Biosecurity and disease control perceptions and practices of Vietnamese smallholder pig farmers.

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I declare that this dissertation is solely my own work

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Abstract

Pork is the most widely consumed meat in Vietnam and plays a key role in meeting the public demand for protein. It is estimated that 80% of pork consumed in Vietnam is sourced from smallholder farmers who can have their animal production and livelihood impacted by the introduction and spread of infectious diseases. Implementation of biosecurity and disease control practices can play a crucial role in negating these impacts. This study sampled 420 smallholder pig farmers in Vietnam to identify farmer perceptions and practices relating to biosecurity and disease control. The study found a majority (82%) of farmers reported experiencing one or more instances of pig disease in the last year, with self-treatment as the first response for 70% of farmers. Other measures such as disinfection mattresses and visitor control were used by 94% and 75% of the farmers respectively. Measures such as rodent control and quarantine of animals were poorly adopted, with respective adoption rates of 20% and 6%. Farmer perceptions revealed a desire to improve their knowledge and understanding of pig production and specifically biosecurity and disease control practices. Findings from this study will form part of a participatory approach to improving farm production and livelihoods through a understanding of current biosecurity and disease control practices and perceptions.

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2.0 Abbreviations

FMD: Foot and mouth disease

PRRS: Porcine reproductive and respiratory syndrome

CSF: Classical swine fever

PHFD: Porcine high fever disease

PCV2: Porcine circovirus type 2

SIV: Swine influenza virus

ADV: Aujeszky's disease virus

ASF: African swine fever

VNUA: Vietnam National University of Agriculture

3.0 Introduction and Literature review

Smallholder livestock farmers are a key source of food for populations in many developing countries. With a growing demand for protein rich food sources, these farmers face a number of challenges to ensuring that they can produce safe and sustainable products for consumers (Grace, 2015). In Vietnam, livestock farming and production represents a significant portion of the economy and plays a vital role in meeting the increasing nutritional demands of the local population (Lapar et al., 2009). Pork is the most widely consumed meat in Vietnam making up 56% of the total meat intake and Vietnam's per capita pork consumption of 29.1 kg per year is among the highest in the world (Lapar et al., 2012). The majority of pig farming in Vietnam is conducted by smallholder farmers. These farmers are responsible for approximately 80% of Vietnam's pork production while also forming an integral livelihood source for poor and rural Vietnamese people (Pham et al., 2016). Smallholder farmers can often have their production and livelihoods significantly impacted by the introduction and spread of infectious diseases. Between 2006 and 2012, there were nearly 5650 foot-and mouth disease (FMD) outbreaks reported in 62 provinces of Vietnam, with 1767 of these FMD outbreaks occurring in pig farms (Nguyen et al., 2013). Since 2007, there have also been 3614 reported outbreaks of highly pathogenic porcine reproductive and respiratory syndrome (PRRS) virus with 60,000 pigs being culled as a result (Do et al., 2013).

For the purposes of this study biosecurity can be broadly defined as a series of measures or step taken by a farmer aiming to stop disease-causing agents entering or leaving the area where livestock are present (Shortall et al., 2017). The introduction and utilization of appropriate biosecurity and disease control measures has the potential to significantly prevent or limit the losses from these diseases and subsequently enhance farm profitability and

livelihoods for farmers. Especially in countries or regions that are densely populated and have high concentrations of livestock in close proximity, biosecurity measures such as quarantine for new animals and restricting visitor access can be extremely important to help prevent the introduction and spread of infections within and between farms (Amass and Clark, 1999; Gunn et al., 2008). There are a number of different methodologies and approaches that have been used to investigate and analyze farmer perceptions and behaviours. Social-psychological studies investigating farmer behaviour have adapted aspects of the Theory of Reasoned Action and the Theory of Planned Behaviour to help explain how individual attitudes and subjective norms can influence the intention of a farmer to engage in a particular behaviour (Alacorna et al., 2014). A number of studies have also highlighted the importance of investigating and understanding farmers' perceptions in relation to disease control and using divergent methods of data collection to substantiate study findings (Ellis-Iverson et al., 2010; Garforth et al., 2004). The aim of this study is to identify and describe the most common farmer practices and perceptions related to biosecurity and disease control and investigate if significant differences exist between the types of pig production systems surveyed and the two geographical areas of the study.

To provide effective interventions and disease control practices, an understanding and awareness of the current knowledge, perceptions and common practices related to biosecurity and disease control is required. This is particularly important in the context of smallholder farms in developing countries where farmers have limited resources and the capacity to implement more advanced and comprehensive measures can be difficult or impossible. Unfortunately, there is limited scientific literature in Vietnam focusing specifically on this issue among smallholder farmers. A study conducted in the Mekong delta area of Vietnam

demonstrated that even in areas where government policy mandated vaccination against infectious diseases such as Classical Swine Fever (CSF), the disease was still identified as a significant influence on piglet mortality and overall farm production. Poor vaccine administration, record-keeping and lack of biosecurity or disease control practices along with high pigs movement were some of the constraining factors highlighted in the study. This particular study also found that government breeding farms which supplied smallholder farmers with breeding stock were found to have animals testing positive for PRRS virus (Kamakawa et al., 2006). Another study conducted in 2015 found transient movement of pigs posed a significant risk for the introduction and spread of disease, particularly as certain animals such as a breeding boar may circulate prolifically in a local village or commune with little to no disease control or prevention measures taken (Baudon et. al, 2015). A regional study into pig production in Cambodia, Laos and Vietnam revealed a low level of knowledge and understanding among Vietnamese livestock producers regarding the benefits of disease control and prevention. The study found that smallholder pig farmers generally have traditional farrow-to- finish production systems, often with very close mixing of different age groups. The review noted that replacement stock often came from a variety of sources with unknown health statuses and rarely were any quarantine measures implemented. Hygiene application was also very poor or did not exist with respect to the contact between farm workers, outsiders and pigs on farms. The most common disease control practice reported was the utilization of vaccinations. In addition, the regular use of antibiotics and anti-bacterial agents without adequate supervision or veterinary advice was found to be very common. The study also found that effluent was most commonly disposed into large ponds near the farm, and that these ponds were prone to overflowing during the wet season into the local rivers and waterways (Huynh et al., 2007).

In 2006 a study was conducted evaluating the management and performance of smallholder pig production systems in the mountainous provinces of north-western Vietnam. The study identified common practices employed by the farmers in this region that included the utilization of “communal” or village boars that would be moved from farm to farm for mating purposes. The study also found that farmers tended to handle pig diseases themselves, seeking veterinarians' support only in severe cases. The study found that dewormers were very commonly used with 71% of the 64 farmers interviewed stating they dewormed their pigs. The study also identified that there was a lack of veterinary services in these regions, particularly for farmers in more remote areas and this may have influenced their decision to utilize de-wormers more than vaccines (Lemke et al., 2006). A study conducted on smallholder livestock systems also found farmers in northern Laos had limited knowledge on health, nutrition and diseases affecting livestock. The study stated that only 29% of 238 farmers interviewed in the study knew about FMD), despite there being numerous FMD outbreaks reported in the country. The study also reported significant gaps in farmer knowledge of transboundary disease risks and lack of understanding of common biosecurity principles (Nampanya et al., 2010). Similar results were also reported for other parts of South East Asia where a study in Eastern Indonesia into smallholder pig production systems found biosecurity practices to be minimal with forty-five percent (45%), of farmers reporting that pigs are consumed after sudden death and the majority of pig farmers (65%; 187/287) had never had a veterinarian or animal health worker visit their village. This study also reported that farmers reared pigs using traditional housing type systems: either penning in a local shelter called a *kandang*, tethered on farm or in some cases free roaming. All of these systems could influence disease spread as none completely prevent direct contact between pigs and with other livestock species. The study also stated that the borrowing of boars for the

purposes of breeding, reported by over half of the farmers who bred pigs in this survey, is not uncommon in the smallholder sector (Edwina et. al, 2015). Studies conducted on smallholder farming systems in the Philippines have also revealed that biosecurity and disease control practices are restricted and often implemented in response to disease outbreaks rather than as part of a regular farm management strategy. An overwhelmingly majority (over 80%) of farmers in the study across different production systems allowed unauthorized entry of people and vehicles to their farm. Burial was also the most common method of disposal of dead pigs with over 83% of 471 farmers in the study utilizing this strategy. The study also documented that quarantine of newly purchased or introduced animals was not common with only 33% of smallholder farmers in one cluster and 10% in another enforcing quarantine practices (Alawneh et al., 2014).

There have also been studies conducted on smallholder pork farming systems in other parts of the world, particularly in sub-saharan Africa. A 2009 study conducted with smallholder pork farmers in Madagascar found that there were limited biosecurity measures implemented in the pig farms included in the study. The study found that 91% of 709 farmers surveyed self treated sick pigs with almost a third (27.5%) of farmers also lending boars to other farms for natural service. The study also stated that the most common visitors to farmers were veterinarians or animal health workers followed by family and friends, butchers, traders and other pig farmers (Costard et al., 2009). Information on biosecurity and disease control practices was also gained from a study characterizing smallholder pork production systems in Kenya. This study found that dewormers were the most common animal health treatment, being used by 69% of the 182 farmers surveyed. The study also found that 96% of the pig shelters had a mud floor that was rarely cleaned, while only 4% were made of concrete. Sixty

five percent (65%) of the pigs were tethered while 33% were kept in a mixed system. The latter was characterized by free-range during the dry season and tethering during the crop (rainy) season. Only 2% of the farmers kept pigs permanently indoors (Kagira et al., 2010). The review of the current literature available on the biosecurity and disease control practices of smallholder pork farmers reveals some similar findings amongst farmers in Vietnam and other parts of the world. With limited access to quality veterinary services and sufficient economic resources, a large portion of these farmers lack knowledge, capability or even willingness to implement such measures. The literature also reveals some differences farming systems particularly when it comes to utilization of treatments such as vaccines or de-wormers and the housing of pigs between different regions.

Along with an understanding and awareness of the practices currently utilized by farmers, it is important to identify particular practices that could increase the risk of infectious diseases in smallholder farms. Extensive studies looking at risk factors for infectious diseases in pigs are limited in Vietnam. From 1999 to 2002, an epidemiological survey was conducted in the Can Tho province of Vietnam targeting major viral diseases of CSF and PRRS. The survey found that vaccination failure and movement of pigs between farms with no biosecurity protocols were high risk factors for disease. Despite high reported rates of vaccine use by farmers, the study noted that vaccine failure was common due to the lack of regular and well management vaccination programs and protocols of farm stock, in particular for younger stock in the transition period from maternal to acquired immunity (Kamakawa et al., 2006). Another study conducted in 2012 also aimed to identify risks factors for Porcine high fever disease (PHFD) in a Southern Vietnamese province. Receiving pigs from an external source was identified as key risk factor for the disease. This included farms receiving either

nursery pigs or sows in herds of all sizes. This study also found that farms using water green crops for pig feed and having ducks on the farm (with or without direct contact with pigs) were at a higher risk. The authors of the study hypothesize that significant interaction between the disease and the presence of ducks and feeding of water green crops to pigs could be due to the pathogen surviving in the water (environment) and further replicating or spreading in or on ducks (Le et al., 2012). A study was also conducted with backyard pig farms in Bhutan to determine the prevalence of antibodies and identify possible risk factors for CSF, PRRS virus, porcine circovirus type 2 (PCV2), swine influenza virus (SIV) subtype H1N1 and Aujeszky's disease virus (ADV). A multi-variable analysis found that risk factors for CSFV were swill feeding and contact with the neighbour's pigs. For PCV2 the most significant risk factor was the lending of boars for local breeding purposes (Monger et al., 2014).

There have also been studies conducted in other parts of the world looking at infectious disease risks for smallholder pig farming systems. A study was carried out with 642 smallholder farmers in Uganda to identify risk factors associated with the occurrence of African Swine Fever (ASF) and identified that introduction of new pigs to the farm (*with no quarantine or biosecurity protocols)* and the feeding of untreated swill were the two major risks factors for ASF. The study also found that risk for ASF was further increased as rumors of ASF outbreaks frequently lead farmers to sell off their pigs rather than dying from the disease resulting in accelerated movement of pigs (Nantima et al., 2015). Another study stated that "panic sales" during periods of ASF disease outbreaks were unanimously reported by all value chain actors and stakeholders as being a high risk, thus facilitating the movement of potentially infected pigs (Dione et al., 2016). Similar findings were also found in a long term surveillance study in Nigeria that was conducted from 1997 to 2011. High pig

movements and feeding of swill were two risk factors identified for ASF among study participants. In addition, the study found that separation or isolation of sick pigs from healthy ones and regular washing and disinfection of farm equipment and tools was found to be negatively associated with ASF infection and seropositivity (Fasina et al., 2012).

The scientific literature has identified a number of high risk practices that can increase the risk of infectious diseases on smallholder farmers. High live animal movement with no biosecurity and disease control measures was one of the most common high risk factors identified. In addition, feeding of swill along with poor or irregular disinfection practices were also identified as high risk behaviours. The overall influence and impact of infectious diseases on Vietnamese smallholder farmers will depend heavily on the biosecurity and disease control measures practiced at both an individual farm and regional level.

4.0 Methods

Being part of a larger ACIAR funded project (PigRISK) two study provinces were selected as study sites. Hung Yen, a province in the Red River Delta of northern Vietnam and Nghe An, a province in the north central coast region. These two provinces were selected using a site selection process which included criteria such as: being part of previous studies, sufficient local government engagement and existing capabilities to successfully complete the current study. The two provinces were also selected as they can be can be characterized as having strong agricultural and livestock sectors with pig farming heavily featured. The province of Hung Yen has a population of approximately 1.1 million people and is considered more developed with greater infrastructure, more urban and peri-urban environments along with a wider range of production systems including commercial and large scale herds. The province of Nghe An has a population of approximately 3 million people and is considered more rural and employing more traditional farming practices. In each province a shortlist of districts was created based on following factors; pig densities, types of pork value chains and pig production systems, local government contacts and if local project partners were also operating in the district. The districts that met these required criteria were selected for inclusion in the project. In each district one commune was randomly selected and in each selected commune, farmers were then randomly selected from a larger sampling frame provided by local authorities. In total, 212 farmers were selected in Hung Yen and 208 farmers were selected in Nghe An. For the purposes of the study, the unit of interest was described as the individual farm with three different approaches utilized to investigate farmer perceptions and behaviour. A standardized semi-structured questionnaire was be used to gain insight into farmer practices and protocols with specific additional questions looking at farmer

perceptions to particular biosecurity and disease control issues using a likert scale. The likert scale used five categories; strongly agree, agree, neutral, disagree and strongly disagree. To triangulate between farmers responses and applied practices the third component used was the the implementation of a farm observation checklist that was conducted by study enumerators on farm. Study enumerators were qualified researchers from the Vietnam National University of Agriculture (VNUA) agricultural economics department. The study enumerators were provided with training on how to perform the questionnaire and it was tested on small groups initially before being implemented for the study. All interviews were conducted with farmers in Vietnamese with data being uploaded into Microsoft excel and then translated into English. A chi-squared test was used to identify significant differences between farm location and production type. This statistical analysis was conducted using the Epitools online resource (Sergeant, 2017).

5.0 Results

Farmer demographics and production system

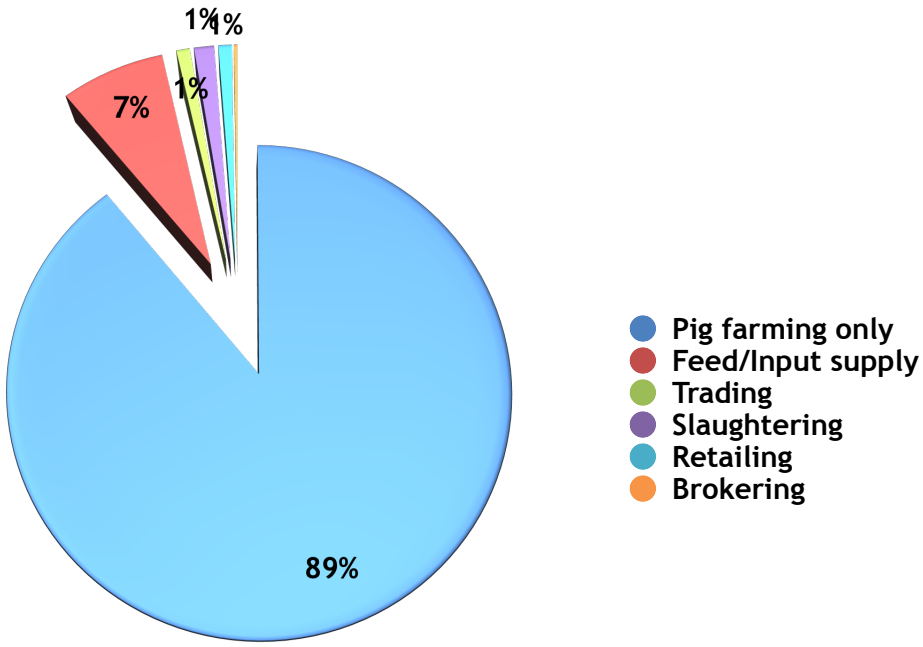
The average age of the farmers interviewed in the study was 47 years old with the oldest farmer being 66 and the youngest 21 with no difference between the two provinces. Overall there is an almost equal division of gender with 49% (204/420) male and 51% (216/420), but the proportion of female farmer respondents is significantly higher in Nghe An (Table 1).

Table 1: *Distribution of farmer gender and production type in study area (n=420)*

		Study Area	
	Overall ***n*** **(%)**	**Hung Yen** ***n*** **(%)**	**Nghe An** ***n*** **(%)**
Gender of farmers			
Male	204 (49)	135 (64)[a]	69 (33)
Female	216 (51)	77(36)[a]	139 (67)
Type of Production			
Farrow to finish	238 (57)	28 (13)	73 (35)
Farrow to weaning	101 (24)	40 (19)	40 (19)
Fattening/Finishing	81 (19)	144 (68)	95 (46)

Graph 1 highlights that the overwhelming majority (89%; 374/420) of farmers in this study are exclusively involved pig farming. A small minority (7% 31/420) were also involved supplying inputs such as feed with small numbers of farmers also participating in slaughtering, trading and retailing.

Graph 1: *Farmer participation in additional value chain activities.*



Occurrence of diseases

A majority of respondents (83%; 351/420) stated that they had experienced at least one or more incidences of disease on their farm during the last 12 months (Table 2). Table 2 also highlights that farms in Hung Yen reported higher instances of disease ($p<0.001$) compared to those in Nghe An.

Table 2: *Incidences of disease as reported by farmers by study area and production type.*

	Farm had experienced at least one or more incidences of disease on their farm during the last 12 months	
	Yes ***n*** **(%)**	**No** ***n*** **(%)**
Study Area		
Hung Yen	192 (91)	20 (9)
Nghe An	159 (76)	49 (24)
Production System		
Farrow to finish	210 (88)	28 (12)
Farrow to weaning	77 (76)	24 (24)
Fattening/Finishing	64 (79)	17(21)

Practices in response to diseases

Table 3 provides a detailed summary of the farmer responses in relation to current practices and responses to disease. The most common response to a pig disease is self-treatment as reported by 70% (295/420) of farmers, with the most common response to disease on neighbouring farms being to increase disinfection practices and keep pig numbers unchanged (72%; 301/420). There were significant differences in the number of farmers adopting these practices between the two geographical regions ($p<0.001$) but not between farmers engaged in different production systems. A small but potentially important portion of farmers also report that they immediately sell sick pigs (7%; 31/420) and also take no action when faced with disease on neighbouring farms (12%; 49/420). In response to pig deaths, 75% (314/420) of respondents report burial of the carcass as their most common practice with more farmers utilizing this practice in Nghe An compared to Hung Yen ($p<0.001$). A concerning finding was that 11% of farmers reported that they sold (for reduced price), or consumed dead pigs. Another 6% of farmers just disposed dead pigs to the environment. More to this only 4% of farmers stated that they seek for advice from a vet when pig die. The practice of farm disinfection varies in application among all the respondents and also between the geographical location and production system. The most common animal medicine used by farmers was vaccines (84%; 354/420) with significantly ($p<0.001$) higher rates of use in Hung Yen (93%) compared to Nghe An (76%). The two primary sources of vaccines are pharmacies (40%; 143/354) and para-veterinarians (42%; 148/354) with a significant difference between the two regions in which of these two methods is preferred by farmers ($p<0.001$).

Table 3: *Practices and response to disease on farm, classified by farm location (Hung Yen, n=212 and Nghe An, n=208) and farm production type (A: Farrow to weaning farms, n=101, B: Fattener/finishing farms, n=81, C: Farrow to finish farms, n=238).*

Practices and Responses to Disease	**Overall**	**By Study Area**			**By production system**			
	***n* (%)**	**Hung Yen *n* (%)**	**Nghe An *n* (%)**	**P value**	**A *n* (%)**	**B *n* (%)**	**C *n* (%)**	**P value**
Farmer responses to pig disease on farm								
Treat the pig on your own	295(70)	173(82)	122(59)	<0.001	73(72)	50(62)	172(72)	0.175
Treating the pig on your own and if not recovered, ask vet for treatment	139(33)	50(24)	89(43)	<0.001	38(38)	25(31)	76(32)	0.532
Ask vet for treatment	111(26)	39(18)	72(35)	<0.001	27(27)	28(34)	56(24)	0.150
Sell immediately	31(7)	20(9)	11(5)	0.107	4(4)	4(5)	23(10)	0.119
Ask neighbour	17(4)	6(3)	11(5)	0.198	1(1)	4(5)	12(5)	-
Eating the pig	2(0.5)	1(0.5)	1(0.5)	0.989	0(0)	1(1)	1(0.4)	-
Do nothing	1(0.2)	0 (0)	1(0.5)	0.312	0(0)	0(0)	1(0.4)	-
Farmer responses to pig deaths on farm								
Burying dead pigs	314(75)	142(68)	172(86)	<0.001	80(79)	60(74)	175(74)	0.529
Incinerate	35(8)	18(9)	17(8)	0.968	5(5)	3(4)	27(11)	-
Sell at a lower price	39(9)	33(16)	6(3)	<0.001	6(6)	7(8)	26(11)	0.343
Throw away	26(6)	17(8)	9(4)	0.132	6(6)	8(9)	12(5)	0.293
Ask vets for advice	16(4)	1(0.5)	15(7)	<0.001	3(3)	3(4)	10(4)	-
Eating the dead pig	7(2)	3(1)	4(2)	0.660	0(0)	2(2)	4(2)	-
Farmer reponses to diseases on a neighbouring pig farm								
Maintain pig numbers but increase disinfection	301(72)	176(83)	125(60)	<0.001	64(63)	60(74)	178(75)	0.090
Restrict visitor access to farm	85(20)	51(24)	34(16)	0.065	12(12)	18(22)	55(23)	0.055
Use prophlytic anti-biotics	36(9)	27(13)	9(4)	0.003	7(7)	6(7)	23(10)	0.653
Sell all pigs immediately	8(2)	6(3)	2(1)	0.284	1(1)	1(1)	6(3)	-
Do nothing	49(12)	8(4)	41(20)	<0.001	20(20)	8(9)	21(9)	0.013
How often is the farm disinfected								
Daily	1(0.2)	0(0)	1(0.5)	0.495	0(0)	0(0)	1(0.5)	-
Weekly	87(21)	74(35)	13(6)	<0.001	13(13)	16(20)	58(24)	0.056
Fortnighty	84(20)	64(30)	20(10)	<0.001	13(13)	18(22)	53(22)	0.121
Monthly	107(25)	59(28)	48(23)	0.314	24(24)	16(20)	67(28)	0.293
After selling pigs in current production cycle	97(23)	14(7)	83(40)	<0.001	33(33)	21(26)	43(18)	0.011
Do not disinfect farm	44(10)	1(0.5)	43(21)	<0.001	18(18)	10(12)	16(7)	0.007
Most common medicine used on pigs								
Vaccine	354(84)	197(93)	157(76)	<0.001	63(62)	56(69)	201(84)	<0.001
Anti-biotics	31(7)	6(3)	25(12)	<0.001	14(14)	7(9)	10(4)	0.007
Anti-helmintic	8(2)	1(0.5)	7(3)	0.035	2(2)	4(5)	4(2)	-
Traditional medicine	7(2)	0(0)	7(3)	0.006	4(4)	2(2)	3(1)	-
Anti-biotic spray	2(0.5)	1(0.5)	1(0.5)	1.00	0(0)	1(1)	1(0.5)	-
Growth Promotant	1(0.2)	1(0.5)	0(0)	1.00	0(0)	1(1)	0(0)	-
Probiotics	2(0.5)	0(0)	2(1)	0.244	1(1)	1(1)	1(0.5)	-
Others	15(4)	6(3)	9(4)	0.442	18(18)	6(7)	18(8)	0.010
Primary source of Vaccines (*n=354)*								
Pharmacies	143(40)	103(52)	40(25)	<0.001	17(17)	27(33)	82(34)	0.048
Paravet services	148(42)	48(24)	100(64)	<0.001	36(36)	26(32)	79(33)	0.041
Private veterinary servcies	42(12)	32(16)	10(6)	0.007	9(9)	2(2)	26(11)	-
Government veterinary servcies	13(4)	11(6)	2(1)	0.044	1(1)	1(1)	11(5)	-
Neighbours	1(0.3)	1(1)	0(0)	1.00	0	0	1(0.5)	-
Other	7(2)	2(1)	5(3)	0.248	0	0	2(0.5)	-

Input suppliers and traders

The results show on farm veterinary input in these production systems is limited with 71% (300/420) farmers reporting that veterinary services never visit their farm. This response is consistent in both study areas and also in the different production systems. However, there is a small portion (17%; 35/212) of farmers in the Hung Yen province who report monthly visits from veterinary services *(Table 4)*. Meat traders visit farms more commonly and most often in relation to the farmers production cycles. More than half (52%; 219/420) of farmers have meat traders visit their farm overall, this number being significantly higher in Nghe An compared to Hung Yen. As expected the number of meat/pig traders visiting finishing farms is also higher compared to weaner farms. Approximately 20% of farmers do have feed suppliers that visit the premise on a monthly or fortnightly basis, while the majority (75%; 313/420) do not have feed suppliers visiting their farms.

Table 4: *Frequency of farm visits for input suppliers (Hung Yen, n=212 and Nghe An, n=208) and farm production type (A: Farrow to weaning farms, n=101, B: Fattener/finishing farms, n=81, C: Farrow to finish farms, n=238)*

Frequency of farm visits for input suppliers	**Overall**	**By Study Area**			**By production system**			
	n **(%)**	**Hung Yen** ***n*** **(%)**	**Nghe An** ***n*** **(%)**	**P value**	**A** ***n*** **(%)**	**B** ***n*** **(%)**	**C** ***n*** **(%)**	**P value**
How often do Veterinary services vist the farm								
Monthly	45(11)	35(17)	10(5)	<0.001	9(9)	5(6)	34(14)	0.093
Fortnightly	11(3)	9(4)	2(1)	0.062	1(1)	5(6)	6(3)	-
Once per production cycle	63(15)	25(12)	38(18)	0.085	12(12)	14(17)	38(16)	0.538
Never	300(71)	142(67)	158(76)	0.054	79(78)	57(70)	160(67)	0.127
How often do meat traders vist the farm								
Monthly	5(1)	5(2)	0(0)	0.061	2(2)	0(0)	3(1)	-
Fortnightly	0(0)	0(0)	0(0)	1.00	0(0)	0(0)	0(0)	-
Once per production cycle	219(52)	92(43)	127(61)	<0.001	30(30)	39(48)	129(54)	<0.001
Never	196(47)	115(54)	81(39)	0.002	49(49)	42(52)	106(45)	0.487

How often do feed suppliers vist the farm								
Monthly	31(7)	16(8)	15(7)	1.00	5(5)	1(1)	22(9)	0.032
Fortnightly	48(11)	30(14)	18(9)	0.077	2(2)	11(14)	33(14)	0.004
Once per production cycle	28(7)	5(2)	23(11)	<0.001	1(1)	8(10)	13(5)	0.027
Never	313(75)	161(76)	152(73)	0.574	93(92)	60(74)	170(71)	<0.001

Observational checklist

Table 5 provides a detailed summary of results from an observational checklist performed by study enumerators on farm. Due to logistical constraints during the course of the study, 120 of the 420 farmers did not have observational checklist data recorded and were subsequently excluded from the analysis below. The majority of farmers have different age classes of stock in separate enclosures (74%; 221/300). Nearly half (48%; 145/299) of the farms have enclosures where physical contact is possible between enclosures and pigs respectively. Quarantine pens are very uncommon with only 7% (20/300) of farms having such a facility. The majority (75%; 225/300) of farmers restrict visitor control to the farm, but there is a significantly (P<0.001) higher portion of farmers in Nghe An (96%; 145/152) restricting visitor control compared to Hung Yen (56%; 80/148). Disinfection mattresses are used in almost all farms (94%; 283/300) and appear to be used consistently across farms with different production systems and in different regions. Measures such as rodent control and protective clothing for workers are applied less commonly with only 21% (62/300) and 17% (53/300) of farms respectively utilizing these measures. The majority of farms (57%; 172/300) have other livestock in close contact with pigs. However, this number is significantly (P<0.001) higher for farms in Nghe An (82%; 123/150) compared to those in Hung Yen (33%; 49/150). Checklist data shows that more than half of farms (55%; 166/300) do adequately cover and stored feed. However, the checklist also reveals that a majority of the visible feed (76%; 228/300) shows indications of moisture, contamination or clotting. In particular, farms in Hung Yen appears have to a higher percentage of these farms in

comparison to Hung Yen. The study also found that only 14% (42/300) farms provide pigs with access to drinking water at all times. This number was significantly lower in Nghe An with only 5% of farms offering freely available drinking water.

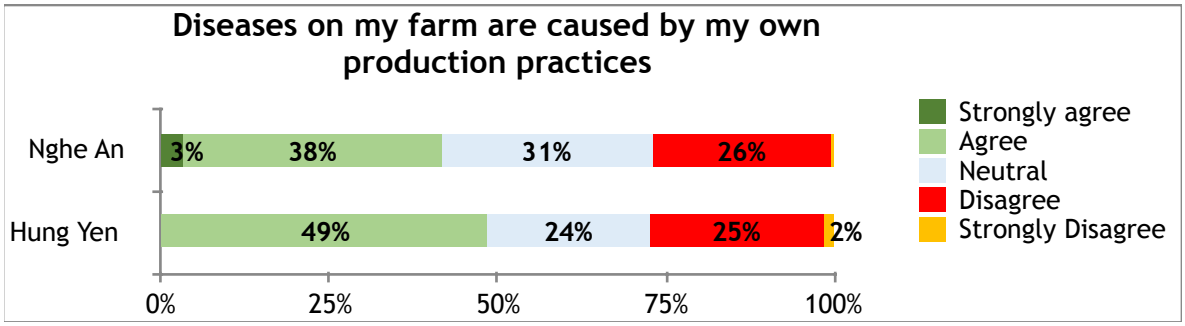
Table 5: *Observational checklist of Farm Practices, classified by farm location (Hung Yen and Nghe An) and farm production type (A= Farrow to weaning farms, B= Fattener finishing farms, C= Farrow to finish farms).*

Observational checklist of farm practices	**Overall**	**By Location**			**By production system**			
	***n* (%)**	**Hung Yen *n* (%)**	**Nghe An *n* (%)**	**P value**	**A *n* (%)**	**B *n* (%)**	**C *n* (%)**	**P value**
Different age classes are in separate enclosures								
Yes	221(74)	129(86)	92(61)	<0.001	42(66)	35(56)	144(83)	<0.001
No	79(26)	21(14)	58(39)		22(34)	27(44)	30(17)	
Physical contact possible between different groups and age classes								
Yes	145(48)	92(62)	53(35)	<0.001	25(39)	19(31)	102(58)	<0.001
No	155(52)	58(38)	97(65)		39(61)	43(69)	72(42)	
Quarantine pen on farm								
Yes	20(7)	13(9)	4(3)	0.043	4(6)	3(5)	10(6)	1.00
No	280(93)	139(91)	144(97)		61(94)	58(95)	163(94)	
Visitor access to farm restricted								
Yes	225(75)	80(54)	145(96)	<0.001	55(85)	52(84)	118(68)	0.004
No	75(25)	68(46)	7(4)		10(15)	10(16)	55(32)	
Disinfection mattress present and used								
Yes	283(94)	137(92)	146(97)	0.085	61(95)	58(95)	164(94)	0.943
No	17(6)	12(8)	5(3)		3(5)	3(5)	11(6)	
Workers wear protective clothes and boots								
Yes	53(17)	26(17)	26(17)	1.00	8(13)	14(23)	30(17)	0.293
No	247(83)	124(83)	124(83)		56(87)	46(77)	146(83)	
Rodent control measures used on farm								
Yes	62(21)	34(23)	26(17)	0.284	10(16)	7(12)	27(15)	0.794
No	238(79)	115(77)	125(83)		53(84)	53(88)	150(85)	
Pig feed is covered and stored								
Yes	166(55)	124(83)	42(28)	<0.001	26(41)	32(53)	107(61)	0.017
No	134(45)	25(17)	109(72)		38(59)	28(47)	67(39)	
Visible parts of feed show indication of moisture, contamination or clotting								
Yes	228(76)	129(86)	99(67)	<0.001	48(70)	46(81)	134(77)	0.318
No	72(24)	23(14)	49(33)		21(30)	11(19)	42(23)	
Pigs have access to drinking water at all times								
Yes								
No	42(14)	33(22)	8(5)	<0.001	4(6)	8(14)	35(20)	0.029
	258(86)	115(78)	144(95)		64(94)	48(86)	141(80)	
Pigs have close contact to other livestock								
Yes	172(57)	49(33)	123(82)	<0.001	45(70)	42(68)	86(49)	0.002
No	128(43)	101(67)	27(18)		19(30)	20(32)	89(51)	

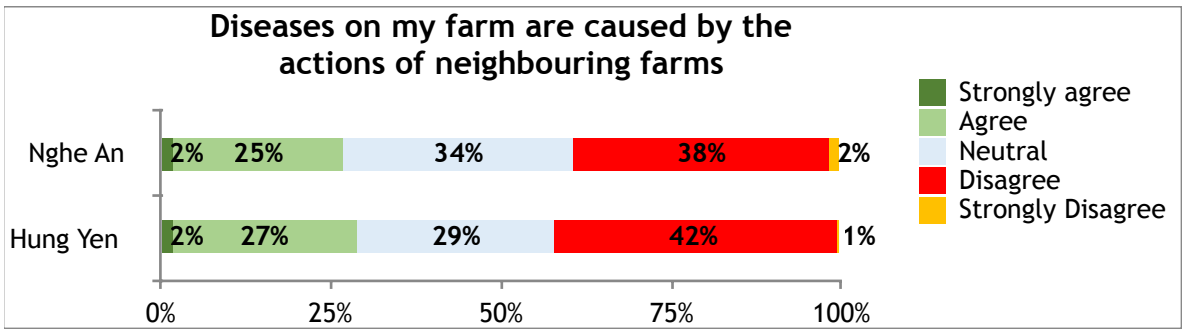
Farmer perceptions

Farmer perceptions were also recorded with the survey data using likert scales. When asked about the cause of disease almost half of the farmers agreed or strongly agreed that practices on their farm were directly responsible for diseases on their farm (*Graph 2)*. However, almost one third of farmers also perceived that the diseases on their farm are due to actions of their neighbours (*Graph 3).* With respect to traders , a majority of farmers appear to view them as less of a risk for introduction of disease on their farm *(Graph 4)*. Compared to differences in practices and farm behaviours, the perceptions of the farmers to these questions were very similar in both Hung Yen and Nghe An.

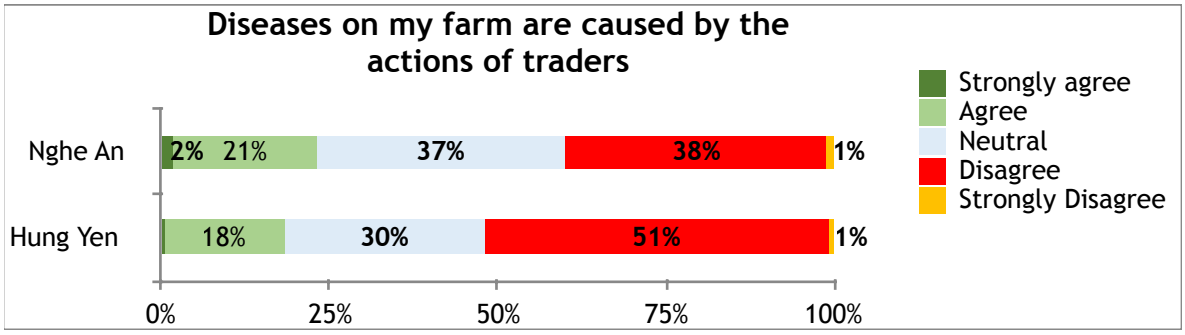
Graph 2: *Farmer perceptions on diseases on farm being caused by their own production practices*



Graph 3: *Farmer perceptions on diseases on farm being caused by actions of neighbouring farms*

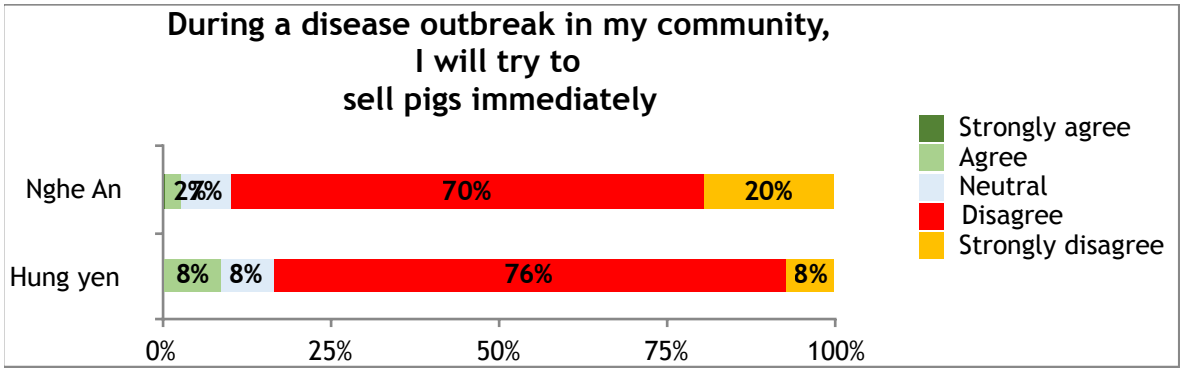


Graph 4: *Farmer perceptions on diseases on farm being caused by actions of traders*

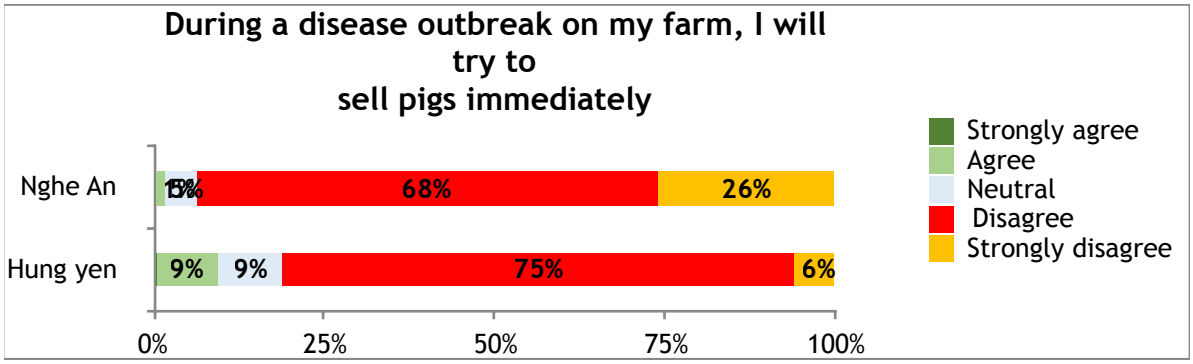


Graph 5 and 6 show that a high majority of farmers view immediate selling of pigs during an outbreak in the community or on farm unfavourably. However, there is still a small number who agree that this is a suitable course of action.

Graph 5: *Farmer perceptions on selling pigs in response to disease outbreaks in community*

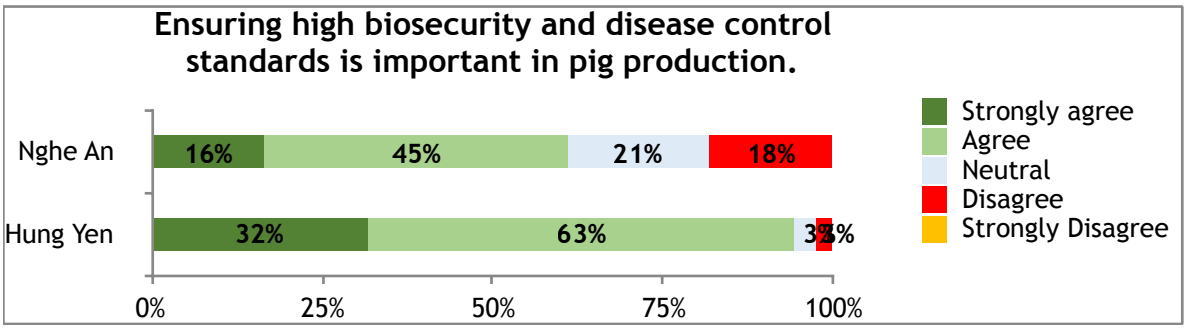


Graph 6: *Farmer perceptions on selling pigs in response to disease outbreaks on farm*

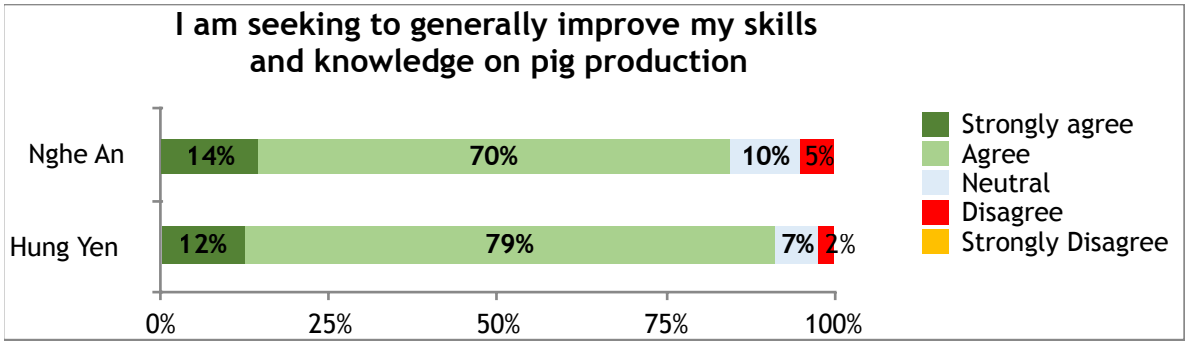


A large portion of farmers agreed or strongly agreed that good bio-security and disease control standards are important for pig production (Graph 7). However, there is a higher portion of farmers in Nghe An (17%; 37/208) that disagreed with this statement compared to Hung Yen (3%; 6/212).

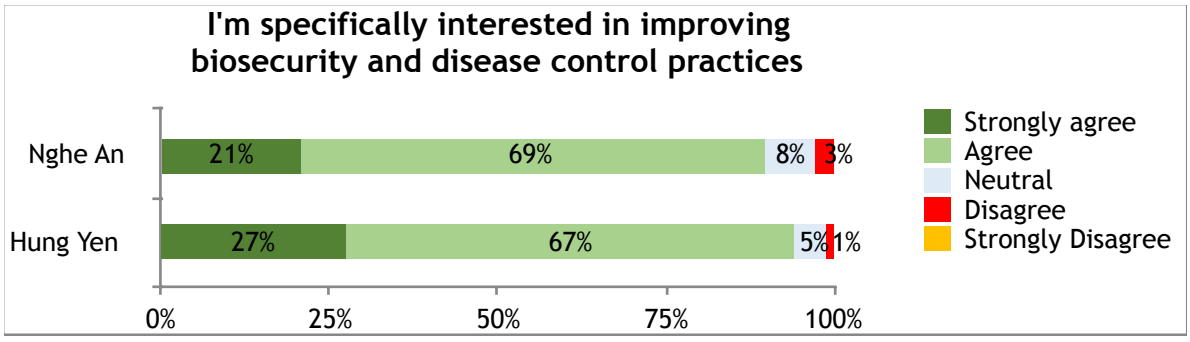
Graph 7: *Farmer perceptions on the importance of biosecurity and disease control standards in pig production*



Graph 8: *Farmer perceptions on seeking to generally improve their skills and knowledge on pig production*



Graph 9: *Farmer perceptions on seeking to biosecurity and disease control practices*


I'm specifically interested in improving biosecurity and disease control practices
Nghe An
Hung Yen
21%
69%
8%
3%
27%
67%
5%
1%
0%
25%
50%
75%
100%
Strongly agree
Agree
Neutral
Disagree
Strongly Disagree

6.0 Discussion

The information from this study has provided a valuable insight into the practices and perceptions of smallholder Vietnamese farmers in relation to biosecurity and disease control. An overwhelming majority (82%; 345/420) of farmers reported that they had experienced one or more instance of disease on their farm in past 12 months. The study also revealed the common measures undertaken by farmer include self-treatment of sick animals, burial of dead pigs, preference for vaccines and separation of animal classes into different enclosures. Some of the practices identified are consistent with other pig farmers in the region and also in other parts of the world. A review into pork production practices in the South East Asia region found that self treatment by farmers and vaccine use are two widely adopted measures (Huynh et al., 2007). A study conducted in the Philippines also found between 83-96% of farmers using burial as their primary method for dealing with dead pigs (Alawneh et al., 2014). However, this study has also identified practices or lack of that could present a significant disease risk to farms. Irregular disinfection of farms, lack of visitor control and low utilization of quarantine pens are some of the risk factors identified in this study that could contribute to the introduction and spread of disease. There are also a number of high risk practices that were reported by a small portion of farmers. In response to sick pigs, 7% of farmers reported immediately selling pigs as a practice and 9% sell dead pigs at a lower price. Although not practiced by a large majority of farmers these high risks practices could lead to disease outbreaks and spread in the commune in particular considering the high potential basic reproduction rate (Ro) for pig diseases such as FMD and CSF that are endemic in Vietnam. A study conducted in the United Kingdom in 1997 found that for high density pig areas with ideal meteorological the Ro was estimated at 38.4 (Haydon et al., 1997). Another

study conducted on the Ro for CSF in the Netherlands also found Ro ranging from 15.5 – 3.39 in slaughter pigs (Klinkenberg et al,. 2002). There are no known studies documenting Ro for these diseases in Vietnam but considering limited farmer knowledge, poor biosecurity practices and high pig densities it is plausible that similar if not high Ro could be expected. In addition, 12% of farmers report taking no action in response to diseases on neighbouring farms this is another high risk behaviour that could see more rapid spread of disease. These behaviours and practices have the potential to significantly increase the risk for introduction and spread of infectious disease. Studies on risk factors for diseases such as CSF and PRRS have shown that pig movements between farms with no biosecurity or disinfection measures are a significant risk. These studies conducted in pig populations in smallholder systems in Vietnam and commercial systems in the United States also show the farms with good disinfection practices reduce their risk of disease (Cho et al., 2006; Do et al., 2013). In particular, the high risk practice of selling sick and dead pigs was identified as a major factor in the introduction and spread of ASF in other smallholder pig farming systems in Uganda (Dione et al., 2016; Nantima et al.,2015). A risk assessment workshop funded by ACIAR in Vietnam conducted in March 2016 concluded that natural boar mating and high visitor traffic were two of the riskiest practices of introduction of PRRS on smallholder farms. The workshop brought together experts from the private and academic sector who also concluded that input suppliers, particularly animal health works, veterinarians and traders presented a significant risk for spreading PRRS from one farm to another (ACIAR, 2016) .

The poor adoption and implementation of some biosecurity and disease control measures in this study could also be influenced by the lack of quality veterinary advice and service that the Vietnamese farmers receive. A large majority (71%) of farmers in the study

reported that veterinary services never visited the farm. Development of a successful and efficient biosecurity strategy requires veterinary input and good understanding and awareness of individual farm characteristics and constraints. In reality, smallholder farmers may not have the ability or resources to implement advanced or highly technical measures. Therefore, having veterinary services that are able to provide low cost, practical and locally adapted measures based on a working knowledge of the farms is important. For smallholder farmers in Vietnam, without veterinary services actually visiting farms it would be difficult to achieve this outcome. In addition, a high portion of farms in this study have other livestock species such as buffalo or poultry in close contact with pigs. This presents a risk for transmission and amplification of particular infectious pathogens such as Avian influenza or Foot and Mouth disease (Baudon et al., 2015; Kamakawa et al., 2006). This study has found that 86% of farmers do not provide their pigs with access to drinking water at all times. This is not only a major production constraint but can also play an important role in increasing stress and making animals more susceptible to disease (Mavromichalis, 2006). There are a number of studies in the literature that stress the importance of providing pigs, especially growing animals with enough water to help ensure optimal health and production (Brumm et al., 2000; Mroz et al., 1995). Accessibility of drinking water is also regarded as a key requirement of animal welfare standards (EFSA, 2007). The provinces in this study normally experience high levels of annual rainfall and sufficient deep wheel water supply. Thus, it is unlikely that lack of water is the reason for farmers not providing their pigs permanently with water. It is more likely that poor farmer knowledge or lack of water dispensing equipment could be the reason for this. It is an area where farmers can look to for relatively cost effective and quick improvement in their production systems.

Farmer perceptions revealed that traders are viewed as less of a disease risk by farmers compared to neighbouring farms and personal farm practices. This in spite of more than half of farms (52%) having traders visit during every production cycle. Along with poorly implemented visitor control practices in Hung Yen particular, this perception is one that can be target for improvement. The lower risk perception by farmers towards traders may be reflective of poor knowledge or simply acceptance that these actors are required on farm to facilitate production outcomes. There a number of studies showing that in smallholder systems with high movement of people and animals there are significant risks for introduction and spread of disease presented by traders and middlemen (Baudon et al., 2015; Nantima et al., 2015; Kamakawa et al., 2006;). There is also a difference between farmer perceptions and farmer behaviour on the disease risk posed by neighbouring farms. A significant majority of farmers take action in response to disease on neighbouring farms but a lower number report perceiving neighbours as a risk. This could due to farmers adopting a reactionary approach to the risk posed by their neighbours instead of adopting a more active approach. A large portion of farmers in the study also appear to support the importance of biosecurity and disease control measures to pig production. However, this does not always correlate with farmer behaviour as the adoption and implementation of biosecurity measures varied significantly depend on the type of practice with some such as disinfection mattress being widely adopted and other such as quarantine pens being very poorly adopted. There could be a number of factors influencing farmer decisions on biosecurity. As mentioned above, low engagement with veterinary services leading to low knowledge and understanding could be a key factor. In addition, there could be cost or geographical constraints to the adoption of some biosecurity measures. With high population and farm densities for some areas the availability of land for

quarantine pens or separate enclosures for younger stock may not be physically possible but also require considerably higher investment compared to simple disinfection mattress.

The study has also identified some significant differences in farm practices between the two study regions and between different production systems. Farmers in Hung Yen province have higher rates of self-treatment for disease and source vaccines more from pharmacies compared to Nghe An where self treatment with veterinary input is more common, along with paravets being the primary sources of vaccines. These differences could be attributed to Hung Yen being a more urban farming environment with higher concentration and accessibility to pharmacies with farmers there being move heavily influenced by in their behaviour by pharmacies. High human and farm population densities in Hung Yen compared to Nghe may also explain why visitor access in Hung Yen appears harder to enforce and also why more regular disinfection practices are undertaken in Hung Yen compared to Nghe An. There were also differences identified between the three types of production system. As expected, farmers in a complete farrow to finish system are more likely invest in vaccines and have their different classes of stock separated. The investment into vaccines or enclosures is more likely to be justified in this system where stock will stay on farm for a longer period. However, the study also shows that in many areas such as treatment and response to diseases, there are similar practices being adopted by farmers. This would indicate that to a certain extent the farmers are more heavily influenced by the practices in their local region or area rather than the type of production system they are engaged in. Identification and further study of the differences between different areas and production system is important for the development and implementation of more effective and relevant strategies to improve

biosecurity and disease control. Farms in more rural areas such as Nghe An may require more targeted measures to address particular constraints.

A strength of this study was the combination of different surveys and data collection tools used to gain information from farmers. The utilization of an on-farm checklist allowed a triangulation and comparison between actual farm practices and those reported by farmers in surveys and questionnaire. The observational checklist also highlighted the importance of having on-farm expertise and input by demonstrating how adoption of practices is not necessarily linked to desired outcomes. The checklist found that over half of farms do cover and store their feed. However, there is still a very high portion, 76%, of farms that have visible parts of feed show indication of moisture, contamination or clotting. Farmers may be incorrectly storing or covering feed and this could be leading to unfavourable outcomes in relation to feed quality. The study also used a likert scale to gather information on farmer perceptions, this provided additional insight into what practices or behaviours farmers were more likely to engage in and if there was a consistency between farmer attitudes and farmer behaviours.

One of the limitations in the study was the loss of 120 farmers from the on-farm checklist data. Due to logistical constraints the study enumerators could not reach these farms and they were removed from the analysis of farm checklist data. Another aspect of the study that could influence validity is the use of farm recall and self-reporting for questionnaire data. It is possible that farmers may have some errors in their ability to recall data or may not necessarily provide some information which could be deemed sensitive or against accepted norms. There is evidence that smallholder pig farmers in Vietnam are selective in how they report animal disease. Farmers fear of the negative consequences from disease notification,

poor relationship with veterinary services, and general apathy toward disease occurrence and control are the main reasons limiting more active farmer reporting (Pham et. al, 2017). The two provinces selected in this study represent two areas which are representative of the typical pork production systems being used in Vietnam. It must also be taken into account that the selection of these study sites was influenced by practical and logistical considerations as previous projects and studies had been conducted in the area by project partners and a strong network of collaborators could be engaged.

The results from this study highlighted particular areas where smallholder pig farmers in Vietnam can better improve their biosecurity and disease control practices. It can be recommended that all farmers implement better measures for providing water to their pigs. This is a measure that can be economically and efficiently adopted and can provide significant production returns. In addition further training should also be provided to farmers about the risk of engaging in high risk practices such as purchasing or selling dead and sick pigs or not having any disinfection or visitor control measures in place on their farm. This study has provided the groundwork for further investigation into the reasons behind why farmers may not be or are adopting particular practices or behaviours. As part of larger project that this study was conducted in, another study was carried out looking at the uptake of particular animal health and farming guidelines known as VIETGAP (Vietnam Good Animal Health Practices). Farmers in this study stated that lack of resources (land and capital) and lack of knowledge were two key reasons for poor adoption of particular practices. In addition, farmers also stated that some practices such as record keeping were not perceived to produce enough benefit for the resources and labour costs required to implement them (Lapar et al., 2016).

The results from this study can also help guide further investigation and study into biosecurity and disease control for Vietnamese smallholder farmers. In particular, collating diagnostic and disease incidence data in combination with farmer practice surveys could help identify and evaluate which particular disease control strategies and biosecurity practices are most effective at helping Vietnamese farmers reduce disease. In addition, economic analysis should also be conducted to determine the cost of particular disease control interventions and the subsequent potential benefit from prevention or control of the disease. Detailed economic analysis and quantification of diseases impacts can be difficult due to the different factors that can affect the impact of the diseases such as the diversity of production systems, variation of market prices in geographical areas and variations in the cost of disease management and control (Rushton, 2009). However, providing farmers with these economic incentives is very important to help improve the adoption and sustained implementation of disease control strategies (Cardwell et al., 2016; Young et al., 2016; Young et al., 2015).

In conclusion, this study provided a description of the major disease control and biosecurity practices in smallholder pig farms in two provinces of Vietnam, and the identification of particular practices that differ significantly between different study areas or production systems. The practices or lack of investigated in this study can have a significant potential influence on the introduction and spread of infectious diseases and results from this study should be used to further enhance training and knowledge of farmers to improve their practices when it comes to biosecurity and disease control.

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