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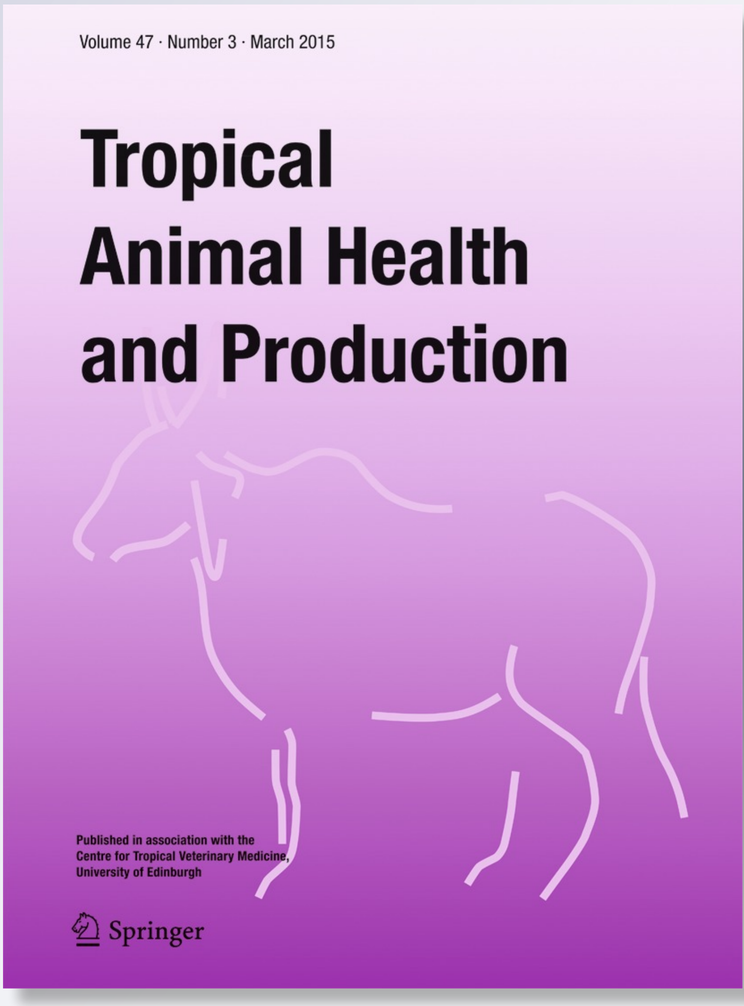

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REGULAR ARTICLES

Risk factors associated with occurrence of African swine fever outbreaks in smallholder pig farms in four districts along the Uganda-Kenya border

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Abstract A cross-sectional survey was carried out to assess risk factors associated with occurrence of African swine fever (ASF) outbreaks in smallholder pig farms in four districts along Kenya-Uganda border. Information was collected by administering questionnaires to 642 randomly selected pig households in the study area. The study showed that the major risk factors that influenced ASF occurrence were purchase of pigs in the previous year ($p<0.000$) and feeding of pigs with swill ($p<0.024$). By employing cluster analysis, three clusters of pig production types were identified based on production characteristics that were found to differ significantly between districts. The most vulnerable cluster to ASF was households with the highest reported number of ASF outbreaks and composed of those that practiced free range at least some of the time. The majority of the households in this cluster were from Busia district in Uganda. On the other hand, the least vulnerable cluster to ASF composed of households that had the least number of pig purchases, minimal swill feeding, and less treatment for internal and external parasites. The largest proportion of households in this cluster was from Busia district Kenya. The study recommended the need to sensitize farmers to adopt proper biosecurity practices such as total confinement of pigs, treatment of swill, isolation of newly purchased pigs for at least 2 weeks, and provision of incentives for farmers to report suspected outbreaks to authorities and rapid confirmation of outbreaks.

Keywords African swine fever · Smallholder systems · Pigs · Uganda · Kenya

Introduction

African swine fever (ASF) is a highly infectious and most lethal transboundary disease of pigs which causes devastating effects to the pig industry, globally. ASF used to be primarily a disease occurring in Africa; however, following accidental introduction of the disease to Georgia in 2007, the disease has remained uncontrolled and it has spread to other countries in eastern Europe (Costard et al. 2013). This has drawn international attention to the serious threat that the disease poses to global food security. In sub-Saharan Africa, ASF is endemic in at least 26 countries where it causes devastating impacts to the livelihoods of smallholder farmers (Penrith et al. 2013; Muhangi et al. 2014). There is currently no cure or vaccine to combat the ASF menace, which causes 100 % mortality in a naïve pig population (Bishop 2010; Atuhairwe et al. 2013). The current control measures are implementation of biosecurity measures along the entire pig value chain. These measures include the following: improved hygiene, separating sick pigs from healthy ones, movement control, proper treatment of household leftovers, and proper disposal of dead pigs

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among others (FAO 2010). At the production node, implementation of biosecurity measures is feasible for pigs under confined systems. However, smallholder pig farmers find it difficult to fully comply with these proposed biosecurity measures because of the nature of their production systems which are characterized by poor housing and husbandry practices. Because of that, ASF has continued to occur in the region and it is currently endemic in Kenya and Uganda (Muhangi et al. 2014). The widespread occurrence of ASF outbreaks in Kenya (Monda et al. 2012) and Uganda (Atuhairwe et al. 2013) in the past shows that the control measures being used currently are not effective. Despite the devastating effects of the disease, there is limited evidence on the risk factors associated with the transboundary nature of ASF in smallholder pig farmers especially along Kenya-Uganda border. Advanced genomic studies done on isolated strains of ASF virus using the sequence analysis of the central variable region (CVR) from Ugandan isolates during outbreaks in 2007 identified 22 different tetrameric amino acid units. This was identical to the sequence of six isolates responsible for the second wave of infections that occurred in Western and Central Kenya from October 2006 to January 2007. This suggests that ASFV exchange between the two countries might have occurred on more than one occasion (Gallardo et al. 2011). The objective of this study was therefore to identify the risk factors associated with the occurrence and spread of ASF among smallholder pig farmers along Kenya-Uganda border using survey data, in order to generate information that would guide policy in developing appropriate strategies for prevention and control of ASF.

Material and methods

Study area

The study was carried out along Kenya-Uganda border in the districts of Tororo and Busia (Uganda) and Busia and Teso (Kenya), an area extending 75 km north from Lake Victoria.

Study design

Data was collected through desk reviews and household cross-sectional surveys using in-person questionnaire interviews. The desk reviews involved collation of secondary data on ASF prevalence, veterinary services, policies and strategies for ASF control, pig production systems, institutional arrangements, and socioeconomic indicators. The household surveys were conducted between 12 July and 30 November 2012. The target respondents were household heads in pig-keeping households. The questionnaire was designed by a multidisciplinary team comprising economists, veterinary epidemiologists, practicing veterinary scientists in research and policy roles, a molecular biologist, a mathematician, a social ecological systems scientist, and a geographer. The aspects covered in the questionnaire included household information, pig production systems, socioeconomic indicators, ASF awareness, biosecurity practices, access to advisory services, and social networks.

Sampling design

Twenty pig-keeping households were randomly sampled from each of the 32 selected villages, yielding a total of 640 households. The villages were sampled through randomized cluster design. The sample size was influenced by resources available for the cross-sectional survey. The sample size was also guided by Magningi (1997), who proposes determining a sample size for random sampling according to Eq. 1 and then multiplying by a factor of 2 for cluster sampling to account for design effect.

$$n = z^2 \mathrm{x} p(1-p)/m^2 \quad (1)$$

where n = sample size, z = confidence level at 95 % (standard value of 1.96), p = estimated prevalence of ASF in the project area, and m = margin of error at 5 % (standard value of 0.05).

Using an estimated prevalence of ASF in pigs of 0.3 (Okoth et al. 2013), a sample size of 645 households resulted after design effect of cluster sampling was accounted for as indicated above. The methodology used to select households was based on a two-stage sampling process.

Village clusters were selected by spatial random sampling executed using GIS and the 2008 Kenya and 2010 Uganda administrative boundaries, the most recent available data sets in mid-2012. Villages were selected within level 3 administrative units that had any part of their boundary within 25 km of Kenya-Uganda border. Level 3 units correspond to location and sub-county in Kenya and Uganda, respectively (Table 1). In Uganda, for each district (level 2 administrative unit), four level 3 administrative units (sub-counties) were selected being sub-counties that contained one of the four random points in each level 2 administrative unit that were generated using GIS. In Kenya, for each district (level 2 administrative unit), four level 3 administrative units (locations) were also selected using the above criteria. With each selected level 3 administrative unit in each country, two level 4 administrative units being parishes in Uganda and sub-locations in Kenya that contained one of the two random points were selected. One of these level 4 administrative units was randomly selected. For the selected level 4 administrative units in Kenya and Uganda, lists of villages and number of households keeping pigs were obtained assisted by veterinary officers and local chiefs. A criterion was

Table 1 Descriptive analysis of the proportions of variables in the clusters

Variable	Descriptive values	Clusters			Total
		1	2	3	
N		417	174	48	639
Number of pigs purchased last year	Mean	0.59	2.50	1.00	1.14
	SD	0.63	1.43	0.92	1.26
Pig management system (1 = free range, 0 = otherwise)	Mean	0.37	0.33	0.46	0.37
	SD	0.48	0.47	0.50	0.48
Households feeding swill to pigs (1 = yes, 0 = otherwise)	Mean	0.19	0.29	0.25	0.22
	SD	0.39	0.46	0.44	0.42
Treatment of internal parasites (1 = yes, 0 = otherwise)	Mean	0.66	0.77	0.67	0.69
	SD	0.48	0.42	0.48	0.46
Treatment of external parasites (1 = yes, 0 = no)	Mean	0.63	0.62	0.58	0.62
	SD	0.48	0.49	0.49	0.49
Usage of disinfectant's for biosecurity (1 = yes, disinfectants, 0 = no)	Mean	0.04	0.06	0.06	0.05
	SD	0.19	0.23	0.25	0.21
No. of ASF outbreaks experienced by a household	Mean	0.14	0.26	5.21	0.56
	SD	0.39	0.64	2.29	1.54
District—Busia_Ke	Mean	0.32	0.1	0.15	0.25
District—Busia_Ug	Mean	0.15	0.44	0.38	0.24
District—Teso_Ke	Mean	0.26	0.27	0.15	0.25
District—Tororo_Ug	Mean	0.26	0.18	0.33	0.26
Household head age (years)	Mean	45.81	44.51	43.79	45.30
	SD	14.73	12.17	13.28	13.97
Household head gender	Males	0.84	0.87	0.96	0.86
	Females	0.15	0.13	0.04	0.14
Household head education (number of years of schooling)	Mean	8.66	9.08	8.17	8.74
	SD	3.82	4.18	3.86	3.93
BestEduc_H/h member (number of years of schooling)	Mean	10.88	11.06	11.37	10.97
	SD	3.06	3.21	3.11	3.10
Household head occupation (1 = farmer 0 = otherwise)	Farmer	0.68	0.67	0.73	0.68
	otherwise	0.32	0.33	0.27	0.32
Pig herd size (local)	Mean	2.14	2.38	1.52	2.16
	SD	2.73	2.04	0.95	2.47
Pig herd size crosses	Mean	0.24	0.34	0.25	0.27
	SD	1.12	1.27	0.84	1.15
Total household pig size	Mean	2.39	2.72	1.77	2.43
	SD	2.79	2.11	0.99	2.53
Total household Income	Mean	626.45	652.09	685.65	637.90
	SD	1218.71	1401.34	1190.29	1267.21
Access to veterinary Services	Yes, vet	0.06	0.05	0.10	0.06
	Otherwise	0.94	0.95	0.90	0.94
Whom do you trust when you have problem in pig keeping (1 = veterinary 0 = otherwise)	Veterinarian	0.10	0.07	0.13	0.09
	Otherwise	0.90	0.93	0.88	0.91
Average income/pig	Mean	25.33	27.56	31.47	26.40
	SD	50.11	46.81	51.78	49.32

adopted such that each of the villages had at least 20 pig-keeping households to be selected for sampling. Where more than two villages of at least 20 pig-keeping households existed in selected level 4 administrative units, then two villages of this size were randomly selected. In villages that had less than 20 pig-keeping households, the selection was extended to include households from adjoining villages to make up a total of about 20 households across a contiguous area. In total 32, villages' clusters were randomly sampled.

Data analysis

Cluster analysis using SPSS version 14 was applied in this study to identify different clusters of pig farmers based on a priori hypothesized risk factor variables from the survey data. These variables included the following: (i) management systems (free range vs tethering), (ii) feeding (swill feeding vs otherwise), (iii) number of pig purchases during the last 1 year, (iv) biosecurity practices (use of disinfectant or not), and (v) treatment for internal and external parasites and district of origin (location fixed effects). Cluster analysis allows identification of different groups, characterized by maximal within-group homogeneity and between-group heterogeneity (Punj and Steward 1983). In the first step, Ward's hierarchical clustering method, based on squared Euclidean distances, was used to determine the number of clusters. This agglomerative method works stepwise to combine pairs of individual observations or clusters while minimizing within cluster variance. For our analysis, a three cluster solution provided optimal balance between parsimony and homogeneity. We then analyzed how these clusters differ in terms of number of ASF outbreaks experienced by a household and other socioeconomic and resource factor variables including (i) household head characteristics namely education level, occupation, age, gender, and number of years of schooling; (ii) best educated member of the household; (iii) number of adults in the household; (iv) experience in pig keeping; (v) access to credit; (vi) household income; (vii) average income per pig; (viii) herd size; (ix) exposure to veterinary services; (x) access to information sources; (xi) type of housing; (xii) land size; and (xiii) social capital.

Using one-way ANOVA, further analysis was done to test for levels of significance amongst the clusters. Post hoc analysis was done to determine which clusters were different and to identify sources of differences between the clusters. The results generated using risk-based variables were compared with resource factors to further determine the cause of differences among the clusters. Comparison was made by using cross tabulations for categorical variables and comparing means for continuous variables.

Results

Descriptive statistics was done to show the proportion of different variables in each cluster, and the results are shown in Table 1. Three clusters were produced based on vulnerability to ASF. Cluster 1 composed of the least vulnerable households. These were characterized by least number of pig purchases, minimal swill feeding, and less treatment for internal and external parasites. The majority of the households in this cluster were from Busia and Teso districts in Kenya. Cluster 3 composed of the most vulnerable households to ASF. The largest proportion of the households practiced free range and had the highest number of ASF outbreaks. The majority of the households in this cluster were from Busia and Tororo districts in Uganda.

Variables that were significant were as follows: number of pigs purchased last year ($p<0.000$), swill feeding ($p<0.024$), treatment for internal parasites ($p<0.024$), number of ASF outbreaks ($p<0.000$), and location (Busia district Uganda and Kenya) as shown in Table 2.

Differences among clusters were noted with the following variables as shown in Table 3: Clusters 1 and 2 were different with regard to swill feeding and districts of Busia Kenya and Uganda. Clusters 1 and 3 were different with regard to number of outbreaks. Clusters 2 and 3 were also different with regard to number of ASF outbreaks. The risk of ASF outbreaks among households in cluster 3 was five times higher than in other clusters. Clusters 1 and 2 were different regarding the number of treatment for internal parasites.

Discussion

The major risk factors that influenced ASF outbreak occurrence were purchase of pigs in the previous year and feeding pigs with swill (Table 2). Purchase of pigs was shown to be a major risk factor associated with introduction of ASF into farms since; in most cases, the health status of the new pigs would be unknown. These results were in agreement with findings in Nigeria (Fasina et al. 2012) and in Uganda (Kabuuka et al. 2014; Muhangi et al. 2014) where movement of pigs was found to be a high risk factor to ASF occurrence. Rumors of ASF outbreaks frequently lead farmers to sell off their pigs rather than dying from the disease resulting in accelerated movement of pigs. This observation was in agreement with findings in Uganda (Muwonge et al. 2012; Dione et al. 2014). The habit of selling pigs during outbreaks has serious implications on the spread of the virus between countries, since sale of pigs occurs between countries.

Swill feeding was found to be a high significant risk factor, as it increased the risk of introduction of ASF virus into farms. The majority of the households feeding swill were not aware that they were supposed to treat swill. Studies in Nigeria (Fasina et al. 2012) also showed swill feeding as an important risk factor in ASF occurrence. Feeding constituted a major

Table 2 The level of significance among the variables using one-way ANOVA

Variable		Sums of squares	Mean square	*F*	Significance
Number of pigs purchased last year	Between groups	451.153	225.577	255.858	0.000
	Within groups	560.728	0.882		
	Total	1011.881			
Pig management system (1 = free range, 0 = otherwise)	Between groups	0.599	0.300	1.290	0.276
	Within groups	147.710	0.232		
	Total	148.310			
Households feeding swill (1 = yes, 0 = no)	Between groups	1.294	0.647	3.572	0.024
	Within groups	109.704	0.172		
	Total	110.998			
Treat for internal parasites (1 = yes, 0 = no)	Between groups	1.594	0.797	3.742	0.024
	Within groups	135.433	0.213		
	Total	137.027			
Treat for external parasites (1 = yes, 0 = no)	Between groups	0.100	0.050	0.212	0.809
	Within groups	149.759	0.235		
	Total	149.859			
Disinfectants (1 = yes, 0 = no)	Between groups	0.060	0.030	0.691	0.502
	Within groups	27.624	0.043		
	Total	27.684			
No. of ASF outbreaks	Between groups	1125.370	562.685	940.747	0.000
	Within groups	380.408	0.598		
	Total	1505.778			
District—Busia_Ke	Between groups	6.525	3.263	18.297	0.000
	Within groups	113.412	0.178		
	Total	119.937			
District—Busia_Ug	Between groups	11.663	5.832	34.907	0.000
	Within groups	106.252	0.167		
	Total	117.915			
District—Teso_Ke	Between groups	0.607	0.303	1.611	0.201
	Within groups	119.828	0.188		
	Total	120.435			

constraint to smallholder pig production in developing countries (Kagira et al. 2009; Mutua et al. 2012; Ouma et al. 2014). Availability and accessibility of good quality feeds was a big problem to smallholder pig farmers. Because of that, usage of swill was high in farms that had access to it especially in peri-urban and urban areas. However, it should be emphasized that swill treatment is the most appropriate way of avoiding the introduction of the virus in farms.

Significant differences noted among the three clusters with regard to number of ASF outbreaks could have been attributed by some risk factors. For instance, households in cluster 1 that had purchased the least number of pigs reduced their risk to ASF compared to the other two clusters. Household heads in this cluster could have been more knowledgeable about ASF and therefore paid more attention to pig management. On the other hand, cluster 3 that was most vulnerable had the majority of the households practicing free range which increased ASF risk into these farms. Households in this cluster were more vulnerable to ASF outbreaks compared to other clusters. Although cluster 2 had more households feeding swill, few of these households were affected by ASF outbreaks because few were practicing free ranging and had good management practices such as treatment of pigs for internal and external parasites which could have improved the health status of their pigs.

Location was very important, as farms in cluster 3 mainly located in Uganda were five times more likely to be largely affected by ASF compared to those in Kenya, and outbreaks were always starting from Uganda and moving to Kenya. Differences in ASF prevalence could have been due to pig population density. Households in Kenya had slightly fewer pigs compared to Uganda whose pig population density was

Table 3 Results to determine which variables differentiated the clusters using post hoc analysis

Dependent variable	Ward method (I)	Ward method (J)	Mean difference (I–J)	Standard error	Significance
Number of pigs purchased last year	1	2	−1.915	0.085	0.000
		3	−0.415	0.143	0.011
	2	1	1.915	0.085	0.000
		3	1.500	0.153	0.000
	3	1	0.415	0.143	0.011
		2	−1.500	0.153	0.000
Pig management system (1 = free range at least some of the time, 0 = otherwise)	1	2	0.036	0.043	0.686
		3	−0.089	0.073	0.446
	2	1	−0.036	−0.125	0.686
		3	−0.125	0.079	0.250
	3	1	0.089	0.073	0.446
		2	0.125	0.079	0.250
Households feeding swill (1 = yes, 0 = no)	1	2	−0.101	0.037	0.019
		3	−0.058	0.063	0.629
	2	1	0.101	0.037	0.019
		3	0.043	0.068	0.800
	3	1	0.058	0.063	0.629
		2	−0.043	0.068	0.800
Treat for internal parasites (1 = yes, 0 = no)	1	2	−0.113	0.042	0.019
		3	−0.010	0.070	0.990
	2	1	0.113	0.042	0.019
		3	0.103	0.075	0.355
	3	1	0.010	0.070	0.990
		2	−0.103	0.075	0.355
Treat for external parasites (1 = yes, 0 = no)	1	2	0.010	0.044	0.972
		3	0.047	0.074	0.074
	2	1	−0.010	0.044	0.972
		3	0.037	0.079	0.884
	3	1	−0.047	0.074	0.798
		2	−0.037	0.079	0.884
Disinfectants (1 = yes, 0 = no)	1	2	−0.019	0.019	0.567
		3	−0.024	0.032	0.728
	2	1	0.019	0.019	0.567
		3	−0.005	0.034	0.988
	3	1	0.024	0.032	0.728
		2	0.005	0.034	0.988
No. of ASF outbreaks	1	2	−0.123	0.070	0.184
		3	−5.067	0.118	0.000
	2	1	0.123	0.070	0.184
		3	−4.944	0.126	0.000
	3	1	5.067	0.118	0.000
		2	4.944	0.126	0.000
District—Busia_ Ke	1	2	0.220	0.038	0.000
		3	0.178	0.064	0.016
	2	1	−0.220	0.038	0.000
		3	−0.042	0.069	0.812
	3	1	−0.178	0.064	0.016
		2	0.042	0.069	0.812
District—Busia_ Ug	1	2	−0.296	0.037	0.000
		3	−0.229	0.062	0.001
	2	1	0.296	0.037	0.000
		3	0.068	0.067	0.569
	3	1	0.229	0.037	0.001
		2	−0.068	0.067	0.569
District—Teso_ Ke	1	2	−0.014	0.039	0.936
		3	0.111	0.066	0.216
	2	1	0.014	0.039	0.936
		3	0.124	0.071	0.185
	3	1	−0.111	0.066	0.216
		2	−0.124	0.071	0.185

very high thus increasing the risk. This was in agreement with a study done in Nigeria where high-pig-density-producing regions were found to be perpetually infected with ASF (Fasina et al. 2012).

It was noted that implementation of biosecurity practices was poorly adopted by farmers. Most farmers were not practicing biosecurity measures. Similar findings were reported in a study in Uganda (Kabuuka et al. 2014; Muhangi et al. 2014). This therefore shows the strong need to sensitize farmers to adopt proper biosecurity practices to reduce their vulnerability to ASF. Efficient pathways and incentives for farmers to report suspected outbreaks should be put in place. Rapid mechanism for confirmation of outbreaks and rapid quarantine responses should be available at community level.

The findings from this study show the need for designing and implementing strategies to guide farmers, policy makers, and planners to improve ASF control which would result in increased pig productivity and sustainability of off-take rates, with potentials for improving household incomes if combined with appropriate marketing strategies.

The results have implications for the design of ASF control and prevention strategies in Eastern Africa region. ASF being a transboundary disease that spreads very fast respecting no borders requires a regional approach in managing the disease. Efforts should therefore be directed toward designing coordinated regional approaches among contiguous countries for the control and eradication of the disease.

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Conflict of interest There is no conflict of interest identified.

Ethical standards The manuscript does not contain clinical studies or patient data. Involvement of human participants was in accordance with the ethical standards of the CSIRO Social Science Human Research Ethics Committee and ILRI Instititional Research Ethics Committee.

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