 1: AL, CT, DE, FL, GA, ME, MD, MA, NH, NJ, NY	0	0.0
Region 2: IL, IN, IA, KY, MI, MN, OH, WI	733	99.5
Region 3: AR, LA, MS, MO, OK, TX	3	0.4
Region 4: ID, KS, MT, NE, ND, SD, WY	1	0.1
Region 5: AK, AZ, CA, CL, HI, NV, NM, OR, UT, WA	0	0.0
TOTAL	**737**	**100**

3.3. Perceptions of Influenza A Viruses

Table 2 summarizes perceptions of the respondents who were active swine producers related to the presence of IAV-S in their swine operations or production systems. A large proportion of participants expressed some level of concern regarding IAV-S (86.5%; 633/731) and potential zoonotic transmission of the disease (73%; 639/876). Most producers also associated presence of IAV-S in the herd with some economic repercussions (77.5%; 675/871) and believed that regional swine or nearby swine were the primary source for introduction of new IAV into breeding and gestation farms.

Table 2: Perceptions of active swine producers and presence of influenza A virus in swine production systems.

Variables	Frequency (*N*)	Percent (%)
Level of concern regarding presence of IAV		
Very concerned	77	10.5
Concerned	252	34.5
Somewhat concerned	304	41.6
Unconcerned	55	7.5
No opinion/unsure	43	5.9
TOTAL	**731**	**100**
Primary source for introduction of new IAV into breeding/gestation farms		
Regional swine farms/nearby swine	448	59.5
Replacement gilts	141	18.7
Humans	86	11.4
Other source	78	10.4
TOTAL	**753**	**100**
Magnitude of economic impact		
High economic impact	115	13.2
Moderate economic impact	418	48.0
Low economic impact	142	16.3
No economic impact	8	0.9
No opinion/unsure	188	21.6
TOTAL	**871**	**100**
Level of concern regarding potential zoonotic transmission of IAV		
Very concerned	75	8.6

Concerned	212	24.2
Somewhat concerned	352	40.2
Unconcerned	158	18.0
No opinion/unsure	79	9.0
TOTAL	**876**	**100**

3.4. Farm-level and employee biosecurity practices

The survey asked producers to identify biosecurity practices applied at the farm level as well as preventative measures implemented for employees. Table 3.1 demonstrates the vast majority of respondents reported implementation of most entry/exit procedures and policies designed to prevent entrance and spread of infectious disease within the farm. However, results shown in Table 3.2 suggests that producers are less stringent about use of PPE such as gloves and respirator or dust masks. The survey also asked producers to report any employee influenza prevention policies applied in their swine operations. Table 3.3 shows that a large proportion of producers do not enforce employee policies such as body temperature monitoring as a method to monitor potential human IAV infections that could be a source of transmission from humans to swine. A low proportion of producers implement personnel vaccination and require farm employees to receive an annual influenza vaccine. In addition, the survey revealed few producers recommend, although do not require, annual vaccination and fewer enforce a mandatory sick-leave policy depending on severity of illness. An even lower proportion of producers (3.6%; 26/732) stated having an in-house vaccination clinic to give influenza vaccines to their employees.

Table 3: Survey results of farm-level influenza A virus biosecurity practices and policies.

Variables	**Yes (*N*)**	**Yes %**	**No (*N*)**	**No %**	**Unknown/ NA (*N*)**	**Unknown/ NA (%)**	**No. employees (*N*)**	**No. employees (%)**	**Total (*N*)**
1. Swine biosecurity practices									
Facility entry procedure, policy, or SOP for employees	494	67.8	179	24.6	56	7.7	NA	NA	729
Procedures for non-employees/visitors/maintenance repair	614	84.3	103	14.1	11	1.5	NA	NA	728
Procedures for swine transport vehicles/trailers	601	82.2	111	15.1	19	2.6	NA	NA	731
Procedures for feed/supply delivery	453	62.4	233	32.1	40	5.5	NA	NA	726
Procedures for rendering	445	64.4	214	31.0	32	4.6	NA	NA	691
Other	26	3.6	677	93.0	25	3.5	NA	NA	728
2. Employee personal protective equipment									
Coverall/Tyvek dedicated to a farm or building	420	58.6	249	34.7	6	0.8	42	5.9	717
Gloves	283	40.8	364	52.4	5	0.7	42	6.1	694
Respirator/dust mask (N95)	223	32.4	418	60.7	6	0.9	42	6.1	689
Boots dedicated to a farm or building	617	84.5	69	9.5	2	0.3	42	5.8	730

Other	34	4.7	629	86.4	23	3.2	42	5.8	728
3. Employee influenza prevention policies									
Employee vaccination	147	20.6	488	68.4	33	4.6	45	6.3	713
Sick leave policy	185	26.1	447	63.0	32	4.5	45	6.3	709
Body temperature monitoring	4	0.6	631	89.4	26	3.7	45	6.4	706
Entry procedures (shower in, etc.)	251	34.9	406	56.5	17	2.4	45	6.3	719
Employee requirement to receive annual influenza vaccine	71	9.7	524	71.6	*92	*12.6	45	6.1	732
Mandatory sick-leave policy if influenza-like illness	47	6.4	505	68.8	**70	**9.5	112	15.3	734
Other	13	1.80	640	89.00	21	2.90	45	6.30	719

NA: not applicable
*no, recommended but not required
**depends on severity

3.5. Influenza A virus vaccine perspectives

Only 116 producers, representing 16.0% of respondents, reported using IAV vaccine in their breeding herds (Table 4). Producers who answered ‘no’ were asked to skip subsequent questions related to vaccine use in their swine operations. Most producers stated they prefer the commercial vaccine over other types of vaccines and that timing for vaccine administration should take place during gilt isolation.

Table 4: Influenza A virus vaccine perceptions and use in swine production systems.

Variables	**Yes (*N*)**	**Yes %**	**No (*N*)**	**No %**	**Unknown /NA (*N*)**	**Unknown /NA (%)**	**Total**
Use of IAV vaccine in breeding herd	116	16.0	214	29.6	393	54.4	723
Use of IAV vaccines in nursery/grow/ finish swine	45	17.1	149	56.7	69	26.2	263
Use of commercial vaccine	89	77.4	18	15.7	8	7.0	115
Use of autogenous vaccine	27	30.7	47	53.4	14	15.9	88
Use of replicon particle subunit vaccine	12	13.8	60	69.0	15	17.2	87
Use of other type of vaccine	NA	NA	67	89.3	8	10.7	75
Vaccination during gilt isolation	59	60.8	21	21.6	17	17.5	97
Pre-breeding vaccination	26	29.5	44	50.0	18	20.4	88
Pre-farrowing vaccination	31	34.8	41	46.1	17	19.1	89
Quarterly mass vaccination	17	20.2	49	58.3	18	21.4	84
Biannual mass vaccination	31	35.6	39	44.8	17	19.5	87

NA: Not applicable

3.6. Interactions/Explanatory variables

Frequency tables were used to analyze the relationship between explanatory and response variables from the survey. Some of the explanatory variables considered were (1) number of swine marketed, (2) level of concern regarding IAV, (3) magnitude of economic impact and (4) level of concern regarding potential zoonotic transmission of IAV-S. Results from the chi-square test showed that several associations of the response and explanatory variables are not independent. For example, survey responses indicate that use of coveralls or Tyvek dedicated to a farm or building corresponded with the number of swine marketed in the last year by a swine operation. Producers who marketed less than 5,000 pigs (35.7%; 76/213) reported no coverall or Tyvek requirement, whereas producers who marketed 5,001-25,000 (69.7%; 212/304) and more than 25,000 pigs (86.6%; 129/149) reported coverall or Tyvek requirement. Findings also suggest swine producer perceptions of IAV-S may be associated with the adoption and application of certain biosecurity procedures. For instance, producers who are concerned (89.2%; 288/323) or somewhat concerned (81.9%; 244/298) about the presence of IAV-S in their operations were more likely to implement biosecurity procedures for non-employees, visitors and maintenance/repair workers. Moreover, the majority of producers who reported to be concerned (72.3%; 224/310) or somewhat concerned (59.0%; 170/288) regarding the presence of IAV-S also apply biosecurity practices to supply and feed deliveries. Likewise, producers who reported some level of concern about economic impact regarding the presence of IAV (85%; 470/553) were more likely to practice preventive measures for swine transport vehicle and trailers. In other words, implementation of certain biosafety measures could be related to producers' apprehension regarding the presence of IAV-S and its potential repercussions.

In addition, these relationships could elucidate why producers are perhaps not as stringent regarding implementation of the biosecurity practices evaluated in the survey. Results indicated that 65% (475/737) of respondents reported IAV-S had not been diagnosed in their swine operations in the previous 12 months. The fact that producers did not have any recent experiences with IAV-S may explain why they do not enforce more prevention strategies in their operations.

4. Discussion

Response rates of epidemiologic studies have been declining worldwide, especially in the last decade (Galea and Tracy, 2007). This survey had a response rate of 31%, which is similar to rates obtained in other mail-out surveys (Hernandez-Jover, et al., 20011, 39.6%; Pearson et al., 2008, 11.3%; Schembri, 2009, 29%) and a recent email survey conducted of swine producers in the US (Pudenz et al., 2017). In this study, the response rate appears to be higher compared to other published surveys and suggests an adequate representation of our target population, as well as minimizes the concern over selection bias given that the characteristics of non-respondents and respondents are systematically similar (MacDonald et al., 2008).

The US is one of the largest swine producing countries and exporters in the world (Pudenz, et al., 2019). The center of swine production is in the 'Corn Belt' of the Midwest, including Iowa, Illinois, Indiana and Minnesota (Nelson, et al., 2011), which is consistent with the majority of the current survey respondents that were located in Region 2. Economic losses due to IAV-S infections are substantial and rank among the top three major health challenges in the swine industry (Vincent et al., 2016). In the US, the IAV-S cost per finishing pig is estimated at $10, which represents a major financial concern if porcine respiratory disease complex (PRDC) co-infections include IAV-S in herds with endemic infections (Salvesen et al., 2021). The current IAV-S swine producer survey showed that while 77.5% (765/871) of participants believe IAV-S could have an economic impact in the swine industry, a relatively large percentage (22.5%; 196/871) may not appreciate the full economic cost of IAV-S in their swine operation.

The survey also revealed that most producers believe regional and nearby swine are the primary source of introduction of new IAV into breeding and gestation farms, followed by replacement gilts. Only 11.4% (86/753) believe humans could be responsible for the transmission of IAV into their operations although studies suggest spillover of human-lineage H1N1, H1N2 or H3N2 viruses is one of the main causes of new IAV-S genetic clades with sustained transmission in swine (Rajao et al., 2019). Once a human-lineage IAV becomes established in the swine population, combined with adaptation to the swine host, and reassortment with current endemic infections allows the establishment of novel IAV lineages that can also become endemic in swine populations and negatively affect the ability to effectively control the virus (Rajao et al., 2019).

The survey reflected producers' perceptions regarding the presence of IAV-S in their operations with the majority reporting some level of concern. These results corresponded with producers' responses related to biosecurity practices applied on-farm and implementation of safety systems for workers. A high proportion of participants indicated that facility entry procedures for employees, non-employees, visitors, maintenance/repair workers, swine transport vehicles/trailers are enforced in their operations. Producers also reported following biosecurity procedures for rendering and feed/supply deliveries. Even though results indicated that most respondents are aware of the zoonotic potential of IAV-S, a relatively large proportion (27%; 195/731) reported being unconcerned, unsure, or not having an opinion. This suggests that producers should become more cognizant of the ecology of influenza viruses in order to significantly decrease the impact of IAV at the human-animal interface.

Regarding farm employee use of PPE when working with swine, a large percentage of producers indicated they require use of coveralls or Tyvek and boots dedicated to a particular farm or building. Conversely, most producers reported a low proportion of respirator or dust mask use in their operations. Although studies indicate swine workers are at risk of zoonotic influenza and that wearing a respirator could decrease such risk (Paccha, et al., 2016), 60.7% (418/689) of respondents reported no respirator requirement. These results are consistent with other studies that also reported low rates of respirator use. A survey of swine workers in Romania reported that only 3% of workers used paper dust masks and no workers used N95 respirators or other protective respirators (Rabinowitz, et al., 2013). In addition, a study in Minnesota revealed that a large proportion of swine workers (70%) did not wear a mask, respirator, or any other type of face covering (e.g. bandana) during work (Beaudoin, et al., 2010). As evidenced by the sharp drop in human IAV cases during the COVID-19 pandemic, the use of masks likely contributed to the reduced transmission between humans and detection of IAV during the influenza season (HSPH, 2021). The fact that the number of H1N1 pandemic IAV detections in swine actually increased during 2020 (ISU FLUture, 2018), likely due to human-to-swine spillover, suggests the lack of mask use in swine farms may be contributing to potential reverse zoonosis of human-lineage IAV, which subsequently could become zoonotic infections after adaptation in the swine host and reassortment with endemic IAV. Additionally, a high percentage of producers (52.4%; 364/694) considered glove use not a priority in their operations; although studies suggest gloves play an important role in reducing potential zoonotic transmission of IAV (Ramirez, et al. 2006).

Most producers expressed concern regarding presence, economic impact and spread of IAV-S. However, their perceptions were not manifested in the need for implementation of employee prevention policies. Agencies such as the CDC urge individuals with occupational exposure to IAV to receive the human seasonal vaccine and to establish sick-leave policies for influenza-like illness on hog farms (CDC, 2011). Despite encouragement to follow these practices, a low proportion of producers reported employee preventive measures that may not only help reduce zoonotic infections, but just as important, to prevent human-to-swine transmission of IAV in their operations. Only a few producers reported having employee vaccination and sick leave policies in place and even a lower proportion employ procedures such as body temperature monitoring. Likewise, most pig producers reported not providing an in-house vaccination clinic to offer the opportunity for easy access to IAV vaccines for their employees. The survey also revealed that entry procedures (e.g. showering in upon entering the facilities) were not common practices at these sites. However, a shower may not always be necessary, especially on growing-pig sites (Pork Checkoff, 2021).

Out of an average of 733 respondents, only 118 (16.1%) reported requiring employees to receive an annual influenza vaccine and having mandatory sick leave for farm employees with influenza-like illness (fever, sore throat, body ache, cough, etc.). A study conducted in China reported swine workers' overall human influenza vaccination rate to be 9.0%, which is similar to the rate obtained in this survey (9.74%). A low prevalence of influenza vaccination among swine workers poses a concern given that vaccination is one of the most effective strategies to build immunity (Ma et al., 2015) and reduce the recurring bidirectional exchange of IAV between swine and humans (Rajao, et al., 2015). During the 2009 influenza pandemic, reverse zoonosis was confirmed with outbreaks recorded among domestic swine, other animals, and humans (Rabinowitz, et al., 2013). In more recent years, other human-to swine transmission events have been reported such as the 2011 H3 human seasonal sustained spillover; an additional H3 human-lineage strain found in pigs in 2016 and other events that have occurred yet never become established in swine (Zeller et al., 2017). A study conducted in Canada in 2011 also suggested human introduction of IAV into herds after healthy swine tested positive for the H1N1 pandemic virus following contact with infected staff (Forgie, et al., 2011). Furthermore, another study revealed that novel human-like IAV viruses that infect pigs via airborne transmission also pose a threat to the swine population due to lack of population immunity (Rajao, et al., 2015). These data suggest controlling IAV in humans is also important to swine health and to help reduce the spillover of IAV from humans to swine that has impacted the ecology of IAV-S and the potential to cause future zoonotic infections in humans (Anderson et al., 2020).

Another effective strategy to ameliorate influenza infection is vaccination of animals (Vincent et al., 2016; Ma et al., 2010). Several IAV-S vaccines are currently available including commercial, autogenous and replicon particle (CFSPH, 2016; Sandbulte, 2015). IAV vaccines may help reduce disease when not rendered ineffective by the rapid genetic evolution of IAV and ability of virus variants to evade host immunity (Sandbulte, 2015; Vincent et al., 2016). Vaccination is a common control measure used by large producers in the US mostly in breeding females (Vincent et al., 2008). This is consistent with producers' responses in this survey regarding timing of vaccination in their herds as the majority reported vaccinating during gilt isolation (Table 4). However, although vaccines may help mitigate spread and clinical signs of IAV-S in pigs, only 16% (116/723) of producers reported using IAV-S vaccines in their breeding herds. Results also indicated a large proportion (56.7%; 149/263) of producers do not use IAV-S vaccines in nursery or grow/finish swine in their operations. Among the few respondents who indicated their pigs are vaccinated, most reported a preference for the commercial vaccine, which can control IAV-S by generating immunity against genetically similar strains of the virus. (Sandbulte, 2015). Correspondingly, a similar study described that the majority (72%) of farms that reported vaccinating their sows against IAV-S also used the inactivated commercially licensed vaccine (Chamba Pardo, et al., 2018).

Only those respondents who reported use of IAV-S vaccine in their breeding herds were asked to answer survey questions that inquired about types of vaccines used in their operations. In contrast, all 879 respondents were asked to answer questions about vaccine platform efficacy. A significant proportion of respondents concurred that neither commercial whole virus inactivated multivalent (87.2%; 740/849), autogenous whole virus inactivated multivalent (87.3%; 741/849), nor subunit inactivated multivalent vaccines (94.1%; 799/849) are the best at controlling IAV-S in swine. These responses may have been influenced by a lack of knowledge concerning the function and/or efficacy of these vaccines given that the majority (94.0%; 798/849) prefer not to use vaccines or do not know (70.9%; 602/894) and thus their perception is based on the subjective evaluation of the clinical effects of the vaccines in herds that have elected to use some type of vaccine product in their operation. Vaccination has been observed to reduce the reproduction ratio of IAV-S in naïve pigs by inducing the production of virus-specific antibodies via a humoral adaptive immune response (Salvesen, 2021). For vaccines to be adopted by swine producers, it is imperative that they are incentivized and well-informed on the ecology of IAV and the benefits of vaccination (Salvesen, 2021). It is also fundamental to combine this practice with other biosecurity systems or containment measures to effectively mitigate spread of infection (Vincent et al., 2016).

Overall, these findings indicate that active swine producers, IPPA members who were involved in research, allied industries, or previous swine production alike, believe monitoring of IAV-S is important. The survey asked respondents if the US should continue to fund an IAV-S surveillance program and only 9.07% (69/761) replied *'no'*. It is significant that participants believe surveillance programs are necessary because they are useful tools for understanding the epidemiology of infectious diseases and in turn, aid the development of control and prevention strategies (Corzo, et al., 2013). Among respondents who answered *'yes'*, 9.46% (72/761) said *'yes, but only in sentinel subset of herds in each state'*, 11.7% (89/761) said *'yes, but only in breeding swine',* 2.89% (22/861) said *'yes but only in nursery/grow/finish swine,'* and 66.9% (509/761) *said 'yes, continue without changes.'* Although respondents had different opinions regarding which area of swine production needs surveillance, most agreed it is a necessary practice in the swine industry.

5. Conclusions

Given that swine influenza is an ongoing health threat, continued funding for research and surveillance is required to control the presence of diverse IAV (Vincent et al., 2016). Moreover, public health officials should strongly urge pork producers to systematically monitor their staff and animals for IAV infection, encourage workers to receive annual seasonal influenza vaccines and wear PPE. Swine production companies should also vaccinate their herds and participate in programs that expound the ecology of IAV and strategies to prevent transmission (Ma et al., 2017). This study suggests that pork producers in the Midwest are mostly aware about the occurrence and repercussions of IAV-S. Most participants already implement or encourage biosecurity and safety practices in their swine operations and favor surveillance programs. Low rates associated with certain recommended prevention practices suggest producers and individuals involved in swine production may need to increase their awareness of the ramifications of IAV-S infection among herds. Furthermore, they need to get better acquainted with the long-term benefits of combining – not just some – but all recommended biosecurity practices designed to prevent within-herd transmission, zoonosis and reverse zoonosis of IAV.

Appendix A. Supplementary data

IOWA STATE UNIVERSITY Veterinary Diagnostic Laboratory & IOWA PORK PRODUCERS ASSOCIATION

Survey of Swine Producers: Influenza A Virus in US Swine

Spring 2017

For each question, please circle the response that most accurately reflects your experiences and opinions.

1. Which best describes your role in swine production?

1 = Owner/Co-owner – Commercial Operation
2 = Contract Grower – Commercial Operation
3 = Manager / Herdsperson – Commercial Operation
4 = Owner/Manager/Herdsperson – Non-Commercial Operation
5 = Allied Industry or Technical Service
6 = University or Researcher
7 = Not directly involved in swine production

(5–7) ***GO TO Q 18***

2. What is the approximate size of your breeding herd, including sows, replacement gilts, and boars?

1 = Less than 1,000 sows
2 = 1,000-5,000 sows
3 = 5,001-25,000 sows
4 = More than 25,000 sows
5 = Don't Know/Not Applicable (no breeding herd)

3. What is the approximate number of swine your operation marketed last year?

1 = Less than 1,000 swine
2 = 1,000-5,000
3 = 5,001-25,000
4 = 25,000 – 100,000
5 = More than 100,000 swine

4. Which geographic region best describes the location of this swine operation?

1 = Region 1: AL, CT, DE, FL, GA, ME, MD, MA, NH, NJ, NY, NC, PA, RI, SC, TN, VT, VA, WV
2 = Region 2: IL, IN, IA, KY, MI, MN, OH, WI
3 = Region 3: AR, LA, MS, MO, OK, TX
4 = Region 4: ID, KS, MT, NE, ND, SD, WY
5 = Region 5: AK, AZ, CA, CL, HI, NV, NM, OR, UT, WA

5. Has Influenza A Virus (IAV) been diagnosed in your swine operation in the previous 12 months?

1 = Yes
2 = No
3 = Don't Know/Not Applicable

6. What is your level of concern regarding the presence of IAV in your swine operation?

1 = Very Concerned
2 = Concerned
3 = Somewhat Concerned
4 = Unconcerned
5 = No opinion, Unsure

7. Is a facility entry procedure, policy, or SOP currently required and utilized for employees in your swine operation?

1 = Yes
2 = No
3 = Don't Know/Not Applicable

8. Are **biosecurity procedures** implemented for any of the following aspects of your swine operation?

		Yes	No	Don't Know
a.	Non-employees/visitors/maintenance/repair	1	2	3
b.	Swine transport vehicles/trailers	1	2	3
c.	Feed/supply delivery	1	2	3
d.	Rendering	1	2	3
e.	Other Please specify:	1	2	3

9. Do you require farm employees to use any of the following personal protective equipment when working with swine?

		Yes	No	Don't Know
a.	Coveralls/Tyvek dedicated to farm or building	1	2	3
b.	Gloves	1	2	3
c.	Respirator/dust mask (N95)	1	2	3
d.	Boots dedicated to farm or building	1	2	3
e.	Anything else? Please specify:	1	2	3

10. Which of the following farm employee biosecurity procedures are implemented in your swine operation?

		Yes	No	Don't Know
a.	Employee vaccination	1	2	3
b.	Employee sick leave policy (illness = no work)	1	2	3
c.	Employee body temperature monitoring	1	2	3

d.	Employee entry procedures (shower in, etc.)	1	2	3
e.	Anything else? Please specify:	1	2	3

11. Are your farm employees **required** to receive an annual influenza vaccine for humans?

1 = Yes
2 = No
3 = No, recommended but not required or provided

12. Does your swine operation have an in-house vaccination clinic to give vaccines to employees?

1 = Yes
2 = No

13. Does your swine operation have a mandatory sick-leave policy that is enforced for farm employees with influenza-like illness (fever, sore throat, body ache, cough, etc.)?

1 = Yes
2 = No
3 = Depends on the severity of influenza-like illness (100.5°F fever, combination of two or more symptoms, etc.)
4 = Don't Know/Not Applicable

14. Does this swine operation use IAV vaccine in the **breeding herd**?

1 = Yes
2 = No ***[IF NO IAV VACCINE IS USED IN THE BREEDING HERD, GO TO Q18]***
3 = Don't Know/Not Applicable ***[IF NO BREEDING HERD, GO TO Q18]***

15. If you do use an IAV vaccine in your breeding herd, what type of vaccine(s) are used?

		Yes	**No**	**Don't Know**
a.	Commercial vaccine	1	2	3
b.	Autogenous vaccine	1	2	3
c.	Replicon particle (RP) subunit vaccine (Merck Animal Health)	1	2	3
d.	Other type Please specify:	1	2	3

16. If you do use an IAV vaccine in your breeding herd, when is it administered?

		Yes	**No**	**Don't Know**
a.	During gilt isolation?	1	2	3
b.	Pre-breeding?	1	2	3
c.	Pre-farrowing?	1	2	3
d.	Quarterly mass vaccination?	1	2	3
e.	Biannual mass vaccination?	1	2	3

17. Does this swine operation use IAV vaccines in nursery/grow/finish swine?

1 = Yes
2 = No
3 = Don't know/Not Applicable (no nursery/grow/finish swine)

18. What would you say is the level of economic impact regarding the presence of IAV in swine?

1 = High economic impact
2 = Moderate economic impact
3 = Low economic impact
4 = No economic impact
5 = No opinion, Unsure

19. What is your level of concern regarding the potential transmission of influenza from pigs to people or from people to pigs?

1 = Very Concerned
2 = Concerned
3 = Somewhat Concerned
4 = Unconcerned
5 = No opinion, Unsure

20. Which of the following do you believe to be the **primary** source for introduction of new IAV into breeding/gestation farms?

1 = Replacement gilts
2 = Regional swine farms/nearby swine
3 = Humans
4 = Other source *(Please specify: ____)*

21. Which vaccine platform(s) do you believe are best at controlling IAV in swine? *(Circle all that apply.)*

1 = Commercial whole virus inactivated multivalent vaccine
2 = Autogenous whole virus inactivated multivalent vaccine
3 = Subunit inactivated multivalent vaccine (Merck animal health RP vaccine)
4 = None/Prefer not to use vaccine
5 = Don't Know

22. Should the United States continue to fund an IAV surveillance program in swine?

2 = No
1 = Yes, continue without changes
3 = Yes, but only in breeding swine
4 = Yes, but only in nursery/grow/finish swine
5 = Yes, but only in a sentinel subset of herds in each state

23. Please record any comments you would like to make regarding the Influenza A Virus in swine.

Thank you very much for your assistance. Please return the completed survey in the envelope provided.

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