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UNDERSTANDING THE DRIVERS FOR COMMUNITY-BASED PREVENTION OF AFRICAN SWINE FEVER SPREAD: A CASE STUDY OF KASAWO AND KATOSI SUB COUNTIES, MUKONO DISTRICT, UGANDA

Savino Biryomumaisho[1*], Geoffrey Otuba[1], John Okongo[1], Frank Mwiine[2]

[1] Makerere University, School of Veterinary Medicine and Animal Resources, Uganda
[2] Makerere University, School of Biosecurity, Biotechnical and Laboratory Sciences, Uganda

Abstract

Pig production in Uganda is a thriving business as the demand for pork and pork products is increasing. Pork consumption per capita in Uganda is estimated to be 3.5 kg and is considered the highest in Africa. Pig production is, however, limited by several factors, including endemic diseases, particularly African swine fever (ASF), which can result in up to 100% mortality. The factors responsible for ASF outbreaks are poorly understood, especially at farm level. A study conducted in Kasawo and Katosi sub-counties between February and March 2023 aimed to examine biosecurity and husbandry practices on pig farms. A questionnaire was distributed to pig farmers and a Focus Group Discussion (FDG) of animal health care workers was held. Blood samples were collected from pigs of all ages and sex in the two sub counties and ASF virus antibodies were tested using competitive ELISA. Out of the 777 collected blood samples, none was seropositive for ASF virus antibodies. Of the 292 households sampled, 70% kept their pigs indoors, while only 0.7% had fenced enclosures, and 4% had functional foot baths. The FGD revealed that animal health workers, who were on daily calls, carried disinfectants to sanitize their personal protective equipment (PPE) every time they left a farm. The lack of centralized slaughter facilities was identified as a key factor contributing to the spread of the ASF virus, as well as the panic selling of pigs during suspected ASF outbreaks. Sharing boars, purchasing and stocking pigs without veterinary health certification

[1*] Corresponding Author: sbiryomumaisho15@gmail.com

were identified as contributing factors. The results from this study showed that although active ASF infections were not found in pigs, the district experienced ASF outbreaks in the past. The study concluded that educating farmers about the spread and prevention of ASF, ensuring ongoing disinfection of PPE by animal health professionals, and establishing pig slaughter facilities could help eliminate ASF transmission and spread in the area.

Key words: African swine fever virus, biosecurity, seroprevalence

FAKTORI KOJI DOPRINOSE PREVENCIJI ŠIRENJA AFRIČKE KUGE SVINJA U ZAJEDNICAMA: STUDIJA SLUČAJA U OKRUZIMA KASAVO I KATOSI, MUKONO DISTRIKT U UGANDI

Savino Biryomumaisho[1], Geoffrey Otuba[1], John Okongo[1], Frank Mwiine[2]

[1] Univerzitet Makerere, Fakultet veterinarske medicine i animalnih resursa, Uganda
[2] Univerzitet Makerere, Katedra za biosigurnost,
biotehničke i laboratorijske nauke, Uganda

Kratak sadržaj

Proizvodnja svinja u Ugandi predstavlja uspešan privredni sektor, jer potražnja za svinjetinom i svinjskim proizvodima konstantno raste. Procenjuje se da je potrošnja svinjskog mesa po glavi stanovnika u Ugandi 3,5 kg, što ovu zemlju čini liderom u Africi. Međutim, proizvodnja svinja suočava se sa izazovima, među kojima su endemske bolesti, a posebno afrička kuga svinja (AKS), koja može izazvati mortalitet i do 100%. Faktori koji dovode do izbijanja AKS slabo su istraženi, posebno na farmama. Istraživanja sprovedena u oblastima Kasavo i Katosi u periodu između februara i marta 2023. godine imala je za cilj da ispita biosigurnosne mere uzgoja svinja na farmama. Uzgajivačima svinja podeljeni su upitnici, a takođe je održana i Fokus grupa (FDG) sa radnicima iz polja zdravstvene zaštite životinja. Uzorci krvi su prikupljeni od svinja svih uzrasta i pola u dve oblasti, a antitela na virus AKS testirana su ELISA testom. Od 777 prikupljenih uzoraka krvi, nijedan nije bio seropozitivan na antitela na virus AKS. Od 292 uzorkovana domaćinstva, 70% je držalo svoje svinje u zatvorenom prostoru, dok je samo 0,7% imalo ograde, a 4% je imalo funkcionalne dezinfekcione bari-

jere. Fokus grupa (FGD) je ustanovila da su zdravstveni radnici nosili dezinfekciono sredstvo za čišćenje svoje lične zaštitne opreme svaki put kada bi napustili farmu. Nedostatak centralizovanih objekata za klanje prepoznat je kao ključni faktor koji doprinosi širenju virusa AKS, kao i panična prodaja svinja tokom sumnjivih izbijanja bolesti. Utvrđeno je da su deljenje nerastova, kupovina i držanje svinja bez veterinarske zdravstvene potvrde faktori koji doprinose širenju AKS. Rezultati ove studije pokazali su da, iako aktivne infekcije AKS nisu detektovane kod svinja, okrug je u prošlosti imao epidemije ove bolesti. Zaključak istraživanja je da bi edukacija farmera o širenju i prevenciji AKS, stalna dezinfekcije lične zaštitne opreme od strane stručnjaka za zdravlje životinja, kao i upotreba specijalnih objekata za klanje svinja, mogli značajno doprineti smanjenju prenošenja i širenja AKS u ovom području.

Ključne reči: virus afričke kuge svinja, biosigurnost, seroprevalenca

INTRODUCTION

Pig production in Uganda is a thriving business driven by the increasing demand for pork and pork products. Per capita consumption of pork in Uganda at 3.5 kg is the highest in East Africa (Roesel et al., 2019) and is considered the highest in Africa (Atherstone et al., 2021). Most pig farmers are smallholders, keeping 1 to 5 pigs that are tethered around their homesteads (Payne et al., 2022). Pigs are a source of additional income and offer several advantages over other types of livestock: their short production interval and high multiplication rates, little rearing space and ability to convert human food leftovers to calories depending on quantity and nutrient content. The pig industry, however, faces several challenges, including inadequate feed resources, a disorganized marketing system, and endemic diseases, notably African swine fever (ASF), which can result in up to 100% mortality (Kalenzi Atuhaire et al., 2013). Mukono district in central Uganda is among the districts that experienced numerous ASF outbreaks in the past (Ogweng et al., 2020). Epidemiological factors of spread of ASF are not well understood in the context of what is practiced along the pig value chain.

African swine fever (ASF) is an infectious disease that affects domestic and wild pigs of all breeds and ages, caused by ASF virus (ASFV), a member of the *Asfarviridae* family. The clinical symptoms vary from per acute, acute, subacute, to chronic, depending on the virulence of the virus. Acute disease

is characterized by high fever, haemorrhages in the reticuloendothelial system, and a high mortality rate (Ngan et al., 2023caused by ASF virus (ASFV). African swine fever (ASF) is one of the most complex infectious swine diseases. Notification of African Swine Fever (ASF) to the World Organization for Animal Health (WOAH) is mandatory due to its high mortality rate, rapid transmission, and significant sanitary and socioeconomic impact on the international trade of pigs and pork products. ASF has been endemic in over 20 sub-Saharan African countries and in Sardinia since the last century. ASFV has demonstrated its huge capacity for transboundary and transcontinental spread jumping to several hundreds of kilometers away such as Asia (China) and European region (Gallardo et al., 2019). The disease was first detected on the Italian island of Sardinia in 1978. ASF was detected in Georgia in 2007 (Gallardo et al., 2015) and spread to other countries.

African swine fever is endemic in Uganda and several outbreaks of ASF have been reported across the country (Atuhaire et al., 2013). The virus is transmitted through the known sylvatic cycle, domestic and wildlife cycles. African swine fever virus is a unique and complex DNA virus that is unrelated to other viruses, which has contributed to the challenges in developing a vaccine for the disease (Cukor et al., 2020). The virus is the only member of the *Asfarviridae* family and the only known DNA arbovirus. It has remained endemic in Africa since its discovery in Kenya in 1921 (Madden, 2021). The virus is maintained in a sylvatic cycle between *Ornithodoros* soft ticks and warthogs (*Phacochoerus africanus*) which do not develop clinical disease with ASFV infection; these ticks are widespread outside Africa, in parts of Europe and the Americas. Eradicating ASF, which is transmitted through the sylvatic cycle, is extremely difficult because soft ticks can survive for up to five years without feeding, while retaining a significant viral load (Sánchez-Vizcaíno et al., 2009). In addition, the virus can be maintained in soft ticks through sexual transmission, trans-ovarially, and transstadially, allowing the infection to persist without the need for pigs, and enabling it to sustain over long periods.

Another transmission cycle is the domestic cycle, which occurs due to the constant contact between domestic pigs. In this cycle, the infection is primarily spread through oronasal routes (Björnheden, 2011). An infected pig can continue to shed the virus for at least 30 days. Other transmission routes, particularly for spreading the disease to new areas, include swill-feeding with undercooked pork and the movement of contaminated fomites (Penrith and Vosloo, 2009). The virus can survive between 3-6 months in the environment. Contributing factors include stability of the virus in the environment and meat products, low awareness about the disease of pig farmers, laxity on farm bios-

ecurity practices and illegal movements of pigs and their products (Guinat et al., 2016).

Efforts to develop an effective vaccine have not been very successful in the past as vaccines failed to induce effective protective immunity. These have included inactivated DNA, subunit and adenovirus-vectored vaccines (Wu et al., 2021). Genome sequencing of the ASFV shows it is approximately 170-194kb and encodes 105-170 proteins whose functionality remains unclear according to Cackett et al. (2020). Cackett further states that due to its lack of neutralizing antibodies, ASFV is classified on the basis of capsid protein p72 encoded by viral B646L gene, generating 24 different genotypes. Promising live attenuated vaccines have shown protection against homologous challenges, but not against heterologous virus isolates. However, the issue of more virulent strains emerging remains a concern. In the absence of vaccines, observing biosecurity measures becomes the only viable option (Penrith, 2020).

In a serological survey of ASF in different districts in Uganda, Atuhaire et al. (2013) found a prevalence of 26% (47/181 pigs); however, prevalence of ASF in this study was much higher than results in other studies. In a study of slaughtered pigs in Mubende district, central Uganda, 38/997 pigs (3.8%) tested positive to ASF antibodies (Muwonge et al. 2012). Delgado-Baquerizo et al. (2013) collected blood samples from clinically sick pigs from central Uganda districts of Mukono, Wakiso and Nakasongola in a 2007 ASF outbreak, and none of the sera were positive for ASFV antibodies using recommended WOAH tests *viz.* conventional PCR and immunoblotting assays using an antigen lysate of ASF-infected cells. According to (Björnheden, 2011) in a study carried out in Rakai district in Southern Uganda, a much lower seroprevalence of 2.1% was reported among pigs brought for slaughter. Using archived samples from seven districts of Pallisa, Lira, Abim, Nebbi, Kabarole, Kibaale, and Mukono from 2001-2012, serological examination detected 6/39 positive samples and all of them originated from Abim district; samples from the other six districts (187/193, 96.9%) all tested negative (Kabuuka et al., 2023). However, 8.47% of tissue samples tested positive.

A clear understanding of these factors is essential for designing effective control measures. Mukono district was among those where frequent outbreaks of ASF had been reported in the recent past years (Ogweng et al., 2020). There is a lack of information regarding the epidemiological factors responsible for the outbreaks as well as the level of exposure of pigs to ASFV in Mukono district. Specifically, the biosecurity implementation practices across the entire pig value chain are not well-defined. The extent of the pig population's exposure to ASFV in Kasawo and Katosi sub-counties was not well understood,

nor were effective community-based ASF control strategies clearly defined. Therefore, this study aimed to understand the level of awareness of ASF among farmers, exposure of pigs to ASFV and the interventions aimed to control the spread of ASF. We aim to identify the risk factors behind the recurrent ASF outbreaks in Mukono district and analyze their connection to pig production and marketing systems. We intend to evaluate the extent of the application of biosecurity measures on farms and in villages as well as the role of carrier pigs in ASF epidemiology.

MATERIAL AND METHODS

Study Area

The study was carried out in Mukono District (0.2835° N, 32.7633° E), located in the Central region of Uganda. Mukono District covers an area of 2,986.47 square kilometers and is bordered by Buikwe District to the east, Kayunga District to the north, Wakiso District to the southwest, and Lake Victoria to the south (UBOS, 2017). Mukono district was selected because it has a very high number of pigs (181,846 pigs during the 2008 census), which has increased significantly from that time up until now. This situation contributes to an increased risk of disease outbreaks in the area, including ASF, providing a basis for this study to assess the current conditions and promote early detection. The district is composed of 15 sub-counties, 81 parishes, and 795 villages with a population of 596,804 people and 144,160 households (Mabaya et al., 2021). Katosi and Kasawo sub-counties were selected due to their high pig population, as reported by the District Veterinary Officer (DVO) of Mukono District, and because they have experienced African swine fever outbreaks in the past.

The research protocol was approved by the Department of Veterinary Pharmacy, Clinical and Comparative Medicine Academic Board meeting held on 29th September 2022 at the School of Veterinary Medicine and Animal Resources, Makerere University, Uganda. A consent was sought from each farmer before administering the questionnaire and taking a blood sample from their pigs.

Study on the population

The study was conducted among farmers who reared pigs in their homesteads or on pig farms. Questionnaire interviews were conducted with farmers who agreed to participate in the study and consented to the collection of blood samples from their pigs. Blood samples were collected from pigs of all ages

and both sexes. Any adult member of the selected household who interacted with the pigs participated in the interview, although preference was given to the head or owner of the pigs if they were present during the data collection.

Study design

The study was a cross-sectional study conducted on pig farms across two sub-counties Kasawo and Katosi in Mukono district, from February 2023 to March 2023. This study used a quantitative approach, where questionnaires were administered to farmers involved in the study, and blood samples were collected from the pigs on the farms of the interviewed farmers.

Sampling strategy

A snowball sampling technique was employed during data collection, where a farmer with a pig farm would refer to the research team to the next pig farmer they knew in the village. It was ensured that the whole sub-county would be represented by selecting farmers in each village in the various parishes.

Sample size

The sample size for the study was calculated using the formulae by (Das et al, 2016)

$$n=Z^2 P(1-P)/d^2$$

Taking a 95% confidence interval, the prevalence of 50% and desired absolute precision of 5%; where n was the required sample size; Z was the multiplier from a standard normal distribution (1.96) at a probability level of 0.05; P was the estimated prevalence at 50%, considering there was no reliable prevalence of ASF in the area, and d was the desired precision for the estimate (± 5%). A sample size of 385 pig farmers was required for this study. The sample size was equally divided into the two sub-counties. Pigs of all ages were sampled including piglets, growers, and adults from the pig farms.

Sample collection and laboratory sample analysis

A blood sample (2-4 mL) was collected from the anterior vena cava in

younger pigs (younger than 6 months) and from the jugular vein in older pigs into plain vacutainers, and it was stored in a cool box with ice packs and transported to the laboratory. Upon arrival at the laboratory, serum was carefully pipetted into cryotubes. In some cases, centrifugation was performed, and the serum was then stored at -20°C until analysis. The serum was analysed for presence of African swine fever IgG antibodies using commercial kits of competitive Enzyme-linked immunosorbent assay (c-ELISA). Optical densities against positive and negative controls were read using a digital ELISA reader. Positive cases cut-offs were calculated by subtracting the mean positive controls from mean negative controls and by dividing the difference with 0.5 according to the manufacturer's instructions. Mean negative cut offs were calculated by subtracting mean positive controls from mean negative controls and dividing the difference by 0.4.

A sample optical density was positive if the cell reading OD was less than the positive cut-off (0.953) and negative if the cell OD was greater than the negative cut-off point (1.128). A sample was considered suspicious if the cell OD was greater than the positive cut-off (0.953) but less than the negative cut-off (1.128).

RESULTS

The most common pig rearing system was intensively practiced by 62% of farmers. Free range (roaming) pig rearing was the least practiced by 1.7% of farmers. In both sub counties, only 21% kept local breeds of pigs. The rest kept crossbreeds with exotic breeds. The majority (57%) fed their pigs using feed troughs. In terms of cleaning, only a few farmers (39%) regularly cleaned the drinkers and feeders on a daily basis. Most households (97%) kept small pig herds sized between 1-10 pigs (Table 1). Regarding breeding, the majority of farmers used boar for mating; the boar was either owned by a farmer or borrowed from a neighbor. Although artificial insemination has been introduced, it has not yet been widely practiced, especially in Kasawo sub-county. As for weaning piglets, the majority of farmers (52%) weaned their piglets at or just over four weeks, while others weaned them at different ages after farrowing.

Table 1: Pig farm management practices

Variable	Characteristic	Kasawo, n=174	Katosi, n=118	Overall, N=292	(95% CI)
Pig breed	Both exotic and local	34 (19.5)	25 (21.2)	59 (20)	(15.85, 25.37)
	Exotic	93 (53.4)	79 (66.9)	172 (59)	(53.01, 64.56)
	Local	47 (27.0)	14 (11.9)	61 (21)	(16.47, 26.10)
Breeding method	Artificial insemination	12 (6.9)	1 (0.8)	13 (4.5)	(2.493, 7.677)
	Boar from neighbour	85 (48.9)	80 (67.8)	165 (57)	(50.60, 62.24)
	Farmers' own boar	63 (36.2)	31 (26.3)	94 (32)	(26.93, 37.93)
	Village boar	14 (8.0)	6 (5.1)	20 (6.8)	(4.341, 10.54)
Pig herd size	1-10	152 (87.4)	103 (87.3)	255(87)	(82.83, 90.81)
	Above 10	22 (12.6)	15 (12.7)	37(13)	(9.187, 17.17)
	Intensive	104 (59.8)	78 (66.1)	182 (62)	(56.47, 67.86)
Method of keeping pigs	Roaming or free ranging	2 (1.2)	3 (2.5)	5 (1.7)	(0.632, 4.179)
	Semi-intensive	18 (10.3)	15 (12.7)	33 (11)	(8.016, 15.64)
	Tethering	50 (28.7)	22 (18.6)	72 (25)	(19.91, 30.09)
Feed type	Both homemade and commercial feed	66 (37.9)	20 (16.9)	86 (29)	(24.36, 35.10)
	Commercial feeds	7 (4.0)	11 (9.3)	18 (6.2)	(3.800, 9.736)
	Food leftovers from school	1 (0.6)	1 (0.8)	2 (0.7)	(0.119, 2.723)
	Homemade pig feed	77 (44.3)	33 (28.0)	110 (38)	(32.14, 43.53)
	Kitchen leftovers	21 (12.1)	50 (42.4)	71 (24)	(19.59, 29.73)
	Roam around	2 (1.1)	3 (2.5)	5 (1.7)	(0.632, 4.179)
Caretaker	Female children	14 (8.0)	7 (5.9)	21 (7.2)	(4.614, 10.94)
	Hired person	9 (5.2)	6 (5.1)	15 (5.1)	(3.007, 8.508)
	Housewife	87 (50)	80 (67.8)	167 (57)	(51.29, 62.90)
	Husband	30 (17.2)	16 (13.6)	46 (16)	(11.87, 20.56)
	Male children	34 (79.1)	9 (7.6)	43 (15)	(10.97, 19.44)

Variable	Characteristic	Kasawo, n=174	Katosi, n=118	Overall, N=292	(95% CI)
Feed and water	Cemented floor	16 (9.2)	23 (19.5)	39 (13)	(9.778, 17.93)
	Feeding troughs	99 (56.9)	68 (57.6)	167 (57)	(51.29, 62.90)
	Non cemented floor	59 (33.9)	27 (22.9)	86 (29)	(24.36, 35.10)
Cleaning frequency of troughs	After every two days	23 (13.2)	38 (32.2)	61 (21)	(16.47, 26.10)
	Daily	64 (36.8)	49 (41.5)	113 (39)	(33.13, 44.57)
	Never	46 (26.4)	13 (11.0)	59 (20)	(15.85, 25.37)
	Once a week	26 (14.9)	13 (11.0)	39 (13)	(9.778, 17.93)
	Twice a week	15 (8.6)	5 (4.2)	20 (6.8)	(4.341, 10.54)
Keeping both adult pigs and piglets	No	131 (75.3)	84 (71.2)	215 (74)	(68.11, 78.51)
	Yes	43 (24.7)	34 (28.8)	77 (26)	(21.49, 31.89)
Sow care after birth	Both homemade and commercial feed	70 (40.2)	14 (11.9)	84 (29)	(23.72, 34.39)
	Commercial feeds	6 (3.4)	16 (9.2)	22 (7.5)	(4.890, 11.34)
	Homemade feeds	87 (50)	43 (36.4)	130 (45)	(38.76, 50.43)
	Kitchen leftovers	10 (5.7)	41 (34.7)	51 (17)	(13.39, 22.42)
	Left to roam around	1 (0.6)	4 (3.4)	3 (1.0)	(0.266, 3.225)
Water source	Borehole	141 (81.0)	6 (5.1)	147 (50)	(44.47, 56.20)
	Rainwater	3 (1.7)	9 (7.6)	12 (4.1)	(2.241, 7.256)
	River	0 (0.0)	11 (9.3)	11 (3.8)	(1.993, 6.832)
	Spring	1 (0.6)	12 (10.2)	13 (4.5)	(2.493, 7.677)
	Tap	1 (0.6)	9 (7.6)	10 (3.4)	(1.750, 6.404)
	Well	28 (16.1)	71 (60.2)	99 (34)	(28.55, 39.69)
Weaning age	>4 weeks	90 (51.7)	61 (51.7)	151 (52)	(46.16, 57.92)
	1 week	5 (2.9)	2 (1.7)	7 (2.4)	(1.062, 5.124)
	2 weeks	21 (12.1)	6 (5.1)	27 (9.3)	(6.334, 13.40)
	3 weeks	26 (14.9)	11 (9.3)	37 (13)	(9.251, 17.28)
	4 weeks	30 (17.2)	38 (32.2)	68 (23)	(18.78, 28.83)

Variable	Characteristic	Kasawo, n=174	Katosi, n=118	Overall, N=292	(95% CI)
Piglet feed	Both home-made and commercial feeds	68 (39.1)	10 (8.5)	78 (27)	(21.80, 32.24)
	Commercial feeds	5 (2.9)	14 (11.9)	19 (6.5)	(4.069, 10.14)
	Home kitchen leftovers	16 (9.2)	44 (37.3)	60 (21)	(16.16, 25.73)
	Homemade feeds	82 (47.1)	40 (33.9)	122 (42)	(36.10, 47.68)
	Leftovers from school/hospital	1 (0.6)	1 (0.8)	2 (0.7)	(0.119, 2.723)
	Roam around	2 (1.1)	9 (7.6)	11 (3.8)	(1.993, 6.832)
House cleaning frequency	Every 2 days	27 (15.5)	43 (36.4)	70 (24)	(19.28, 29.37)
	Daily	70 (40.2)	34 (28.8)	104 (36)	(30.18, 41.44)
	Never	38 (21.8)	21 (17.8)	59 (20)	(15.85, 25.37)
	Occasionally	22 (12.6)	9 (7.6)	31 (11)	(7.436, 14.87)
	Once a week	17 (9.8)	11 (9.3)	28 (9.6)	(6.575, 13.70)

Table 2: Biosecurity practices at pig farms in Kasawo and Katosi sub-counties

Variable	Category	Kasawo, N=174	Katosi, N=118	Overall, N=292	95% CI
Presence of footbath	No	162 (93.1)	117 (99.2)	279 (96.0)	(92.32, 97.51)
	Yes	12 (6.9)	1 (0.8)	13 (4.0)	(2.493, 7.677)
Pig rearing biosecurity	Fenced facility	1 (0.6)	1 (0.8)	2 (0.7)	(0.119, 2.723)
	Free roaming	1 (0.6)	4 (3.4)	5 (1.7)	(0.632, 4.179)
	Housed	117 (67.2)	88 (74.6)	205 (70.0)	(64.55, 75.32)
	Tethering	55 (31.6)	25 (21.2)	80 (27.0)	(51.49, 79.19)
Changing footbath	Everyday	6 (3.4)	0 (0.0)	6 (13.0)	(5.186, 25.94)
	Irregularly	2 (1.1)	0 (0.0)	2 (4.2)	(0.725, 15.43)
	Never	32 (18.4)	0 (0.0)	32 (67.0)	(22.44, 32.96)
	Once a week	6 (3.4)	1 (0.6)	7 (15.0)	(6.545, 28.38)
	Twice a week	1 (100.0)	0 (0.0)	1 (2.1)	(0.109, 12.47)

Variable	Category	Kasawo, N=174	Katosi, N=118	Overall, N=292	95% CI
Visitors access to farm	Multiple	145 (83.3)	112 (94.9)	257 (88.0)	(83.59, 91.40)
	Only through the main entrance	10 (5.7)	2 (1.7)	12 (4.1)	(2.241, 7.256)
	Visitors not allowed	19 (10.9)	4 (3.4)	23 (7.9)	(5.167, 11.74)
Vehicles accessing farm	No	167 (96.0)	116 (98.3)	283 (97.0)	(94.03, 98.49)
	Yes	7 (4.0)	2 (1.7)	9 (3.1)	(1.512, 5.971)
Source of pigs	Born	78 (44.8)	28 (23.7)	106 (36.3)	(30.83, 42.14)
	Both	2 (1.1)	0 (0.0)	2 (0.7)	(0.119, 2.723)
	Brought	94 (54.0)	90 (76.3)	184 (63.0)	(57.17, 68.51)
Veterinary inspection of farm	No	111 (63.8)	90 (76.3)	201 (83.0)	(77.24, 87.13)
	Yes	32 (36.2)	10 (23.7)	42 (17.0)	(12.87, 22.76)
Disposal of dead pigs	Buried	145 (83.3)	97 (82.2)	242 (83.0)	(77.95, 86.92)
	Burned	13 (7.5)	10 (8.5)	23 (7.9)	(5.167, 11.74)
	Cooked and fed to other pigs	1 (0.6)	0 (0.0)	1 (0.3)	(0.018, 2.194)
	Slaughtered and eaten	15 (8.6)	11(9.3)	26 (8.9)	(6.007, 12.92)
Disposal of faeces	Composite pit	31 (17.8)	27 (22.9)	58 (20.0)	(15.54, 25.00)
	Thrown nearby	143 (82.2)	91 (77.1)	234 (80.0)	(75.00, 84.46)
Feral animals cited at farm	No	127 (73.0)	95 (80.5)	222 (76.0)	(70.63, 80.72)
	Yes	47 (27.0)	23 (19.5)	70 (24.0)	(19.28, 29.37)
Pig slaughter in the village	No	140 (80.5)	108 (91.5)	248 (87.0)	(82.10, 90.32)
	Yes	28 (19.5)	10 (8.3)	38 (13.0)	(9.684, 17.90)
Pork inspection	No	63 (36.2)	17 (14.4)	80 (80.0)	(70.57, 87.08)
	Yes	15 (8.6)	5 (4.2)	20 (20.0)	(12.92, 29.43)
Qualified vet/meat inspector	No	144 (82.8)	113 (95.8)	257 (91.0)	(86.68, 93.80)
	Yes	21 (12.1)	5 (4.2)	26 (9.2)	(6.201, 13.32)

Variable	Category	Kasawo, N=174	Katosi, N=118	Overall, N=292	95% CI
Running water availability	No	147 (84.5)	105 (89.0)	252 (89.0)	(84.67, 92.32)
	Yes	18 (10.3)	13 (11.0)	31 (11.0)	(7.676, 15.33)
Effluent disposal	Buried	69 (39.7)	12 (10.2)	81 (28.0)	(22.76, 33.32)
	Burnt	27 (15.5)	8 (6.8)	35 (12.0)	(8.599, 16.41)
	Bush	78 (44.8)	98 (83.1)	176 (60.0)	(54.39, 65.88)
Centralized slaughter	No	48 (27.6)	20 (16.9)	68 (23.0)	(18.65, 28.64)
	Yes	126 (72.4)	98 (83.1)	224 (77.0)	(71.36, 81.35)

The majority of farms (70%) had their pigs confined in temporary or semi-permanent structures. Most of the farmers did not have a footbath on the farms (96%) and 88% of the farm visitors had access to the pig units. Homesteads which had running water were few n=31 (11%); majority accessed spring and well water. Dead pigs were buried by majority of farmers (83%); most of the farmers disposed of pig feces by throwing it nearby. Pigs that were purchased or exchanged were most commonly not subjected to veterinary inspection; only 17% of the pig acquisitions underwent prior veterinary inspection and certification (Table 2).

Focus Group discussion with animal health workers

Three main topics that were discussed were the following: pig slaughter status in the district, implementation of biosecurity measures during their day-to-day work and pig breeding methods. They highlighted the absence of centralized pig slaughter facilities in the sub-counties and noted that individual veterinarians are unable to travel across the entire sub-county on a daily basis to conduct pork inspections. This called for the need to establish centralized slaughter facilities where all pigs can be slaughtered on designated days, with all pork subjected to inspection in order to promote public health and facilitate the orderly collection of taxes for local governments.

In terms of breeding, some had been trained in pig artificial insemination (AI) but not fully operational. Once AI input supply chain is in place, more pigs will be serviced by AI. They noted that sharing boars for breeding female pigs was common and can be a potential source of spread of diseases particularly ASF in case of an outbreak.

Regarding on-farm biosecurity practices, all animal health workers carried disinfectants on their motorcycles and disinfected their personal protective equipment (PPE) whenever they left a pig farm. They had previously attended training on observing biosecurity measures. Additionally, after completing work at a farm, they disinfected the tires of their motorcycles.

Prevalence of African swine fever virus

A total of 777 blood samples were analyzed in the laboratory for the presence of African swine fever antibodies from both Katosi and Kasawo sub-counties. The prevalence of African swine fever was zero for both Kasawo and Katosi sub-counties.

Table 3: Blood samples of pigs analysed and the prevalence of ASF virus in pigs

Sub-county	Female pigs	Male pigs	Total number of samples	Prevalence (%)
Kasawo	267	193	460	0
Katosi	196	121	317	0
Overall	463	314	777	0

DISCUSSION

ASF seroprevalence for both Katosi and Katosi sub-counties was 0%. This finding is comparable to those reported by other scholars. Some studies have also reported similar findings of 0% in South West and Central Kenya (Okoth et al., 2013; Abworo et al., 2017; Drider et al., 2022) and 0% in Central Uganda (Muhangi et al., 2015). The finding of no seropositive pigs in the two sub counties was partly attributed to highly virulent ASFV strains that cause very high mortality in the affected pigs. At the time of sampling, all affected pigs had died. Additionally, farmers keep pigs for a shorter period of time, and it is possible that survivor pigs after ASF outbreaks are sold off. This significantly reduces the chances of finding serologically positive pigs on farms.

However, other studies have reported higher seroprevalence for ASF. Patrick et al. (2020) obtained 37% in South Kivu Province in DRC; Abwage et al. (2015) and Patrick et al. (2020) reported 13.3% in Taraba state in North East

Nigeria. The differences in the regional findings could probably be explained by the type of husbandry system used as well as the circulating regional ASFV strains (Eblé et al., 2019). Additionally, the higher seropositivity could be attributed to the fact that over time, pigs may recover from the carrier state and continue to test positive serologically. The higher seropositivity could also be due to the pathogenicity of the circulating virus strains. Pigs infected with low pathogenic virus strains may recover and become carriers and therefore remain serologically positive (Eblé et al., 2019). When blood samples, tonsils and lymph nodes from slaughtered pigs in Kampala metropolitan area were collected simultaneously, Okwasiimire, (2022) identified that 0.15%, n=1,208 serum samples only had detectable antibodies yet 59.5% were positive for ASFV DNA. Similarly, other studies in Uganda reported seropositivity of 0.2% in Mubende (Muwonge et al., 2012). The high values were attributed to sampling from pig abattoirs; notably, sampled pigs could have already been in incubation state. Farmers usually sell off their pigs when they suspect a potential disease outbreak in order to avoid losses when a disease outbreak has been confirmed (Muwonge et al., 2012; Atuhaire et al., 2013; Muhangi et al., 2015; Asambe et al., 2019).

In a comparative study at the Western border of Kenya and the Eastern border of Uganda, Abworo et al. (2017) compared different diagnostic techniques for ASF on asymptomatic pigs. It was found that samples taken from tissues including tonsils, lymph nodes, spleen, heart, lungs and liver had better chances of detecting ASFV compared to serological techniques. This further highlights the role of asymptomatic carrier pigs in the spread of ASF. Notably, these samples were obtained after pigs were slaughtered/sacrificed. The last outbreak in Kasawo sub-county had been reported at least six months before samples were taken in the present study. However, the reports were not substantiated with laboratory evidence suggesting possible occurrence of other diseases that present similar or related clinical signs as ASF. Such diseases include swine erysipelas, septicaemic salmonellosis, highly pathogenic porcine reproductive and respiratory syndrome, porcine dermatitis nephropathy among others (Porras et al., 2024).

The majority of farmers kept their pigs confined (99.4%). This could be due to the limited grazing or roaming space and the presence of crop farming activities, as most farmers own small plots of land where they engage in various agricultural enterprises. This practice of confining pigs limits physical interaction among pigs from different farms, which occurs in a free-range system and therefore minimizes the risk of transmission of pig diseases including ASF. Several biosecurity concerns were identified at the farm level, including the sharing of mating boars between pig farms, unauthorized access to pig

units by visitors, the slaughter of sick or dead pigs for sale and consumption, and the open disposal of effluent from pig slaughter. Some of these practices had also been reported by other scholars in earlier studies in other areas of Uganda (Tejler, 2012; Muhangi et al., 2014). The management practices of the majority of farmers in this study was low input in terms of investment and therefore pig farmers may be reluctant to implement the basic biosecurity measures at the farms as they see that as an additional cost of production (Nantima et al., 2015). The slaughter or sale of sick pigs is often done to recover some monetary value and prevent a total loss, disregarding the risk of further spreading the disease. Farmers reported practices of slaughtering sick pigs for sale or consumption, as well as improper disposal of carcasses through open dumping.

The study also identified gaps in terms of hygiene for most of the pigsty and feeders/troughs. Only 39% and 36% of the farmers cleaned the troughs/feeders and pig houses daily respectively; for example, some feeders/troughs and pigsties were found in extremely dirty conditions. This practice may stem from farmers being occupied with other activities, leading to limited attention given to the piggery project, or from a lack of understanding regarding the importance of hygiene. These poor sanitary practices are a risk factor for emergence and spread of other pig diseases at the farm. The farmers also mentioned the most common signs of ASF in pigs including shivering, lack of appetite, weakness, recumbence, high fever, redness of the skin at the body extremities, and death. This suggests the farmers' ability to identify the ASF disease and report it in case of an outbreak in the community. Nonetheless, laboratory confirmation is necessary to rule out other diseases of pigs that present similar or related clinical signs as ASF. However, the obstacle to reporting could be attributed to fear of losses in case of imposition of quarantine since there is no compensation to affected pig farmers (Tejler, 2012).

Animal health providers, veterinary paraprofessionals in particular operating in the areas of both Katosi and Kasawo sub-counties were equipped with disinfectant for decontaminating on their motorcycles and their footwear at all times when entering and leaving farms they visit. This is a commendable biosecurity practice and potentially plays a significant role in limiting the spread of pig diseases between farms. In outbreaks, fomites such as trucks and veterinary equipment, clothes, gumboots among others can carry the virus from farm to farm when proper disinfection is not carried out (Blome et al., 2020). Farmers also reported practices of slaughtering sick pigs for sale or consumption, improper disposal of carcasses by open dumping. These practices have also been reported in other studies (Chenais et al., 2017) and contribute to

spreading the ASF virus during outbreaks.

Lack of authorized and centralized pig slaughter places in local government areas of jurisdiction was identified as one of the factors contributing to introduction and spread of ASFV in the environment in cases of outbreaks or when a pig is slaughtered in a rural setting (Dione et al., 2018). In that case, environmental contamination with blood and body effluent is disposed of in the local environment. It has been established that the ASFV can stay in the environment for a varied length of time. In Armenian conditions, the ASFV survived in the environment for at least six months (Arzumanyan et al., 2021). Scientific research conducted in the 20th century has shown that the ASFV is resistant to heat exposure, desiccation, and decay (McKercher et al., 1978). Other investigations report that the best place for infective ASF virion would be the bone marrow from intact tubular bones e.g. the femur of buried carcasses. Outside the pig carcass, infective virions may not stay beyond one month during summer (Karalyan et al., 2019). However, it has been shown that ASFV can persist in tissues for several months; the virus can survive for more than 100 days in Iberian-cured pork products and sausages (Farez and Morley, 1997). It has been estimated that contaminated pens in tropical regions can remain infectious to domestic pigs for up to three days. In an experiment carried out in order to estimate how long ASF virions remain infective in a contaminated environment by exposing uninfected pigs to ASFV-contaminated pens for varied length of time, pens remained infective for one day. Exposure of 2-7 days did not result in infection confirming that although ASFV environmental contamination results in infection, it happens in a short window (Olesen et al., 2018). In fact, resistance of the virus to inactivation means transmission by fomites such as clothing, equipment and vehicles remain risks (Wilkinson, 1989). That is why it is imperative for animal health workers to disinfect their vehicle tyres as well as their protective clothes between farms.

The results from this study showed that there are no centralised pig slaughter places in the district. Centralised slaughter places would offer several advantages, the first being enhanced public health. All slaughtered pigs would undergo meat inspection, and any pigs found to carry zoonotic diseases, such as porcine cysticercosis, would be condemned. In the present arrangement, less than 10% of slaughtered pigs are inspected by qualified veterinarians or public health practitioners simply because an animal health worker may not move into all villages where slaughter takes place on a daily basis while performing other designated duties. Secondly, the spread of the virus in the environment would be minimised. All effluent would be disposed of safely in a designated place while at the same time any effluent treatment would be done

centrally. Thirdly, revenue collection for the local government would be enhanced leading to better provision of social services to the local population. The following simple model illustrates this point: if 60 pigs are slaughtered daily across the entire district, and a local tax of 5,000 Uganda Shillings (UShs) is charged per pig, it would generate 9,000,000 UShs monthly, which translates to 108,000,000 UShs annually (approximately 30,000 USD). This revenue would be used for the maintenance of slaughter facilities as well as providing other essential services in the community and district at large. If the numbers of slaughtered pigs increased, the revenue would proportionately increase.

CONCLUSION

This study revealed key drivers through which ASF is transmitted in local communities. The practice of ASFV being transmitted via fomites was lowered by animal health workers carrying disinfectants on motorcycles. Since these personnel move from farm to farm, the risk would be significant if this measure was not being implemented. Secondly, increasing farmers awareness of recognizing the disease in pigs and actions to take when suspected cases are observed need to be enhanced. Very few homesteads practiced biosecurity measures at pig pens, a practice that should be widely practiced. Lastly, there is a need to establish centralized pig slaughter facilities as there are many advantages to this practice: establishment of centralized collection and disposal of effluent from the slaughter process. There is also an improvement in public health, as pork is inspected by qualified personnel, with appropriate actions taken, especially if pigs carry zoonotic diseases like porcine cysticercosis. This would allow local authorities to better manage the facility, improve data collection on pig health in the area, implement effective disease control measures, and boost local revenue collection.

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Author's Contribution:

SB and FM conceptualised the study; GO, JO and SB collected field data. GO and SB analysed the data; SB, GO and FM wrote the manuscript.

Competing interest

The authors declare that they have no financial or personal relationships that could have improperly influenced the writing of this article.

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