Transboundary and Emerging Diseases

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ORIGINAL ARTICLE

Risk Factors for African Swine Fever in Smallholder Pig Production Systems in Uganda

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Summary

Smallholder pig production in Uganda is constrained by poor management and high disease burden, with African swine fever (ASF) being one of the most important contributors. However, data to develop appropriate evidence-based disease mitigating interventions along the pig value chain are lacking. This study aimed at determining risk factors associated with the occurrence of outbreaks of ASF in selected districts. A cross-sectional survey of 1195 pig-keeping households in three districts was carried out between April and July 2013. Households were classified into one of three value chain domains (VCDs) based on where the production was located and where most of the products were sold: rural-rural (R-R), rural-urban (R-U) and urban-urban (U-U). Findings revealed that crop farming is the most common primary activity in the R-R and R-U VCDs, while pig keeping was the most common primary activity in the U-U VCDs. Pigs are mostly kept tethered or left to roam in the R-R and R-U VCDs, while in the U-U VCDs, they are mostly confined in corrals. Nearly 20% of the farmers whose farms were hit by an ASF outbreak subsequently sold all their pigs (healthy and sick) to the market in panic. Factors that positively correlated with recent ASF outbreaks were prompt disposal of dead pigs on farms ($P < 0.001$, OR = 2.3), wild animals present in the village ($P < 0.001$, OR = 1.7) and farmers sourcing drugs from stockists ($P < 0.001$, OR = 1.6); while protective factors were the presence of perimeter fences ($P = 0.03$, OR = 0.5), attendance of farmers at secondary-school level and above ($P < 0.001$, OR = 0.6), routine cleaning of the pig pens ($P < 0.001$, OR = 0.6) and pigs being the only livestock kept by farmer ($P = 0.01$, OR = 0.7). Given the current situation, there is a need to raise awareness among farmers and other value chain actors of biosecurity measures and create incentives for farmers to report ASF cases.

Introduction

In Uganda, pork has become an increasingly important animal food source in the diet. In the 1960s, pork accounted for only 1–2% of the per capita consumption of meat (11–12 kg/year); whereas currently, it accounts for at least one-third of the current 10 kg/year (FAOSTAT, 2010). As with other livestock, pig keeping allows both rural and urban households to diversify their income sources and through that, mitigate economic risks and improve livelihood resilience. Pigs also serve as a source of cash in times of need, for example house repairs, school fees, lease of agricultural land or purchase of seeds, fertilizers and other farm inputs (Deka et al., 2007). In Uganda, the main objective for pig keeping is income generation. Money from pig keeping helps farmers pay school fees and household health needs. Other benefits from pig keeping are manure production and source of wealth (Ouma et al., 2014).

The Ugandan National Agricultural Advisory Services (NAADS) aimed at improving pig farming in the rural communities by putting efforts into making pig keeping a viable enterprise (NAADS, 2013). However, several constraints in the development of the pig sector have been identified. These include the high burden of diseases such as helminthiasis and ASF, uncoordinated trade and marketing, poor feeding and husbandry practices (Dione et al., 2014b). Lack of data on the pig production systems has made it difficult for stakeholders to implement successful interventions which aim at combating ASF. Hence, outbreaks persist and affect poor farmers who often suffer heavy financial losses following massive death of their pigs. Therefore, this study aimed at describing the pig management and biosecurity practices and identifying risk factors related to ASF outbreaks in three selected districts with high pig population in Uganda.

Materials and Methods

Site selection

A cross-sectional survey was conducted between April and August 2013 in Masaka, Mukono and Kamuli districts of Uganda. These districts were selected in a participatory manner by stakeholders of the Smallholder Pig Value Chain Development (SPVCD) project implemented by the International Livestock Research institute (ILRI) in Uganda. The selection of districts was undertaken in two steps: first, data on pig population density, human poverty indicators and proximity to urban centres (as a proxy of market access) were used to identify a preliminary list of 10 potential districts that could be used as a study area. Secondly, a participatory process of validation and discussion with different project stakeholders allowed the selection of Masaka, Mukono and Kamuli, as districts with a higher level of disease burden and commercial pig transactions (Ouma et al., 2014) (Fig. 1).

Consultative meetings with district stakeholders were held in each of the districts to select the study sites (subcounties, parishes and villages), and an additional assessment was carried on the pig population at subcounty level using data from the livestock census of 2008. For each district, four to six subcounties with high pig populations were selected to represent each VCD. Consultations to identify the VCDs within the districts were held with partners on the ground including the district veterinary officers, NAADS staff and local NGOs in each district. A minimum checklist was developed and given to a few farmers and other value chain actors during site scoping studies to validate the VCDs in each subcounty and also to identify villages to be targeted for the value chain activities. Within each selected subcounty, two to three villages were randomly selected, bringing the total number of villages that are part of the study to 35. In our study, 20 of the 35 villages were selected across the three districts (Table 1). The number of villages was based on financial resources available and also avoidance of farmer fatigue due to the number of other activities taking place in the same villages.

Sample size calculation

The sample size was calculated considering an infinite population (no recent census data) using the following formula: $n = [Z^2P(1-P)]/d^2$ (Thrusfield, 1995). The resulting sample size per district was 384 farms which was rounded up to 400 to increase precision. The number of farms included in the study in each village was proportional to the number of farms in that village at the beginning of the design. The epidemiological unit was the farm. A farm was considered infected by ASF if at least one pig from that farm had contracted the disease. A complete list of all pig farmers in each participating village was provided by local partners. Farms to be enrolled in the survey were randomly selected from those lists. A list of replacement farms was established for each village in case the targeted farmers had recently sold or lost their pigs following a disease, or did not consent to participating in the study.

Data collection

A semistructured questionnaire was administered to all pig keepers. Information included in the questionnaire was related to pig production systems, husbandry and biosecurity practices. Local facilitators were selected and trained to administer the questionnaires to individual households in local languages (Luganda in Masaka and Mukono districts, Lusoga in Kamuli district).

Case definition for ASF

In the study area, farmers knew about the clinical signs of ASF because they frequently experience the disease. Local names for the disease exist and were widely used by farmers and other value chain actors. For instance, it is referred to as '*Omusujja*' in Luganda (Masaka and Mukono) and '*Omusudha*' in Lusoga language (Kamuli) (Dione et al., 2014b). The most common clinical signs of ASF were described to farmers in their local languages. In short, a farm was suspected as being affected by an outbreak of ASF when the farmer's description of the clinical case corresponded to the following: (i) high fever (huddling), (ii) loss of appetite, (iii) redness of the edges of the ears, the skin and other parts of the body, (iv) unsteady gait (neurological disorder) and (v) sudden and massive death of pigs in the farm following the above clinical symptoms. These symptoms were reported by farmers to be associated with

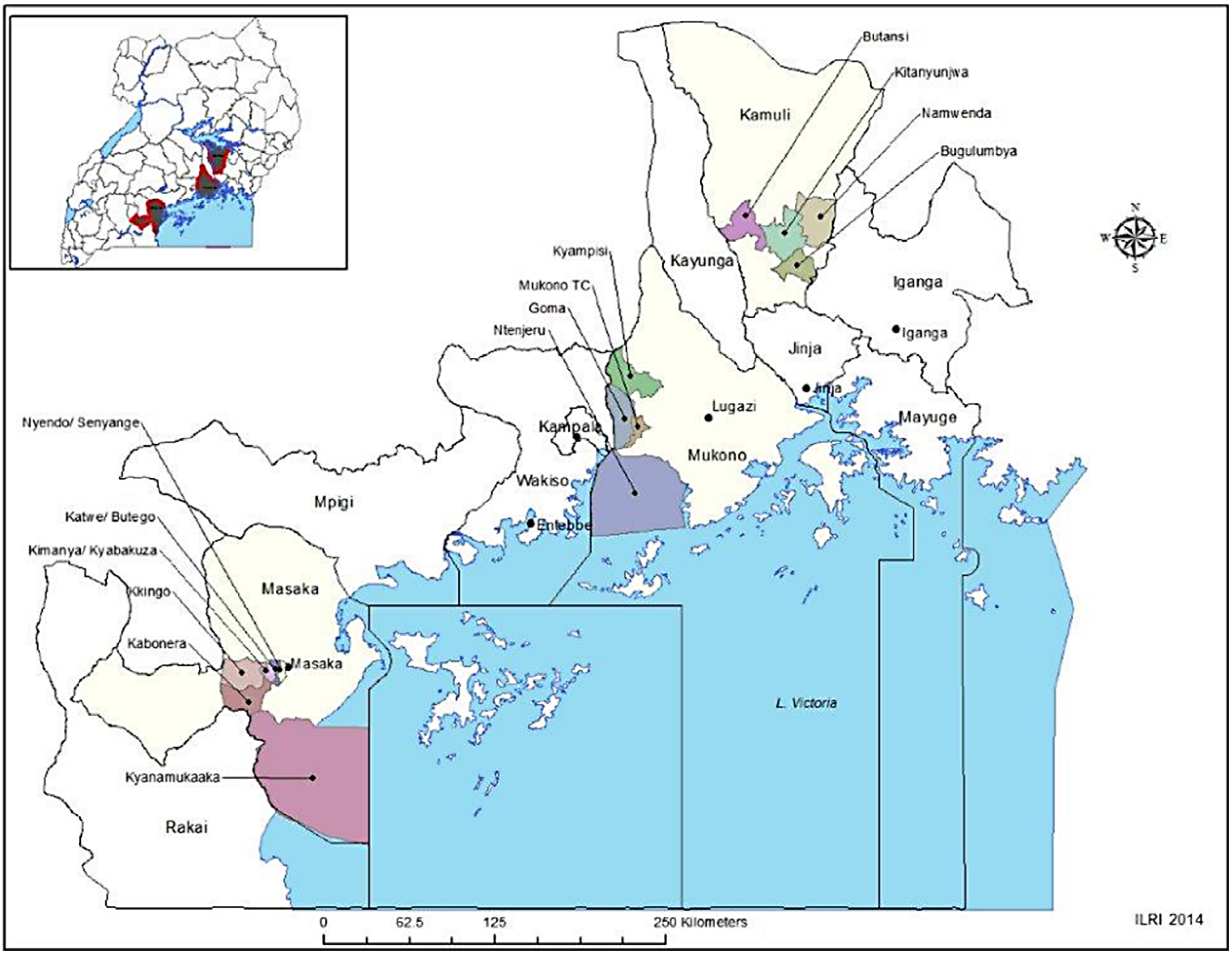

Fig. 1. Map of Uganda with districts and subcounties where the study took place. The black highlights are the districts; the subcounties where the study took place are highlighted with different colours, in each district.

ASF in previous studies in the same districts (Dione et al., 2014b). The same case definition was adopted in similar studies carried out in Uganda (Muhangi et al., 2014; Nantima et al., 2015). Farmers were asked about ASF cases in the year preceding the interview, and their perceptions were triangulated with information provided by animal health professionals operating in the area.

Data management and analysis

Data were recorded on paper by the interviewers and entered into CSPro5.0 (Washington, DC, USA) software database for clean-up. Analysis was performed in Excel (Microsoft Corp., Washington, DC, USA) and Stata version 13 (StataCorp LP, College Station, TX, USA). For the risk factor analysis, univariable logistic regression was applied to 53 variables representing the identified potential risk factors. Variables that were significant in the univariable logistic regression analysis at $P \leq 0.25$ were included in multivariable logistic stepwise regression analysis. A backward elimination procedure was used to exclude the factors one at a time, using $P > 0.05$ as the criterion. Clustering was accounted for at two levels with district as a fixed effect and village as a random effect in the multivariable models. Model diagnostic was undertaken by checking for normality of residuals at village level, as well as heteroscedasticity of residuals as described by Dohoo et al. (2009).

Ethical approval

A consent form and an information sheet describing the aim of the study were handed over to literate farmers before the interview. Translation into local languages was done for the illiterate farmers. Farmers willing to take part in the study signed the consent forms. The study was approved by both the Institutional Ethical Review Committee established by the College of Veterinary Medicine, Animal Resources and Biosecurity (COVAB) of University of

Table 1. Selected villages and their value chain domains

District	Value chain domain	Subcounty	Village	No. household sampled	No. of pig farms	No. of pigs	Protected areas
Masaka	Urban-urban	Kimanya-Kyabakuza	Kijjabwemi	49	90	265	Nabajuzi river
	Urban-urban	Kymanya-Kyabakuza	Kyabakuza-B	42	74	357	Swamps
	Urban-urban	Nyendo-Ssenyange	Ssenyange-A	52	69	219	Rivers and small forest privately owned
	Rural-urban	Kkingo	Kisoso	52	88	351	None
	Rural-urban	Katwe-Butego	Butego	29	63	217	Wetland and a forest bordering the wetland
	Rural-urban	Kyanamukaka	Kanoni-Bukunda	55	131	385	Rivers and a few privately owned forests
	Rural-urban	Kabonera	Kyamuyimbwa-Kikalala	49	102	312	None
	Rural-rural	Kkingo	Ssenya	43	76	240	None
	Rural-rural	Kyanamukaka	Lukindu	41	54	226	Lake/Kitasi Forest reserve
Mukono	Urban-urban	Mukono T.C	Kitete	59	63	379	None
	Urban-urban	Goma subcounty	Misindye parish	67	95	454	Part of Namanve forest
	Rural-urban	Kyampisi	Kyoga	59	80	153	Rivers
	Rural-urban	Kyampisi	Buntaba	70	69	224	None
	Rural-rural	Ntenjeru	Kazo/Kalagala	56	85	272	Lake/Zirimiti Government forest reserve
	Rural-rural	Ntenjeru	Nsanja/Gonve	47	89	266	Lake/Zirimiti Government forest reserve
	Rural-rural	Ntenjeru	Bugoye/Kabira	52	91	261	Lake
Kamuli	Rural-rural	Kitayunjwa	Butabala	48	84	191	None
	Rural-rural	Bugulumbya	Bukyonza	82	60	86	Swamps
	Rural-rural	Namwendwa	Isingo A	64	100	213	None
	Rural-rural	Butansi	Ntansi	179	182	617	None
Total				1195	1745	5688	

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Results

Demographic characteristics of pig farmers

Two-third of pig respondents were male, ranging from 13 to 100 years of age, with a mean of 46, and a median of 45. In all VCDs, 45.2–52.0% of farmers had attended at least primary school, while 10.0–12.0% had never attended school. The number of farmers who had received at least one short training workshop in husbandry practices varied between VCDs, with the U-U having received the highest proportion (59.0%). The primary activity for most farmers interviewed in the U-U VCD was livestock keeping, including pigs (45.2%), while in the R-R and R-U VCDs, crop farming was dominant with 75.5% and 74.7%, respectively. In all VCDs, most farmers kept other animals besides pigs. Poultry seemed to be most widely kept by farmers in U-U VCDs (74.5%), while cattle was most common in the R-R and R-U VCDs with 32.2% and 19.1%, respectively (Table 2).

Table 3 describes the herd population structure, with farmers keeping an average of one to three pigs of different age categories across all VCDs. A large number of farmers kept sows (82.6%), growers and fatteners (42.7.0%) and entire boars (55.8%); while only 23.5% kept piglets of less than 3 months old.

Pig husbandry practices

The main means of pig addition to the herd was purchase of piglets (67.1–70.0%) and births on-farm (23.7–25.0%). Tethering was more common in R-R and R-U VCDs with, respectively, 64.4% and 57.9% households practicing, while intensive housed type was more common in U-U VCDs (89.0%). Free ranging was practised more frequently in R-R and R-U VCDs with 1.5% and 1.7%, respectively. Across all VCDs, crop residues supplemented with commercial or

Table 2. Demographic characteristics of pig keepers

Variable	RR	RU	UU	Total
Mean age (mean ± SD)	46.67 ± 14.1	46.69 ± 12.2	46.33 ± 12.2	
Age group				
<35 years	272 (35.1)	51 (28.8)	72 (30.2)	395 (33.2)
>35 years	502 (64.9)	126 (71.2)	166 (69.8)	794 (66.8)
Total	774 (100.0)	177 (100.0)	238 (100.0)	1189 (100.0)
Sex				
Male	545 (70.0)	127 (71.0)	143 60.0)	815 (68.2)
Female	233 (30.0)	51 (29.0)	96 (40.0)	38 (31.8)
Total	778 (100.0)	178 (100.0)	239 (100.0)	1195 (100.0)
Ethnical group				
Muganda	364 (47.6)	161 (90.9)	208 (88.1)	733 (62.2)
Musoga	361 (47.2)	3 (1.8)	3 (1.3)	367 (31.2)
Others	40 (5.2)	13 (7.3)	25 (10.6)	78 (6.6)
Total	765 (100.0)	177 (100.0)	236 (100.0)	1178 (100.0)
Religion				
Catholic	343 (44.7)	72 (40.7)	142 (58.9)	560 (46.9)
Protestant	329 (42.2)	80 (45.2)	45 (19.1)	457 (38.1)
Born again	69 (8.9)	7 (3.1)	30 (12.7)	106 (8.9)
Others (including Muslims)	33 (4.2)	18 (10.0)	22 (9.3)	73 (6.1)
Total	774 (100.0)	177 (100.0)	239 (100.0)	1190 (100.0)
Education				
Primary school	391 (50.2)	92 (52.0)	108 (45.2)	591 (49.4)
High school	257 (33.0)	51 (29.0)	77 (32.2)	385 (32.2)
University	53 (6.8)	12 (7.0)	29 (12.1)	94 (8.0)
Never	77 (10.0)	23 (12.0)	25 (10.5)	125 (10.4)
Total	784 (100.0)	178 (100.0)	236 (100.0)	1195 (100.0)
Training				
Short duration training on pig husbandry	326 (42.0)	65 (36.5)	141 (59.0)	532 (44.6)
Never	451 (58.0)	113 (63.5)	98 (41.0)	662 (55.4)
Total	777 (100.0)	178 (100.0)	236 (100.0)	1191 (100.0)
Primary activity				
Crop farming	585 (75.5)	133 (74.7)	99 (41.4)	817 (68.5)
Animal keeping (including sales)	88 (11.4)	22 (12.4)	108 (45.2)	218 (18.3)
*Other (business/trade/unemployed salary)	102 (13.1)	23 (12.9)	32 (13.4)	157 (13.2)
Total	775 (100.0)	178 (100.0)	239 (100.0)	1192 (100.0)
Other animals kept				
Poultry + other	103 (13.3)	20 (11.3)	178 (74.5)	301 (25.0)
Cow + other	251 (32.2)	34 (19.1)	12 (5.0)	297 (25.0)
Others animals than poultry and cow	128 (16.5)	28 (15.7)	11 (4.6)	167 (14.0)
No other animals (only pigs)	296 (38.0)	96 (53.9)	38 (15.9)	430 (36.0)
Total	778 (100.0)	178 (100.0)	239 (100.0)	1195 (100.0)

Values presented are absolute numbers and percentages are in brackets.
*Carpenter, tailor, witch doctor, shop keeper, motorcycle riding, mechanic, brick maker, pastor, traditional healer, fishing.

home-mixed feeds was the most common feeding strategy (40.0–51.2%), followed by a provision of crop residues and swill (14.6–34.0%). Forages were also part of the diet, especially in the R-R VCDs (Table 4).

The most common disease prevention measure practiced by farmers was parasite control including deworming and spraying with acaricides. The majority of farmers declared that they dewormed their pigs every 3 months. In VCDs close to urban areas, vitamins were administered to pigs in addition to parasite control. Albendazole and ivermectin were the most commonly used dewormers. These drugs were mainly sourced by farmers from para-veterinarians (40.5–79.2%) and drug stockists (18.0–46.5%) (Table 4).

Pig slaughtering practices

Only 11.0% of farmers slaughtered pigs on their own for home consumption or for sale to butchers or small local pork restaurants referred in the manuscript as 'pork joints'. The majority of farmers (89.0%) sold live pigs to

Table 3. Pig population structure (means ± SD)

Variable	RR (n = 783) Mean	RU (n = 177) Mean	UU (n = 236) Mean	Number of farmers (%)
Growers and fatteners	0.60 ± 1.2	1.05 ± 1.7	1.25 ± 2.1	42.7
Sows	1.35 ± 2.7	1.18 ± 1.1	1.20 ± 1.1	82.6
Entire boar	0.54 ± 1.0	0.49 ± 1.0	0.40 ± 0.7	55.8
Castrated boar	0.48 ± 1.0	0.28 ± 0.8	0.58 ± 1.0	47.6
Piglets (<3 months)	1.0 ± 4.4	1.27 ± 2.5	0.76 ± 1.7	23.5

traders who then slaughtered them and sold the meat to butchers or directly to pork joints. Field observations revealed poor hygiene and improper waste management at all slaughter slabs in the study area. For example, the water used to clean the meat after slaughter was usually used to water plantations in the compound or is given to pigs for drinking, while the offals were generally fed to dogs and pigs, or thrown away in the bush where scavenging pigs had access to it.

Self-reporting biosecurity practices at farm

In all VCDs, biosecurity was poorly implemented at farm level. Only 4.1% of farmers had gates at the entrance of their farms and 3.0% of them used footbaths. The erection of fences around premises was only observed in a limited number of households (6.0%). Nearly half of farmers declared that they routinely cleaned their pig pens. However, only 14.2% of them declared that they used disinfectants when cleaning their farms. Restricted access of visitors to farms was reported by 26.6% of farmers. The majority of farmers declared that they consulted a veterinary practitioner when they had a health problem in their farm (84.3%). Manure removal and safe disposal of faeces and carcass was undertaken by 75.2% and 66.6% of farmers, respectively. Other practices, such as use of rubber boots, record keeping, regular clothes change, quarantine of new stocks, and washing of farm equipment and tools, were not commonly reported by farmers (Fig. 2).

Diseases and ASF outbreaks occurrence during the year prior to the study

Farmers were asked to describe the most recent clinical symptoms observed in their pigs within the year prior to the study. Diarrhoea, lack of appetite and coughing featured among the top three (Fig. 3). Thirty-three percent of the farmers declared having experienced ASF outbreaks in the course of the year prior to the study, with most cases reported in the R-R VCDs (78.9%). The most common action taken by farmers when their pig herds were affected by an ASF outbreak was to call a village veterinarian or para-veterinarian for treatment (51.0–69.0%). Up to 20.0% of farmers, however, got rid of the animals by selling both healthy and sick pigs (referred throughout the manuscript as panic sales) (Table 5). It was reported by farmers that during outbreaks, traders bought pigs at a cheaper price. Furthermore, traders were reported to slaughter sick pigs in the village from where they bought them and transported the meat to butchers in the trading centre. This practice was to prevent pork dealers from establishing the health status of the pigs. Some traders operated during night to avoid being identified by the community as trading sick pigs, or to escape sanitary control check points.

Protected areas and wild animals reported by farmers

Twelve villages were located close to swamps, wetlands, rivers and forest reserves (Table 1).The most common wild animals reported were: squirrels (*Xerus* spp.), monkeys (*Chlorocebus aethiops*), wild dogs (*Lycaon* spp.) and cats (*Caracal caracal*), foxes (*Vulpes* spp), antelopes (*Aeopyceros melampus*) and leopards (*Panthera pardus*) (Fig. 4). Wild pigs were reported by five farmers from three villages neighbouring swamps, lakes and forests, namely: Bukyonza in Kamuli, Kyoga in Mukono and Lukindu in Masaka. The majority of farmers who reported presence of wild animals in their villages (2/3) declared that the animals roamed close to their homesteads. One of those villages (Lukindu), located in Masaka district, is known to be a hotspot region for ASF outbreaks (personal communication from the district veterinary officer).

Risk factors associated with ASF outbreaks

Twenty-five variables related to demographic characteristics and husbandry practices and 28 variables related to self-reporting biosecurity practices or the presence of potential vectors for ASF virus (ASFV) were included in the univariable regressions. Seventeen variables were significant ($P \leq 0.25$) and therefore included in the multivariable analysis, which retained seven variables in the final regression model. Factors that positively correlated with recent ASF outbreaks were prompt disposal of dead pigs at farms ($P < 0.001$, OR = 2.2), wild animals present in the village ($P < 0.001$, OR = 1.7) and farmers sourcing drugs from stockists ($P < 0.001$, OR = 1.6); while factors which correlated negatively included the presence of perimeter fences ($P = 0.03$, OR = 0.5), attendance of farmer at secondary-school level and above ($P < 0.001$, OR = 0.6), routine cleaning of pig pens ($P < 0.001$, OR = 0.6) and pigs being the only farm animal kept by the farmer ($P = 0.01$, OR = 0.7) (Table 6).

Table 4. Husbandry practices

Value chain domain	RR	RU	UU	Total
Origin of pigs introduced to the herd				
Gift from development projects	24 (3.5)	18 (12.7)	13 (6.1)	55 (5.2)
Born from previous stock	165 (23.7)	35 (25.0)	51 (23.9)	251 (24.0)
Gift from fellow farmers	11 (1.6)	0 (0.0)	4 (1.9)	15 (1.4)
Loan	2 (0.3)	2 (1.3)	1 (0.5)	5 (0.5)
Pay for boar service	6 (0.9)	10 (7.0)	1 (0.5)	17 (1.6)
Purchased	487 (70.0)	77 (54.0)	143 (67.1)	707 (67.3)
Total	695 (100.0)	142 (100.0)	213 (100.0)	1050 (100.0)
Confinement types				
Free range	12 (1.5)	3 (1.7)	1 (0.4)	16 (1.3)
Intensive in corrals	265 (34.1)	72 (40.4)	210 89.0)	547 (45.9)
Tethering	504 (64.4)	103 (57.9)	25 (10.6)	632 (52.8)
Total	783 (100.0)	178 (100.0)	236 (100.0)	1195 (100.0)
Breed types				
Local	141 (19.0)	26 (15.0)	20 (9.0)	187 (16.0)
Crossed	394 (54.0)	137 (76.0)	159 (72.0)	690 (61.0)
Exotic	198 (27.0)	16 (9.0)	42 (19.0)	256 (23.0)
Total	733 (100.0)	179 (100.0)	221 (100.0)	1133 (100.0)
Pig feeding practices				
Commercial feeds	8 (1.0)	5 (2.8)	5 (2.0)	18 (1.5)
Crops residues	70 (9.0)	33 (18.5)	19 (8.0)	122 (10.2)
Pastures	11 (1.4)	0 (0.0)	2 (1.0)	13 (1.1)
Swill	5 (0.6)	2 (1.1)	1 (0.4)	8 (0.7)
Crop residues + pasture	102 (13.0)	41 (23.0)	8 (3.4)	151 (12.6)
Crop residues + swill	194 (25.0)	26 (14.6)	80 (34.0)	300 (25.1)
Crops residues + commercial feeds	391 (50.0)	71 (40.0)	121 (51.2)	583 (48.8)
Total	781 (100.0)	178 (100.0)	236 (100.0)	1195 (100.0)
Routine disease prevention measures practised by farmers				
Parasite control	517 (66.9)	60 (33.7)	88 (37.3)	665 (56.0)
Iron injection	24 (3.1)	1 (0.6)	2 (0.8)	27 (2.3)
Parasite control + vitamins	208 (26.9)	115 (64.6)	141 (59.7)	464 (39.1)
None	24 (3.1)	2 (1.1)	5 (2.1)	31 (2.6)
Total	773 (100.0)	178 (100.0)	236 (100.0)	1187 (100.0)
Most common dewormers used by farmers				
Albendazole	350 (44.8)	53 (29.8)	37 (15.7)	440 (36.8)
Ivermectin	172 (22.0)	69 (38.8)	163 (69.1)	404 (33.8)
Levamisole chloride	60 (7.7)	42 (23.6)	21 (8.9)	123 (10.3)
Others	18 (2.3)	0 (0.0)	0 (0)	18 (1.5)
Don’t know	181 (23.2)	14 (7.9)	15 (6.4)	210 (17.6)
Total	781 (100.0)	178 (100.0)	236 (100.0)	1195 (100.0)
Source of treatment for the pigs				
Farmer	4 (0.5)	1 (0.6)	1 (0.4)	6 (0.5)
Para-veterinarian	316 (40.5)	141 (79.2)	174 (74.0)	631 (52.8)
Agro-vet drug shop	364 (46.5)	32 (18.0)	46 (19.6)	442 (37.0)
Village veterinarian	98 (12.5)	4 (2.2)	14 (6.0)	116 (9.7)
Total	782 (100.0)	178 (100.0)	235 (100.0)	1195 (100.0)

Values presented are absolute numbers and percentages are in brackets.

Model diagnostics

Diagnostic evaluation of the final regression model was carried out. The village level residuals were all quite small (between −1 and +1), indicating that, after the district was accounted for, there was not a lot of variation between villages. This was also shown by the quite small value for the village level variance in the final model. Therefore, the fixed effects had very little effect on the size of this variance, which means there was still limited variation between villages even if the fixed effect was removed from the model.

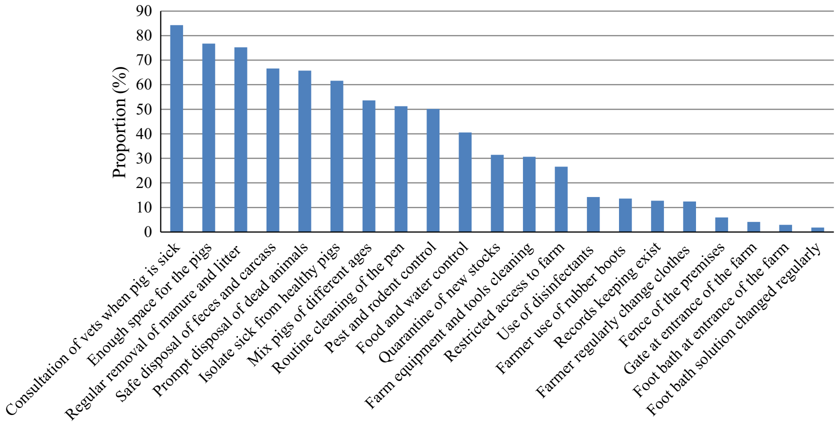

Fig. 2. Self reporting biosecurity practices by farmers (n = 1195).

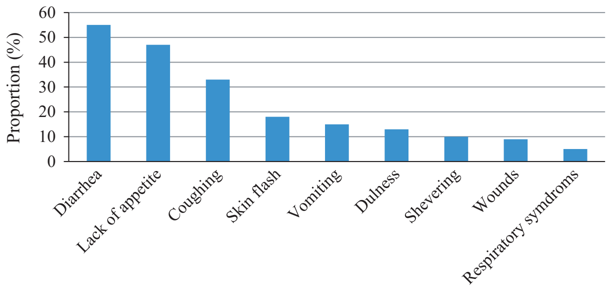

Fig. 3. Frequency of clinical signs reported by farmers on their pigs (n = 1195).

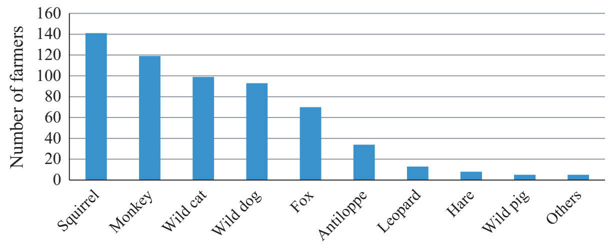

Fig. 4. Wild animals reported in the villages where outbreaks of ASF occurred. Squirrel (*Xerus* spp.); monkey (*Chlorocebus aethiops*); wild dog (*Lycaon* spp.); wild cat (*Caracal caracal*); fox (*Vulpes* spp.); antelope (*Aeopyceros melampus*); leopard (*Panthera pardus*); hare (*Lepus* spp.); wild pigs: bushpig (*Potamochoerus larvatus*) or warthog (*Phacochoerus africanus*); *others* (rodent, edible rat and snake).

Table 5. Practices of farmers when affected by ASF outbreak

Action in case of ASF	RR	RU	UU	Total
Call village vet	218 (69.2)	16 (51.6)	27 (55.1)	261 (68.1)
No action	11 (3.5)	0 (0.0)	1 (2.0)	12 (3.0)
Own treatment	37 (11.7)	5 (16.1)	2 (4.1)	44 (11.1)
Sell only apparently healthy pigs	3 (1.0)	0 (0.0)	4 (8.2)	7 (1.8)
Sell both healthy and sick pigs	23 (7.3)	5 (16.1)	10 (20.4)	38 (9.6)
Sell only sick pigs	23 (7.3)	5 (16.1)	5 (10.2)	33 (8.4)
Total	315 (100.0)	31 (100.0)	49 (100.0)	395 (100.0)

Values presented are absolute numbers and percentages are in brackets.

Table 6. Multivariable logistic regression analysis of risk factors associated with ASF outbreaks on pig farm

Variables	Odds ratio	*P*-value	95% confidence interval
Farmer attended at least secondary school	0.6	<0.001	0.5–0.8
Drug sourced from stockist	1.6	<0.001	1.2–2.2
Farmer kept pigs only	0.7	0.010	0.5–0.9
Presence of wild animals in the village	1.7	<0.001	1.3–2.3
Prompt disposable of dead animals at farm	2.2	<0.001	1.7–3.1
Routine cleaning of the pig pen	0.6	<0.001	0.5–0.8
Fence around the premises	0.5	0.030	0.3–0.9

Discussion

In Uganda, ASF is the most feared pig disease among farmers (Dione et al., 2014b). They face enormous economic losses following outbreaks. Besides keeping pigs, farmers tend to diversify their sources of income by cultivating crops or keeping other livestock species as a strategy to cope with shocks resulting from losses due to disease outbreaks (including ASF) and other unforeseen events. However, some farmers may only keep pigs because they lack financial capacity to take care of other livestock species or did not have enough land. Pig keeping as the sole livestock activity by the farmer was a protective factor against ASF in our study. Probably, this type of farmer might have had more time to take care of his pigs and hence was able to apply better biosecurity measures.

As it is the case in other parts of the country, pig husbandry is dominated by tethering and free range systems in rural and intensive/confinement systems in peri-urban and urban settings (Muhanguzi et al., 2012; Dione et al., 2014b). However, husbandry systems usually correlate with seasonality as most of the time free range is practised during dry seasons when there is no crop cultivation activity. Free range exposes animals to disease because it brings them in contact with vectors and roaming pigs that might be harbouring infectious pathogens. Farmers practise the free range system for several reasons, including lack of financial support to construct housing or a lack of feeds; hence, they allow pigs to scavenge for food (Dione et al., 2014b). Farm perimeter fencing which has been shown in our study to be a protective factor against ASF is a good practice. It minimizes the interaction of pigs with the external environment and hence reduces their exposure to disease. However, in most rural areas included in our study, fencing of premises is a taboo. It is believed that if someone fences his or her premises, then he or she is selfish, and therefore could be isolated or expelled by the community. Consequently, most homesteads remained open, exposing their animals to thieves, predators, roaming pigs and other stray animals. The absence of a perimeter fence could be overcome, for the purposes of controlling ASF, by constructing sturdy pens for the pigs using affordable local materials. The neighbours are unlikely to object to that because it would protect their crops and gardens from the pigs. Total confinement should then be promoted alongside activities that would ensure availability of feeds at an affordable cost to farmers especially during dry season, when the feed shortage is common.

Generally, self reported biosecurity measures are poorly or not implemented at all by farmers. Sharing of farming tools such as wheelbarrow, rakes and shovels was a frequent practice among farmers in rural areas where social interactions were stronger. However, there is a risk associated with this practice especially when the tools are not disinfected before they are used. Swill feeding which has been identified as a potential avenue of transmission for ASF in Uganda and Kenya (Nantima et al., 2015) is largely practised by farmers in the peri-urban areas probably because of their proximity to many restaurants and hotels. Poor feed (including undercooked swill) and water control have been also associated with ASF outbreaks which occurred between 2008 and 2011 in Nigeria (Fasina et al., 2012).

In our study, routine cleaning of the pig pens was a protective factor against ASF, while prompt disposal of pig carcasses was associated with increase in ASF outbreaks. Cleaning is a simple and basic hygienic measure that can reduce the burden of pathogens on farms. Through proper cleaning, faeces and other excreta in the farm are disposed off adequately. The importance of routine cleaning should be emphasized during the training of farmers on biosecurity measures, and farmers ought to be encouraged to buy cleaning materials. Most of the time, carcasses of pigs that have died of diseases were disposed off by farmers, but little information was provided on the method of disposal since the question was not asked during the survey. Yet the disposal method is critical to the assessment of this risk factor. In a study undertaken in six districts of Uganda, including in Kabarole, Mityana, Moyo, Mukono, Soroti, and Tororo, 90.0% of farmers interviewed stated that they disposed off sick and dead pigs by throwing their carcasses in the bush (Muhangi et al., 2014). Proper disposal of dead pigs through burying or burning of carcasses minimizes the risk of ASF dissemination (FAO et al., 2010). Although proper disposal of carcasses as recommended by FAO may be challenging given the fact that it may require human and financial resources, this should be also emphasized during training sessions for farmers. Strategies for supporting proper disposal of dead animals should be put in place by the district veterinary office in each district, especially given that most farmers may lack the capacity to do it by themselves.

Poor waste disposal and lack of hygiene in the slaughter slabs observed in the study areas has been reported in other parts of the country (Tejler, 2012; Muhangi et al., 2014). Poor management of slaughter waste, especially visceral organs, can create a favourable environment for ASFV dissemination since the virus can be contained in tissues and organs of infected pigs. Considering this property of the virus, there is a high risk of transmission when infected pork is distributed or shared with neighbours or traders, and when slaughter waste is discarded in places to which pigs and dogs have access. A recent study in Uganda showed that practices such as the indiscriminate disposal of pig viscera and waste materials after slaughter were the most plausible risk factors associated with the occurrence of ASF outbreaks (Kabuuka et al., 2014). Fasina et al. (2012) identified proximity to a place of slaughter as a significant risk factor for a farm to be infected by ASF in Nigeria. Inspection of pork and live pigs is not common in Uganda; therefore, the trading and processing of diseased animals may occur. Several stakeholders in the pig value chain indicate that there are no clear regulations and guidance for the disposal of pig waste in Uganda (Worsley, 2013).

At the Uganda–Kenya border, outbreaks of ASF were associated with pig movement due to trade, as well as pig restocking, pig exchange with neighbouring districts (Nantima et al., 2015). Although it was not found to be a significant risk factor in the study, panic sales practised by farmers during outbreaks of ASF may play an important role in the spread of the disease. Similar practices were reported in other parts of Uganda (Muhangi et al., 2014). While most farmers can recognize the clinical signs associated with ASF (Dione et al., 2014b; Chenais et al., 2015), they intentionally fail to report suspected cases because they feared losing their pigs following quarantine imposition, as there is no compensation scheme offered to them by the government. Such practices are probably among the key drivers of the rapid spread of the disease in Uganda. Moreover, when a quarantine is imposed in an area, farmers and other value chain actors (especially pig traders and butchers) may not have other income generating activities that can substitute the pig business while they wait for the quarantine to be lifted; this makes them act desperately by carrying out panic sales.

Animal health service providers (drug stockists, veterinarians and para-veterinarians) are important actors in the spread of the disease, because of their numerous movements between farms and villages. The majority of farmers sourced drugs from agro-vets, drug stockists and para-veterinarians. Some actors in this category are neither qualified veterinarians nor licensed drug sellers (Dione et al., 2014a). It has been shown that majority of drug stockists in the study area also provide advisory services to farmers and administer treatments to their pigs, in addition to selling them drugs. The fact that farmers sourcing drugs from stockists has been associated with an increase of ASF outbreaks in our study could be related to several factors: (i) farmers may not be getting the right advice from the drug stockists; (ii) the drug stockists may also be playing the role of the para-veterinarians, moving from farm to farm treating the pigs of their clients, thus spreading the disease in the cases where they do not apply proper biosecurity measures, such as the disinfection of materials, especially syringes.

Previous studies showed that insufficient knowledge of husbandry practices and pig management was among the priority constraints faced by pig farmers in Uganda (Dione et al., 2014b). However, the fact that some farmers had been educated up to secondary-school level and above was a protective factor against an ASF outbreak and an indication of how much knowledge can positively impact on practices. However, even without formal education, some farmers still have access to knowledge on good general husbandry practices through training they receive from rural development partners. Nevertheless, farmers who received a formal education may have more opportunities to access knowledge on biosecurity because of their background. The low level of education coupled with poor access of farmers to training on piggery can have a negative impact on the management and sustainability of piggery as a business, because most farmers in this category may fail to apply good husbandry practices due to their ignorance. The training of farmers is key in order to equip them with knowledge on ASF control. This should be carried out through national organizations in charge of capacity building together with NGOs.

In our study, the presence of wild animals in the village was associated with increased outbreaks of ASF. The role of warthogs and Ornithodoros moubata complex ticks is well known, while the role of bushpigs if anything is unclear. However, the direct transmission of ASFV from acutely experimentally infected bushpigs to in-contact domestic pigs has been demonstrated experimentally (Anderson et al., 1998). It is important to note that no specification was given for the species of wild animals in the multivariate logistic regression model, which could have caused a bias towards an overestimation of this risk factor. Moreover, farmers did not differentiate between bushpigs and warthogs since the same local name is used for both. Nevertheless, the presence of wild animals in the village showed that farmers live at the edge of a protected area, where interactions between wild and domestic pigs can occur. Such interactions can be minimized through total confinement as described earlier.

Two of the strengths of this study were the farm selection process and the large sample size. The study sites represented areas with high levels of pig production, but also high levels of poverty. Random sampling of villages and households ensured representativeness of households in those sites. Data were collected at the farm (household) level and inclusion of a large number (~1200) of households ensured that the study is well capable of detecting farm-level risk factors for ASF.

The two main limitations of the study related to the need to rely on clinical symptoms for diagnosis of ASF and the inability of a cross-sectional study to differentiate between causes and effects (consequences) of an ASF outbreak. Reliance on clinical symptoms and farmer reporting of ASF outbreaks will likely have biased observed associations towards the null, so estimates reported are likely to be underestimates of true effects (this is discussed further below). In a cross-sectional study such as this, it is not possible to determine whether husbandry factors found to be associated with ASF were risk factors for the outbreak (i.e. were in place before the outbreak) or were implemented as a consequence of the outbreak. For example, we found that producers who promptly disposed of dead pigs were more likely to suffer an ASF outbreak. However, it may well be the case that producers who had an ASF outbreak implemented prompt disposal of dead pigs. For other practices (e.g. presence of wild animals in the village), it was unlikely that a producer could have changed this risk factor as a consequence of an outbreak. As such, the bias introduced by misclassification will have been towards the null (Dohoo et al., 2009). While misclassification may have occurred, in the situation where there is lack of capacity to confirm the disease at the time of an outbreak, basing case detection on clinical symptoms is the best option.

This study highlighted production constraints that urgently need to be addressed. Poor management and husbandry practices play a crucial role in increasing the risk of transmission of highly infectious diseases such as ASF. Further studies assessing the capacities and incentives of value chain actors to adopt biosecurity measures should be implemented. Findings from subsequent studies can significantly guide potential interventions for the control of ASF along the pig value chain in Uganda.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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