Drivers and risk factors for circulating African swine fever virus in Uganda, 2012–2013

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A B S T R A C T

We explored observed risk factors and drivers of infection possibly associated with African swine fever (ASF) epidemiology in Uganda. Representative sub-populations of pig farms and statistics were used in a case-control model. Indiscriminate disposal of pig viscera and waste materials after slaughter, including on open refuse dumps, farm-gate buyers collecting pigs and pig products from within a farm, and retention of survivor pigs were plausible risk factors. Wire mesh-protected windows in pig houses were found to be protective against ASF infection. Sighting engorged ticks on pigs, the presence of a lock for each pig pen and/or a gate at the farm entrance were significantly associated with infection/non-infection; possible explanations were offered. Strict adherence to planned within-farm and community-based biosecurity, and avoidance of identified risk factors is recommended to reduce infection. Training for small-scale and emerging farmers should involve multidimensional and multidisciplinary ap-proaches to reduce human-related risky behaviours driving infection.

Keywords:

African swine fever, Uganda, Risk fac tors, Disease drivers, Biosecurity

1. Introduction

African swine fever (ASF) is an important transboundary disease which causes devastating fatalities among pig populations, and poses a threat to the pig industry. ASF is caused by the African swine fever virus (ASFV), an arthropod-borne virus belonging to the family *Asfarviridae* and genus Asfivirus (Dixon et al., 2005; MacLachlan and Dubovi, 2011). A domestic pig cycle which is evidently not dependent on the presence of the tick vector is believed to occur in both West Africa and parts of East Africa (Penrith et al., 2004a), whereas the sylvatic cycle (Lubisi et al., 2007) predominates in other parts of East Africa and southern Africa. The control and eradication of ASFV is made difficult by several factors, including the absence of effective vaccines, marked virus resistance in infected tissues, contaminated materials and infectious animal products, in addition to a complex epidemiology and transmission involving ticks and wild pig reservoirs, domestic pigs and virus interactions (Sánchez-Vizcaíno et al., 2012).

In Africa, ASF has continuous and potentially devastating effects on both the commercial and subsistence pig production sectors. Greater losses are usually experienced by poorer pig producers, who are less likely to implement effective prevention and control strategies, or basic biosecurity measures (Edelsten and Chinombo, 1995). The virus is currently threatening other regions of the world and is expanding its geographical reach at an epidemic rate (Callaway, 2012).

Uganda's economy relies mainly on agriculture (approximately 80% of the total work force is engaged in agriculture). The majority of the population depends on subsistence farming and light agro-based industries (UBOS, 2006). In 2011, the country's gross domestic product (GDP) was estimated at USD 45.9 billion, and agriculture contributed approximately 21.8% of this total. From the 1970s to date, there has been a considerable increase in the number of semi-intensive and intensive pig units in the country, but the production system is still largely dominated by free-range units. Between 1991 and 2008, the Ugandan pig population increased from 700,000 to approximately 3.2 million pigs (MAAIF and UBOS, 2009; Rutebarika and Okurut, 2011). Of the current pig population, the Central Region has the highest population (41%), followed by the Western and Eastern Regions (24.4% and 22.0%, respectively), and the Karamoja sub-region has the lowest (1.8%).

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ASF imposes a major constraint on pig production in the country, as became very evident from recent and incessant outbreaks. At least eight major outbreaks have been reported in 10 districts in the last 7 years. Wakiso reported a fresh outbreak in late 2012, but more recent outbreaks occurred in the Kiboga and Kabarole districts in early January 2013 (Tingiira and Abigaba, personal communication). Other outbreaks were reported in Adjumani and Amuru (The Pig Site, 2012), Bugiri and Arua in 2011, Moyo, Bundibugyo and Gulu in 2010 (All Africa, 2012), Jinja and Wakiso in 2009, Masindi in 2008 and Moyo in 2006 (Uganda Radio Network, 2012). In addition, several other poorly documented outbreaks have occurred in the same period, and it is likely that additional outbreaks have not been documented.

A recent study in Uganda indicated that domestic pigs, bushpigs, warthogs and soft ticks may play various roles in the epidemiology of ASF in Uganda, and some pigs were positively diagnosed with sub-clinical ASF infection (Björnheden, 2011). A previous study in West Africa demonstrated that areas with a high level of pig-related activities, which includes the marketing, consumption and farming of pigs, tend to have a higher prevalence of ASF, and that a significant reduction in ASF prevalence would only be possible if on-farm biosecurity protocols are fostered, and the affected pig farmers are compensated, inclusive routine surveillance and a testing system are instituted, and market and transportation systems are reorganized (Fasina et al., 2010).

The present study was aimed at evaluating ASF risks in Uganda, using field surveys with the objective of identifying the risk/protective factors for disease, and drivers for ASF transmission/prevention in Uganda. It is anticipated that the results of this study will guide decision-making at a policy level to support ASF control efforts in Uganda and other countries with similar, piggery production systems, especially in the East African sub-region.

1. Materials and methods

1.1. Study sample

A cross-sectional survey was conducted in seven districts of Uganda from December 2012 to April 2013. These locations were Pallisa, Lira, Abim, Nebbi, Kabarole, Kibaale, and Mukono (see Fig. 1). These study areas were purposely selected to ensure wide geographic representation of all regions in Uganda, namely the East, the North, Karamoja, the West Nile, the West, the South West and the Central regions.

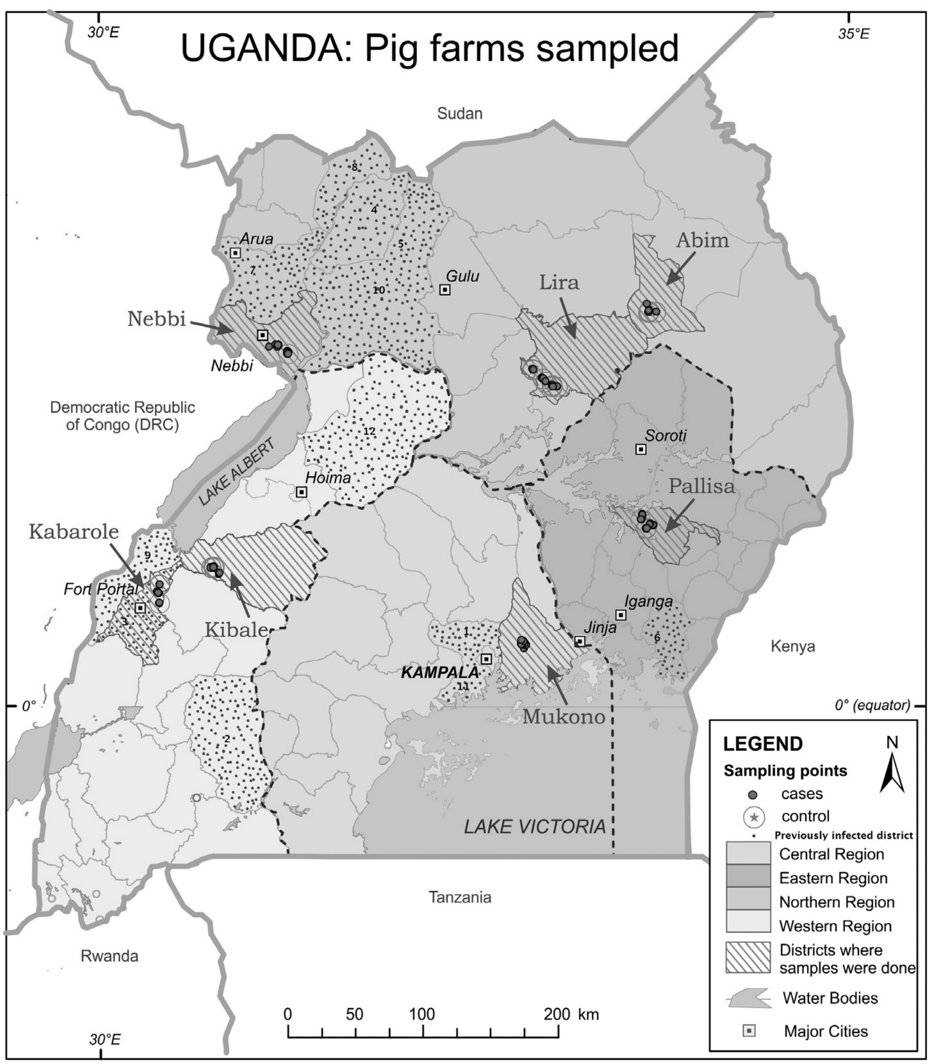

Fig. 1. Map of Uganda showing study sites (cases and control farms per region) and previously infected locations, 2012–2013. Previously infected districts are indicated from 1 to 12: 1 = Wakiso; 2 = Kiboga; 3 = Kabarole; 4 = Adjumani; 5 = Amuru; 6 = Bugiri; 7 = Arua; 8 = Moyo; 9 = Bundibugyo; 10 = Gulu; 11 = Jinja and 12 = Masindi districts.

Within these regions above, the sampling targeted districts that have reported outbreaks in the recent past (2011–2012). For the purposes of the study, an outbreak refers to a situation where unusual mortalities have been observed in a pig population and these mortalities were investigated by veterinary officers, serum and tissue samples were collected, tested and confirmed in the laboratory as serologically positive for ASF antibodies using the OIE prescribed serological test or positive viral genome presence by means of a *p72* gene diagnostic PCR (OIE, 2008). Finally, the districts to be included were carefully selected to represent areas in close proximity to potentially high-risk locations associated with ASF epidemiology, such as game parks, major pig consumption areas and trade or marketing routes, and forest reserves. All the sample locations considered in the study fulfilled these three criteria for inclusion.

Sample size was set to estimate a 50% expected prevalence at a 95% level of confidence with 10% precision and a design effect of 2 to account for clustering within districts, assuming a large population and using a random sampling design (Fosgate, 2009). Sample size was calculated using EpiInfo based on the exact binomial distribution, yielding a final number of 193 farms. These 193 farms were selected among pig farms where an outbreak had previously occurred, or was within the vicinity of such a farm (sampled population). As at the time of sampling, the classifications (case and control) were based on clinical case report and pathological findings but following the conclusion of serology and molecular virology, any suspected case sample that is negative in the laboratory was taken as misclassified and then placed in a control class. Specifically, an ASF case farm is a farm in which positive genetic materials were detected with or without positive serology, and also one with a positive serology only while a control farm is one where samples from the farm were consistently negative for ASF genetic materials and serology. The unit of interest for this study was an individual pig farm where an outbreak had previously occurred, or was within the vicinity of such a farm. For equal representation amongst the sampled populations, 28 respondents were selected from each district, one from each of the kinds of farms defined above, to be interviewed for the questionnaire survey. Within each district, sub-counties served as the primary sampling units, and villages represented the secondary sampling units. These sub-counties and villages were selected randomly, using a multi-stage sampling approach.

1.2. Data collection

A questionnaire on the individual pig farmer, farm demographics, risk factors and self-reported farm-level biosecurity variables was developed and evaluated at the Department of Production Animal Studies at the Faculty of Veterinary Science at the University of Pretoria, Pretoria, South Africa. It was pre-tested on five farmers by two interviewers in Tororo, Uganda, and was adjusted to fit the survey purpose. For the main study, three interviewers were recruited to administer the questionnaire within each district after a self-explanatory letter of consent was submitted to each potential respondent and respondents had signed an informed consent form to confirm their willingness to make available their personal and farm information (see Appendix S1). Farmers who had reported outbreaks and on whose farms these outbreaks had been confirmed were asked additional questions regarding their post-outbreak management and behaviour. A 100% response rate was obtained.

1.3. Data entry and analysis

Data coding, data entry and filtering were done using EpiData® 3.1. Data were exported into Stata® 9 for analysis (Stata Corporation, Texas, USA). A combination of Open Epi® Version 2.3 and Stata® 9 was used to carry out the univariable regression analyses, multivariable logistic regression analysis, and descriptive statistics. The Hosmer–Lemeshow statistical test was used to assess the goodness of fit for our logistic regression model using the estat gof command in Stata. For the collinearity, we checked by plotting a correlation matrix of all independent variables after modelling to check that all correlation coefficients were greater or less than 0.8.

2. Results

2.1. Descriptive statistics

2.1.1. Pig farmers' and farm demographics

A total of 196 farmers were involved in the survey. The majority of respondents were within the age category of 31–40 years ($n = 97$; 49.49%), other age categories are presented in Table 1a. The vast majority (90.31%) of the farmers regarded piggery as their principal occupation ($n = 177$) and over half of the total respondents dedicated 1–2 hours daily to pig farming ($n = 102$; 52.04%) (Table 1a).

Approximately half the farmers kept mixed breeds of pigs ($n = 97$; 49.49%), but local and exotic breeds were also kept (Table 1b). Approximately 89.80% of farmers had an average herd size of 1 to 10 pigs ($n = 176$), and the remainder had between 11 and 50 pigs on average ($n = 20$; 10.20%). The majority (68%) of the farmers obtained new pig stock from neighbouring farms ($n = 134$), while others sourced replacement pigs from the markets ($n = 53$; 27.04%) or other sources (Table 1b). A total of 140 farms were classified as case farms based on the serology (133 farms) and molecular virology (7 farms) for detection of genetic materials while 56 farms were classified as control farms. It should be noted that some farms were positive for both serology and virology (43).

2.2. Univariable logistic regression analysis

2.2.1. Risk factors for infection of farms with ASF virus

A total of 16 variables were analysed in the univariable logistic regression as possible risk factors of ASFV infection in farms (Table 2). The following variables were significant at $P \leq 0.25$ and were

Table 1
Pig farmers' and farm demographics (in percentages) for selected pig farms in Uganda, 2012 to 2013.

Farm and farmers' variable ($n = 196$)	Category	Percentage	95% Confidence interval
Age category of farmer	>1–≤20 years	4.08	2.23; 8.52
	≥21–≤30 years	27.55	20.36; 35.73
	≥31–≤40 years	49.49	40.80; 58.22
	≥41–≤50 years	18.88	12.67; 25.82
Highest level of education	Primary	45.41	36.94; 54.28
	Secondary	48.98	39.83; 57.24
	Post-secondary	4.59	2.23; 8.52
	University	1.02	0.62; 3.62
Main occupation	Piggery	90.31	84.84; 94.38
	Crop	4.59	2.23; 8.52
	Others	5.10	2.86; 9.93
Average time spent daily in the piggery	<1 hour	17.35	11.84; 24.68
	>1–<2 hours	52.04	43.74; 61.14
	>2–<4 hours	30.61	23.02; 38.93
Breed used in the farm	Local	27.04	20.36; 35.73
	Mixed	49.49	40.80; 58.22
	Exotic	23.47	16.88; 31.39
Mean pig population in the farm	1–10	89.80	83.60; 93.64
	11–50	10.20	6.36; 16.40
Source of pigs in the farm	Livestock market/ auction	27.04	20.36; 35.73
	Neighbour	68.37	60.02; 76.08
	Project	4.59	2.23; 8.52

Table 2
Univariable logistic regression analysis of risk factors associated with ASF outbreaks in pig farms, Uganda 2012–2013.

Variable	Category	Case (%)	Control (%)	OR	95% CI	*P*-value
Farm-gate buyers collected pig products from farm	No	18 (41.86)	25 (58.14)	1.00	*Reference*	*NA*
	Yes	122 (79.74)	31 (20.26)	5.41	2.63, 11.32	<0.001
Pig farmer visited other farms	No	16 (11.43)	4 (7.14)	1.00	*Reference*	*NA*
	Yes	124 (88.57)	52 (92.86)	0.60	0.17, 1.79	0.39
Pig farmer provided source of water	No	4 (2.86)	4 (7.14)	1.00	*Reference*	*NA*
	Yes	136 (97.14)	52 (92.86)	2.60	0.57, 11.92	0.21
Pig farmers shared same water source	No	122 (87.14)	50 (89.29)	1.00	*Reference*	*NA*
	Yes	18 (12.86)	6 (10.71)	1.23	0.47, 3.56	0.71
Farmer kept any survivor pigs	No	112 (80.00)	54 (96.43)	1.00	*Reference*	*NA*
	Yes	28 (20.00)	2 (3.57)	6.71	1.78, 43.15	0.002
Farmer saw engorged ticks on pigs	No	136 (97.14)	52 (92.86)	1.00	*Reference*	*NA*
	Yes	4 (2.86)	4 (7.14)	0.38	0.08, 1.76	0.21
Farmer's pig products disposal/sale method	Market	86 (61.4)	34 (60.7)	*1.00*	*Reference*	*NA*
	Farm Buyers	30 (21.4)	14 (25)	0.85	0.38, 1.95	0.664
	Slaughter	24 (17.2)	8 (14.3)	1.19	0.45, 3.2	0.708
Source of feed	Own	95 (67.9)	39 (69.6)	*1.00*	*Reference*	*NA*
	Buy	29 (20.7)	9 (16.1)	1.3	0.54, 3.8	0.511
	Pig roams	16 (11.4)	8 (14.3)	0.8	0.3, 2.41	0.676
Disposal method of pig viscera	Sell for consumption	4 (2.9)	7 (12.5)	1.00	*Reference*	*NA*
	Burn	24 (17.1)	14 (25)	3	0.62, 16.2	0.114
	Dump in refuse pit	60 (42.9)	25 (44.6)	4.2	0.95, 21	0.024
	Indiscriminate	52 (37.1)	10 (17.9)	9.1	1.83, 48.9	0.0006

considered for inclusion in the final multivariable logistic regression model: farm-gate buyers visited farms to collect products, pig farmers provided a source of water to pigs or the pigs fend for water themselves (free-roaming), farmers kept survivor pigs on the farm, farmers sighted engorged hard ticks (*Ixodes* and *Amblyomma*) on pigs, and farmers disposed of pig viscera by selling, burning, dumping them in a refuse pit or indiscriminately.

2.2.2. Self-reported on-farm biosecurity

A total of 27 variables were used for the univariable regression of self-reported on-farm biosecurity parameters (see Table 3). The following variables were significant at $P \leq 0.25$, and were considered for inclusion in the final multivariable logistic regression model: a gate was present at the farm entrance, wire mesh-protected windows were used on the pig house structure, some farm records were kept, sufficient feeding and watering spaces were available for all pigs, disinfectant was routinely used after cleaning, a lock was present for each pig pen, the farmer assessed the health status of pigs coming onto the farm and consulted with a veterinarian in the case of sick pigs.

2.3. Multivariable logistic regression analysis

An explanatory model for multivariable logistic regression analysis was designed for this study, and all 15 variables that were significant in the univariable logistic regression analysis at $P \leq 0.25$ were considered. A backward elimination procedure was used to exclude the factors one at a time, based on non-plausibility. Only eight variables were retained in the final multivariable logistic regression model at $P \leq 0.05$ (see Table 4).

The most plausible risk factors with an association with ASFV infection of pig farms in Uganda were indiscriminate disposal of pig viscera and waste materials after slaughter (OR = 71.9; $CI_{95\%}$ = 12.9, 402; $P < 0.001$), and farm-gate buyers collecting pigs and pig products within the farm (OR = 23.8; $CI_{95\%}$ = 7.53, 74.9; $P < 0.001$). Other factors found to have a significant association with risk included the retention of survivor pigs on a farm (OR = 18.6; $CI_{95\%}$ = 1.59, 17.22; $P = 0.002$), the presence of a gate at the entrance of the farm (OR = 14.11; $CI_{95\%}$ = 2.76, 72.2; $P = 0.001$), the use of open refuse dump instead of underground sewerage (OR = 9.5; $CI_{95\%}$ = 2.69, 33.9; $P < 0.001$), and other factors (Table 4).

The Hosmer–Lemeshow goodness-of-fit X^2 was 1.91 (d.f. = 6), $P = 0.928$. Two variables, namely consultation with a veterinarian when animals are sick and the provision of a source of water/self-fending for water by pigs were collinear ($\Phi = -0.794$; $P \geq 0.8$). The latter variable was eliminated in the multivariable logistic regression model due to collinearity, and the former was removed due to non-significance.

2.4. Perceptions and post-outbreak behaviour of farmers in farms with outbreaks

A total of 140 farmers reported prior outbreaks on their farms. Of the farmers, 79% reported that they had an outbreak on their farm in 2012 ($n = 110$), and 15% had an outbreak in 2011 ($n = 21$) or 2010 ($n = 9$; 6%). Nearly half of the farmers notified the District Veterinary Officer when they realized that there was an outbreak ($n = 68$; 48%), and others reported elsewhere (Table 5). The period between observing clinical signs of disease and reporting the disease to the authorities was approximately 1–2 weeks for 79 farmers (56%); while it took 1–7 days for 56 farmers (40%) and 1 month for four farmers (3%). Only one farmer (<1%) reported the disease within 24 hours of noticing the clinical signs. With regard to the ease of reporting clinical signs of ASF by the farmers, 75% indicated that it was not easy ($n = 105$) (Table 5)

Half of the farmers believed that roaming pigs were responsible for the introduction of infection onto their farms ($n = 70$; 50%), while other farmers attributed infections to other causes (see Table 5). Others indicated that the pigs they owned had roamed prior to infection ($n = 24$; 17%), or suggested various other causes. Of the farmers, 68% were not sure of the status of infection of neighbouring pig farms ($n = 95$) and only 5% ($n = 7$) were sure that there was no infection in the neighbourhood, and the others had infected farms in the neighbourhood. Details are available in Table 5.

3. Discussion

In the current study, factors that impact positively or negative-ly on ASF infection on pig farms in Uganda were evaluated.

The vast majority of pig farmers were within the age range of 21–40 years (77%) and had up to secondary school education

Table 3
Univariable logistic regression analysis of self-reported biosecurity associated with ASF outbreaks in pig farms, Uganda 2012–2013.

Variable	Category	Case (%)	Control (%)	OR	95% CI	*P*-value
Restricted access to all visitors	No	90 (64.29)	36 (64.29)	1.00	*Reference*	*NA*
	Yes	50 (35.71)	20 (35.71)	1	0.52, 1.93	0.99
Fenced premises	No	46 (32.86)	15 (26.79)	1.00	*Reference*	*NA*
	Yes	94 (67.14)	41 (73.21)	0.75	0.39, 1.48	0.42
Gate at entrance	No	87 (62.24)	40 (71.43)	1.00	*Reference*	*NA*
	Yes	53 (37.86)	16 (28.57)	1.52	0.78, 3.04	0.22
Wire mesh-pretected window	No	119 (85.00)	40 (71.43)	1.00	*Reference*	*NA*
	Yes	21 (15.00)	16 (28.57)	0.44	0.21, 0.94	0.04
Record-keeping	No	22 (15.71)	15 (26.79)	1.00	*Reference*	*NA*
	Yes	118 (84.29)	41 (73.21)	1.96	0.91, 4.14	0.08
Food and water control	No	16 (11.43)	8 (14.29)	1.00	*Reference*	*NA*
	Yes	124 (88.57)	48 (85.71)	1.29	0.49, 3.19	0.58
Terminal (end of operation) cleaning	No	63 (45.00)	30 (53.57)	1.00	*Reference*	*NA*
	Yes	77 (55.00)	26 (46.43)	1.41	0.75, 2.64	0.28
Routine (regular) cleaning	No	42 (30.00)	17 (30.36)	1.00	*Reference*	*NA*
	Yes	98 (70.00)	39 (69.64)	1.02	0.51, 1.99	0.95
Safe disposal of feces and dead pigs	No	44 (31.43)	14 (25.00)	1.00	*Reference*	*NA*
	Yes	96 (68.57)	42 (75.00)	0.73	0.35, 1.46	0.38
Quarantine of newly purchased pigs for at least 10 days	No	62 (44.29)	29 (51.79)	1.00	*Reference*	*NA*
	Yes	78 (55.71)	27 (48.21)	1.35	0.72, 2.53	0.35
Regular cleaning and disinfection of feeders and drinkers	No	42 (30.00)	17 (30.36)	1.00	*Reference*	*NA*
	Yes	98 (70.00)	39 (69.64)	1.02	0.51, 1.99	0.95
Sufficient feeding and watering space available for all pigs	No	35 (25.00)	19 (33.93)	1.00	*Reference*	*NA*
	Yes	105 (75.00)	37 (66.07)	1.54	0.78, 3.01	0.22
Sufficient space for each pig (no overcrowding)	No	38 (27.14)	18 (32.14)	1.00	*Reference*	*NA*
	Yes	102 (72.86)	38 (67.86)	1.27	0.64, 2.49	0.49
Routine removal of manure and litter	No	40 (29.67)	17 (30.36)	1.00	*Reference*	*NA*
	Yes	100 (71.43)	39 (69.64)	1.09	0.54, 2.14	0.80
Used disinfectant after cleaning	No	123 (87.86)	54 (96.43)	1.00	*Reference*	*NA*
	Yes	17 (12.14)	2 (3.57)	3.71	0.94, 24.5	0.06
Lock for each pen	No	73 (52.14)	35 (62.50)	1.00	*Reference*	*NA*
	Yes	67 (47.86)	21 (37.50)	1.53	0.81, 2.92	0.19
Assessed health status of pigs coming onto farm	No	23 (16.43)	15 (26.79)	1.00	*Reference*	*NA*
	Yes	117 (83.57)	41 (73.21)	1.86	0.87, 3.90	0.11
Never mixed different ages	No	56 (40.00)	19 (33.93)	1.00	*Reference*	*NA*
	Yes	84 (60.00)	37 (66.07)	0.77	0.40, 1.47	0.44
Never mixed different species	No	80 (57.14)	27 (48.21)	1.00	*Reference*	*NA*
	Yes	60 (42.86)	29 (51.79)	0.70	0.37, 1.31	0.26
All-in all-out production	No	128 (91.43)	50 (89.29)	1.00	*Reference*	*NA*
	Yes	12 (8.57)	6 (10.71)	0.78	0.28, 2.37	0.64
Consulted with a veterinarian in case of sick pigs	No	2 (1.43)	5 (8.93)	1.00	*Reference*	*NA*
	Yes	138 (98.57)	51 (91.07)	6.69	1.28, 51.11	0.02
Changed rubber boots/slippers	No	124 (88.57)	47 (83.93)	1.00	*Reference*	*NA*
	Yes	16 (11.43)	9 (16.07)	0.68	0.28, 1.70	0.39
Washed /disinfected equipment and tools	No	78 (55.71)	31 (55.36)	1.00	*Reference*	*NA*
	Yes	62 (44.29)	25 (44.64)	0.99	0.53, 1.85	0.96
Pest control (rodents and insects)	No	51 (36.43)	19 (33.93)	1.00	*Reference*	*NA*
	Yes	89 (63.57)	37 (66.07)	0.90	0.461, 1.72	0.75
Prompt sick/dead bird disposal from the farm	No	11 (7.86)	7 (12.50)	1.00	*Reference*	*NA*
	Yes	129 (92.14)	49 (87.50)	1.67	0.58, 4.58	0.33
Changed solutions in foot pans regularly	No	135 (96.43)	53 (94.64)	1.00	*Reference*	*NA*
	Yes	5 (3.57)	3 (5.36)	0.66	0.15, 3.44	0.58
Audited	No	64 (45.71)	25 (44.64)	1.00	*Reference*	*NA*
	Yes	76 (54.29)	31 (55.36)	0.96	0.51, 1.79	0.90

(94%) and approximately 90% operated a piggery as their main occupation. These partially literate populations are unable to use highly technical documents on animal health effectively; hence extension manuals should be clear, simple and unambiguous. Learning aids, pictorial guides and other participatory epidemiology tools should be used to convey information to these farmers.

The surveyed farmers preferred larger-scale operations with improved biosecurity. On certain farms in the Kabarole district, pig

Table 4
Multivariable logistic regression of variables associated with ASF outbreaks on pig farms, Uganda, 2012–2013.

Variable	OR	Std. Err.	*z*	*P*	95% CI
Indiscriminate disposal of pig intestines and waste materials after slaughter procedure	71.9	63.2	4.87	0.000	12.9, 402
Farm-gate buyers collecting pig and pig products within farm	23.8	13.9	5.40	0.000	7.53, 74.9
Survivor pig(s) kept by farmer	18.6	23.3	2.33	0.020	1.59, 17.2
Gate at entry of farm	14.1	11.8	3.18	0.001	2.76, 72.2
Refuse dump disposal of pig intestines and waste materials after slaughter procedure	9.5	6.17	3.49	0.000	2.69, 33.9
Lock for each pig pen	9.5	6.79	3.15	0.002	2.34, 38.5
Wire mesh-protected window on pig house structure	0.1	0.05	−3.23	0.001	0.01, 0.30
Engorged ticks seen on pig	0.01	0.02	−3.32	0.001	0.00, 0.16

Table 5
Cross-tabulation of perception and post-outbreak behaviour of farmers in ASF outbreak locations, Uganda, 2012–2013.

	Farmers reporting outbreaks, n = 140, frequency (%)				
	Personnel that was notified				Total (%)
	Local veterinarian	DVO	No one	Other	
Year of reported outbreak					
2010	6 (66.67)	3 (33.33)	0 (0.00)	0 (0.00)	9 (6)
2011	8 (38.10)	12 (57.14)	1 (4.76)	0 (0.00)	21 (15)
2012	46 (41.82)	53 (48.18)	3 (2.73)	8 (7.27)	110 (79)
Total	60 (43)	68 (48)	4 (3)	8 (6)	140
	Ease of report of ASF by farmer				Total
	Easy		Not easy	Very difficult	
How long it takes farmer to detect disease and report to authorities					
24 h	0 (0.00)		1 (100.00)	0 (0.00)	1 (1)
1–7 days	2 (3.57)		50 (89.29)	4 (7.14)	56 (40)
1–2 weeks	3 (3.80)		51 (64.56)	25 (31.65)	79 (56)
1 month	0 (0.00)		3 (75.00)	1 (25.00)	4 (3)
Total	5 (4)		105 (75)	30 (21)	140
	Infected farms in neighbourhood				Total
	Yes		No	Not sure	
What farmer thinks is responsible for infection on the farm					
Visiting farmers	6 (18.18)		1 (3.03)	26 (78.79)	33 (24)
Wild pigs	1 (33.33)		0 (0.00)	2 (66.67)	3 (2)
Roaming pigs Own	15 (21.43)		6 (8.57)	49 (70.00)	70 (50)
pigs roaming	9 (37.50)		0 (0.00)	15 (62.50)	24 (17)
Other	7 (70.00)		0 (0.00)	3 (30.00)	10 (7)
Total	38 (27)		7 (5)	95 (68)	140
	Farmer's reaction after ASF outbreak				Total
	Abandoned piggery	Re-stocked	Tried other stock animals	Other	
Effect ASF had on farm					
Lose pigs	2 (2.25)	84 (94.38)	2 (2.25)	1 (1.12)	89 (64)
Lose income	0 (0.00)	21 (95.45)	1 (4.55)	0 (0.00)	22 (16)
Reduced income	0 (0.00)	23 (92.00)	2 (8.00)	0 (0.00)	25 (18)
More costs for disease prevention	0 (0.00)	4 (100.00)	0 (0.00)	0 (0.00)	4 (2)
Total	2 (1)	132 (94)	5 (4)	1 (1)	140

houses were built on raised platforms (approximately 1.5 m high). This evidence of improved hygiene and management practices can be explored and enhanced with sustained training to reduce mortality-associated losses due to pig diseases and to improve the sources of income of farmers in resource-poor settings.

Pigs have previously been identified as a means of income generation, food security and social security among the rural and peri-urban poor (Dietze, 2011). In this study, approximately 90% of the famers had an average herd size of less than 10 animals, and though no specific question was asked with regard to the living standards of the participating farmers, it was observed that the majority of these farmers were clearly very poor and would need more input from government and non-governmental organisations (NGOs) to practise piggery at a semi-intensive or commercial level. Currently, only about 5% of the farmers interviewed had benefited from government/NGOs' assistance, an indication of low uptake. It may become necessary to revise the existing programmes or expand them to reach and accommodate more small-scale/emerging farmers. The majority of farmers got their pigs from neighbouring farms (68%) whose disease status was unknown, or from markets (27%), which are usually collection areas and have been identified as sources of disease redistribution and dissemination (Costard et al., 2009; Fasina et al., 2010). It should be noted that many of the farmers interviewed confirmed having kept back ASF survivor pigs, or selling them, and taking sick pigs to live animal markets. The effects of such actions to the epidemiology of ASF in Uganda and neighbouring countries cannot be overemphasised.

3.1. Risk and protective factors

Indiscriminate disposal of pig visceral and waste materials after slaughter is the most significant risk factor associated with or influencing the ASF infection of (Table 4). Home slaughtering of sick and untested animals, together with indiscriminate disposal of viscera and excrement may disseminate ASFV to clusters of neighbouring farms through formites, scavengers and open drainage. In Uganda, the lack of well-established abattoir systems that would ensure safe disposal of pig wastes after slaughter, as well as a lack of awareness on the mode of transmission of ASFV, is probably a strong driver of disease dissemination. Sensitisation of pig farmers by the local and regional animal health authorities and regular veterinary extension services will be important to reduce spread in this regard.

The collection of pigs and pig products directly from a farm by farm-gate buyers was also significantly associated with ASF infection of farms. This factor becomes very relevant in view of a causal relationship that exists between infected farms and movements within farms. Of the respondents, 68% could not confirm whether neighbours had had infections on their farms, although 27% confirmed such neighbourhood infections. The farm-gate buyers enter farms to collect pigs, some of which may be infected, and subsequent visits to naïve pig populations by them or other farmers within the neighbourhood may seed infection inadvertently. Prior studies have established the neighbourhood effect and the role of farm-gate buyers in the spread of pig disease (Anon, 2011; Fritzemeier et al., 2000; Penrith et al., 2012).

In our analysis, somewhat surprisingly, the presence of a gate at the point of entry to a farm and the presence of a lock for each pig pen were significantly associated with ASF infection and outbreaks on the farm (Table 4). Vaillancourt and Carver (1998) and Racicot et al. (2011) have established that the presence of a gate and other biosecurity measures do not always correlate with use and compliance. Response bias with regard to biosecurity questions in farms have also been reported in the past (Nespeca et al., 1997). Open fences and gates were observed in farms during our visits.

Furthermore, the presence of survivor pigs usually kept back with other pigs was significantly associated with ASF infection – about 15% of the surveyed farmers indicated that they had kept survivor pigs. Arias and Sanchez-Vizcaino (2002) observed that where a less virulent or asymptomatic variant of ASF occurs; this can lead to apparently healthy carriers, which subsequently play an important role in the endemicity and dissemination of ASF. Some districts had a large population of survivor pigs (data not shown) and there were unconfirmed claims that the local breed withstood disease adversities better and had a higher percentage of survivors. No scientific evidence supports this hearsay, but it is possible that an intrinsic environmental-associated adaptability does enable local pigs to respond better to ASF infection, especially in naïve farms, or possibly, the less virulent viruses are co-circulating with highly virulent forms in the field (Penrith et al., 2004b; Perez et al., 1998).

The refuse dumps also serve as drivers for infection (possibly associated with indiscriminate disposal above), and had a significant association with ASF infection. Scavenging animals (dogs, cats and pigs) may play roles by visiting these dumps and carry infected carcasses or parts thereof back to the farms. Although the use of effective disinfectants and deep burying of carcasses and wastes from suspect animals is more costly, it should be routinely done. Slaughterhouses should also be encouraged to have an underground sewer system for waste disposal (Sánchez-Vizcaíno et al., 2012).

The presence of wire mesh coverings on windows on pig houses seemed to protect pigs inside the houses against ASF infection, perhaps because of the effect on reduction of contacts between free-flying birds, rodents or insects and domestic pigs (although these remain unproven means of spread of ASF (Fasina et al., 2012)); and also limits human contact with the pigs. The presence of engorged hard ticks on pigs was positively associated with lower ASF infection. The reason for this association cannot be readily explained, since the identified hard ticks (*Ixodes* and *Amblyomma* species) have never been associated with ASF, but may have to do with management and hygiene.

3.2. *Post-outbreak perceptions and reactions*

More outbreaks were reported for the year 2012 than in the previous 2 years. This observation can be attributed to recall/memory bias, since farmers' record-keeping skills are poor, but it may also suggest the following: (1) some increasing awareness of the disease, (2) the need for more reporting, (3) more worryingly, the increasing presence of the disease on farms. A few farmers stated that although they saw clinical signs indicative of ASF, they never reported these to the authorities. In the course of our study, we observed that in one sub-county of a district previously considered as not infected by the authorities, there were many dead/dying pigs, and that the local veterinarian in the district was unaware of this. It is also important to realise that the dynamics of ASF in Uganda are changing rapidly – in Nebbi, Kabarole, Abim and Lira, all previously considered to be non-infected locations (Boqvist and Stahl, 2010), there were ASF-positive farms, and some farms were under quarantine at the time of the study.

Records of reported outbreaks held at the District headquarters were at variance with field situations. Report from the previous study by Boqvist and Stahl (2010) confirmed these disparities. Such inconsistencies in the exact numbers of outbreaks and confirmed data have been known to occur due to poor disease awareness (Costard et al., 2009). The majority of the farmers (91%) notified both the DVO and local veterinarians when they recognised signs of abnormality in pigs. It is doubtful if these notifications were timely, based on further enquiries from the farmers. Since the few designated state veterinarians cannot realistically cover all of the districts and administrative areas effectively, the role of veterinary paraprofessionals in the rapid syndromic surveillance and diagnosis is extremely important. Hence, these individuals should be trained in disease recognition, rapid diagnosis, outbreak control, disease management and associated biosecurity under the supervision of competent veterinarians. Worryingly, 75% of the surveyed farmers stated that they had some difficulty (or extreme difficulty, 21%) in reporting syndromes observed in their farms. These situations will impact on the timeliness of reporting and aid the spread of ASF. Logistic supports must enhance rapid reporting, use available structures and other extension services, and harness the currently existing animal disease reporting system.

The use of available rapid pen-side tests and new technologies in disease response programmes should be integrated for rapid responses, especially in difficult terrain, and in inaccessible or distant locations. Communication gaps between farmers and designated veterinary authorities should be minimized (Aanensen et al., 2009; FAO, 2013).

Finally, approximately 94% of the farmers who lost their pigs to ASF restocked, many with disregard to the minimum rest period (≥40 days up to a maximum quarantine period of 3 months) for farms post-infection, and these actions have vast implications for re-infection or the spread of infection to new locations (European Commission, 2002; FAO, 2009; Boinas et al., 2011).

4. Conclusions

Within-farm and community-based biosecurity are important factors in achieving control of ASF in Uganda and neighbouring countries. Adherence to the basic principles of biosecurity and making a conscious effort to avoid the identified associated risk factors and drivers of infection are essential to improve animal health in Uganda. Although the farmers surveyed claimed to have implemented some forms of biosecurity, our assessment revealed that the biosecurity measures that had been implemented are either ineffective or themselves serve as drivers of infection. Commitment from government to compensate affected farmers, the effectiveness of reporting and, good networking of veterinary infrastructure, is advocated (Sánchez-Vizcaíno et al., 2012). The use of veterinary extension services for training farmers, and the inclusion of social anthropologists and human behaviourists in the planning and execution of animal health programmes in East Africa are crucial for achieving compliance and reducing risk.

Ethical clearance

This project passed all ethical clearance of the Ugandan government and was approved by the Faculty Research Committee of Faculty of Veterinary Science, University of Pretoria with approval number: V052/12 'Molecular and Serological Epidemiology of African Swine Fever from Domestic Pigs in Uganda'. All samples involved in the work were transported to the OIE Reference Laboratory for the ASF Transboundary Animal Disease Programme-Onderstepoort Veterinary Institute, South Africa, in compliance with the UN standards for transport of infectious material (UN 2900; http://www .who.int/ihr/training/laboratory_quality/5_c_annex_G_cd_rom_sample_transport_info.pdf).

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Appendix A

A copy of the Letter of consent

NATIONAL AGRICULTURAL

RESEARCH ORGANIZATION

NATIONAL LIVESTOCK RESOURCES RESEARCH INSTITUTE

P. O. Box 96Tororo, Uganda

Tel: 045-4448360

045-4437297

INFORMED CONSENT FORM FOR PIG FARMERS

This Informed Consent Form is for pig farmers in areas that reported outbreaks of African Swine fever and who we are inviting to participate in research. The title of our research project is "Serological and molecular epidemiology of African swine fever in domestic pigs in Uganda"

Name of Principal Investigator: *Dr. Tonny Kabuuka*

Name of Organization: *National Agricultural Resources Research Institute*

Name of Sponsor: *National Agricultural Research Organization*

PART I: Information Sheet

Introduction

I am Dr. Tonny Kabuuka, working for the National Livestock Resources Research Institute. We are doing research on African swine fever, which is very common in this country. I am going to give you information and invite you to be part of this research. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research.

Purpose of the research

African swine fever is one of the most common and dangerous diseases of pigs in this region. There is currently no vaccine and control is purely supportive treatment and management. The reason we are doing this research is to find out how the causative viruses can be controlled better.

Type of Research Intervention

This research will involve questionnaire administration, blood and tissue sample collection.

Participant selection

We are inviting willing pig farmers in areas that had outbreaks.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind later and stop participating even if you agreed earlier.

PART II: Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this research.

Print Name of Participant___________________

Signature of Participant ____________________

Date ____________________________

Day/month/year

If illiterate

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness______________________ AND Thumb print of participant

Signature of witness _______________________

Date _________________________

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1.

2.

3.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Print Name of Researcher/person taking the consent_________________________

Signature of Researcher /person taking the consent___________________________

Date ____________________________

Day/month/year

A copy of the questionnaire

SURVEY ON SEROLOGICAL AND MOLECULAR EPIDEMIOLOGY OF AFRICAN SWINE FEVER IN DOMESTIC PIGS IN UGANDA

QUESTIONNAIRE FOR THE PIGGERY FARM HERDS

This questionnaire is being conducted as part of an on-going Master of Veterinary Science study. It is a non-profit/non-commercial research meant for the public good. The privacy of all participants will be strictly ensured and any information provided will be used only for the purpose of this research.

PART I SECTION A: GENERAL

s/no.						
1	District	2 Sub county				
3	Village					
4	GPS Coordinates	N		E		
5	Name (optional)					
6	Age	**1** <20	**2** 20-30	**3** 31-40	**4** 41-50	**5** > 50
7	Education level	**1** Primary	**2** Secondary		**3** Tertiary	**4** University
8	Main Occupation	**1** Piggery	**2** Crop husbandry		**3** Other animal farming	
9	% time dedicated to pig farming	**1**<1hr	**2** 1-2 hr		**3** 3-4hr	

SECTION B: EPIDEMIOLOGY

10. Types of Pigs	**11. Number**	**12. Age**	**13. Sex**	**14. Source of pig**
1 Local	**1** 1-10	**1** Piglets	1 Male	**1** Market
2 Mixed	**2** 11-50	**2** Growers	2 Female	**2** Neighbouring farms
3 Exotic	**3** 51-100	**3** Adults		**3** Gifts
	4 >100			**4** Other

15. How do you dispose/sell your pig products?	**1** Buyers come to farm	**2** Take to market	**3** Slaughter at home
16. Do farm-gate buyers collect pig/pig product from your farm?		**1** Yes	**2** No

17. Do you have pig abattoir in your premises?					**1** Yes	**2** No
18. Did African swine fever affect your farm in any way?					**1** Yes	**2** No
19. If yes, how (mark as many as applicable)?						
1 Lose pigs	**2** Lose income	**3** Reduction in income	**4** More costs for disease prevention			
(This section can be skipped for uninfected farms)						
20. When was your farm infected?	**1** 2009	**2** 2010	**3** 2011	**4** 2012		**5** Other
21. To whom did you report?		**1** Local Vet	**2** DVO	**3** No one		**4** Other
22. How long does it take you between disease infection and reporting?		**1** 24 hr	**2** 1-7 days	**3** 1-2 weeks		**4** 1 month
23. How easily can you report ASF outbreak?		**1** Easy	**2** not easy	**3** Very difficult		
24. What did you do after loss of all pigs?	**1**Abandoned piggery	**2** Re-stocked	**3** Tried other stock animals			**4** Other
25. What do you think is responsible for infection in your farm (infected farms only)?						
1 Visiting farmers	**2** Wild pigs	**3** Ticks	**4** Roaming pigs	**5** Own pig roaming		**6** Other
26. How did you sell/dispose of your product during the outbreak?						
1 Rapid slaughter and sale in open market	**2** Destroy and bury/burn	**3** Dispose of in the refuse dump	**4** Slaughter and eat/sell	**5** Government officials handle it		
27. Do you visit other people's farm?			**1** Yes	**2** No		
28. Do you have infected farms in immediate neighbourhood?			**1** Yes	**2** No		**3** Not sure
29. How do you dispose your pig intestines and other slaughter waste materials following slaughter procedure?						
1 Burn/bury	**2** Sell for consumption	**3** Dump in refuse site	**4** Dispose indiscriminately	**5** Other (state)		
30. Do wild birds visit your farm?			**1** Yes	**2** No		
31. Do these wild birds have access to such intestinal content?			**1** Yes	**2** No		
32. Source of feeds	**1** Buy ready-made meal	**2** Compound my animal feed		**3** Leave pig to search		
33. Do you see engorged ticks on your pigs?		**1** Yes		**2** No		
34. Do you borrow farm equipment?		**1** Yes		**2** No		
35. If yes, what?						
36. Source of water		**1 F**armer provides		**2** Not provided		
37. Do you share this source with other farms?		**1** Yes		**2** No		
38. Any survivor pigs		**1** Yes		**2** No		

PART II: BIOSECURITY, MANAGEMENT PRACTICES AND COSTING FOR THE OPERATIONS.

Which of the biosecurity measures tabulated below is practiced or present in the farm? Tick all observed measures.

S/NO	BIOSECURITY MEASURES	Yes	No
1	Restricted access to all visitors		
2	Fence around premises		
3	Gate at entrance		

4	Wire mesh window		
5	Foot dips for disinfection before the house		
6	Record keeping		
7	Food and water control		
8	Terminal (End of operation) cleaning		
9	Routine(regular) cleaning		
10	Safe disposal of faeces and dead pigs (protected away from other animal and insect		
11	Quarantine newly purchased pigs for at least 10 days		
12	Regular cleaning and disinfection of feeders and drinkers		
13	Sufficient feeding and watering space available for all pigs		
14	Sufficient space for each pig (No overcrowding)		
15	Remove manure and litter routinely.		
16	Usage of Disinfectant after cleaning		
17	Lock for each pen		
18	Assess Health status of pigs coming in		
19	Do not mix different ages		
20	Do not mix different species		
21	All-in all-out production		
22	Hand sanitizer, gloves and washing		
23	Going from young to older pigs		
24	Change clothing when going in/out		
25	Separate sick pigs		
26	Consult with a veterinarian in case of sick pigs		
27	Change rubber boots/slippers		
28	Wash/disinfect equipment and tools		
29	Pest control (rodents & insects)		
30	Prompt sick/ dead bird disposal from the farm		
31	Change solution in foot pans regularly		
32	Auditing: incentives, education, adherence (encourage assistants to adhere to biosecurity)		

Thank you for your time