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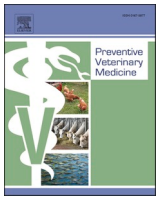

Co-created community contracts support biosecurity changes in a region where African swine fever is endemic – Part II: Implementation of biosecurity measures

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ABSTRACT

Smallholder subsistence pig production is common in Uganda and African swine fever (ASF) is endemic in the country, with its spread driven by human activities along the smallholder value chain. Previous research in the study area has revealed that many stakeholders are aware of how ASF is spread, its prevention and control, and have a generally positive attitude towards biosecurity. Despite this, even basic biosecurity is largely lacking. Costs, as well as a lack of adaptation to the local context, culture and traditions have been identified as factors hindering biosecurity implementation. Community engagement and local ownership of disease problems are increasingly recognised as important for improving disease prevention and control. The objective of this study was to investigate the capacity of participatory action at community level with broad inclusion of stakeholders to improve biosecurity in the smallholder pig value chain. Specific attention was paid to participants' perceptions and experiences of implementing the biosecurity measures included in their co-created community contracts. The study was conducted in Northern Uganda in villages purposively selected on the basis of previous occurrences of ASF. In each village, farmers and traders were also purposively selected. At a first meeting, basic information about ASF was shared and participants presented with a list of biosecurity measures adapted for farmers and traders respectively. Participants discussed each measure in farmer and trader subgroups, decided on the measures to implement for one year, and signed a community contract to this effect. The following year, interviews were again undertaken and implementation support given. Interview data were coded and thematically analysed. Each subgroup chose a minimum of three and a maximum of nine measures, with wide variations between villages in their selection of measures. At the follow-ups, none of the subgroups had fully implemented what had been agreed in their contract, but all had changed some of their biosecurity routines. Some frequently recommended biosecurity measures, such as not borrowing breeding boars, were not considered feasible. Relatively simple and cheap biosecurity measures were rejected for reasons of cost, highlighting the participants' general level of poverty and the relevance of poverty as a specific factor governing disease control results. The participatory methodology allowing for discussions, co-creation and the option to refuse measures seemed to facilitate the implementation of measures that had initially been thought to be controversial. The broad community approach was deemed to be positive for strengthening community identity, cooperation and implementation.

1. Introduction

Smallholder subsistence pig farming is common in the greater Gulu region, an area of Northern Uganda where more people live under the national poverty line than elsewhere in the country (UBOS, 2020). In Uganda, pig farming is frequently promoted as a pathway out of poverty (Sentumbwe, 2017; Ouma, 2014). However, the development of the pig sector and the capacity for pig keeping to generate cash income and act as a tool for poverty reduction are hindered by African swine fever (ASF), which is endemic in Uganda (Chenais et al., 2015, 2017a;

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Muhangi et al., 2015; Dione et al., 2017b). ASF is a viral, haemorrhagic fever affecting domestic pigs and Eurasian wild boar, and is mostly fatal. In Uganda, as in most countries in Africa, the dominating epidemiological cycle of ASF is the domestic pig cycle in which the virus is spread by human activities along the entire smallholder value chain (Nantima et al., 2015a; Dione et al., 2017a; Ouma et al., 2018; Penrith et al., 2019). During the ongoing global epidemic of ASF virus (ASFV) genotype II, vaccine development has advanced and commercial vaccines against that genotype are now on the market in Asia (Gladue and Borca, 2022; Tran et al., 2022). To date, all the investigated outbreaks in the domestic pig cycle in Uganda have been attributed to genotype IX based on the p72 protein (Bastos et al., 2003; Gallardo et al., 2011). In the study area as well in most similar smallholder contexts in Africa, it is likely that biosecurity will remain the only realistic prevention and control method for ASF in the near future (Penrith et al., 2021). Compared to vaccination, biosecurity further has the advantage that the same biosecurity measures will protect against several diseases, in contrast to even a heterologous ASF vaccine that will only protect against ASF (Penrith et al., 2021).

Previous research in the study area has shown that even basic biosecurity is often not implemented despite a generally positive perception of it as well as knowledge about ASF, how it is spread, and methods for prevention and control (Chenais et al., 2017b, 2017c, 2019). In a recent study, failure to adopt biosecurity was attributed to costs for the measures as well as for constructing enclosures (which is the prerequisite for many biosecurity measures), feed costs if pigs are to be kept enclosed and hindered from scavenging, and the fact that other household and livelihood costs need to be prioritised over biosecurity (Aliro et al., 2022). In addition, many biosecurity measures are often considered unfeasible due to them not being adapted to the local culture and traditions and the lack of access to good veterinary advice.

In low-income countries such as Uganda, the veterinary sector is often underfunded and understaffed with insufficient resources for disease surveillance, prevention and control (Forman et al., 2012; Ilukor et al., 2015; Ilukor, 2016). This affects delivery of regular animal health services as well as prevention and control of diseases that are formally under government responsibility such as ASF. In addition, poverty creates a negative animal health and livelihood spiral: lack of resources leads to limited investment in farming and biosecurity, which in turn leads to low production and a high risk of animals catching infectious animal diseases, resulting in low and insecure income and household shocks due to animal diseases and deaths (Krishna, 2007; Wagstaff and Lindelow, 2010; Ebata et al., 2020b, 2020c). One way to break this vicious cycle is to reduce the spread of animal diseases by for example increasing the implementation of biosecurity.

To make implementation feasible in poor rural settings, biosecurity needs to be adapted to local economic, cultural and traditional contexts and prioritised among the numerous other challenges facing smallholder livelihoods (Coffin et al., 2015; Young et al., 2015; Ouma et al., 2018). Previously, farmers' knowledge and attitudes were often highlighted as factors determining biosecurity implementation (Alawneh et al., 2014; Young et al., 2015; Ritter et al., 2017). However, more recent research points to the significant influence of the wider sociocultural, economic and political environments in which people operate their farms on the implementation of biosecurity measures (Ebata et al., 2020c; Lysholm et al., 2020). Factors such as community engagement and the level of ownership of disease control have also been found to be important in relation to disease control decisions (Thys et al., 2016; MacGregor and Waldman, 2017; Zvonareva et al., 2018; Ebata et al., 2020b). The importance of community engagement for disease control was specifically noted during the Ebola pandemic (Hewlett and Hewlett, 2007; Abramowitz et al., 2015; Roca et al., 2015). Recent methodological development of participatory epidemiology and other forms of participatory research in animal health has encompassed the importance of broad participation, and updated versions of the methodology are now being used to stimulate and increase engagement, ensure that actions are guided by participants' priorities, and promote participants' ownership of disease control matters (Barnes et al., 2020b; Barnett et al., 2020; Ebata et al., 2020a; Tasker, 2020).

Based on knowledge of the local ASF epidemiology, the structure of the value chains and the importance of community engagement, the objective of the study was to investigate the capacity of participatory action at community level with the inclusion of stakeholders along the entire value chain to initiate change and increase stakeholder ownership for improved biosecurity in the smallholder pig value chain in Northern Uganda. A previous article (Chenais et al., 2023) describes the applied methodology, paying specific attention to the feasibility of co-created community contracts for the described purpose. In summary, the methodology was found to be appreciated, feasible and to promote biosecurity change while encouraging cooperation and empowering participants. In this article (Part II), there is a specific focus on the participants' perceptions and experiences of implementing the biosecurity measures that were included in their community contracts.

2. Materials and methods

The materials and methods have been described in full in Part I (Chenais et al., 2023) and are briefly summarised here.

2.1. Selection of study sites and participants

The study was conducted in Northern Uganda between October 2019 and October 2020. In the study area the absolute majority of pigs are kept on subsistence smallholder farms with very small herds (on average around three pigs including piglets) managed in free-roaming or tethered systems, and with low levels of biosecurity (Chenais et al., 2017b; Arvidsson et al., 2022a). Six villages (the smallest administrative unit) in three districts (Gulu, Omoro and Amuru) and participants with different roles in the smallholder pig value chain were purposively selected for inclusion. Villages were selected based on having previously been affected by ASF, a perceived community interest in ASF prevention and control, presence of several different types of stakeholders and a suitable number of pig farmers for a focus group discussion (FGD). Participants were invited to participate by the local animal health worker, selection instructions being to invite all pig farmers (disregarding the herd size), as many different stakeholders as possible, and both women and men.

2.2. Study design and data collection

The study comprised several components centred on the co-creation of a community contract on biosecurity, with repeated FGDs, semi-structured and structured interviews and field observations. The initial study design had to be adapted due to the COVID-19 pandemic, therefore the final study consisted of an initial meeting and two follow-up meetings with each study group. Questions about how the COVID-19 pandemic had affected pig rearing, trade and implementation of biosecurity were included in the second follow-up interviews. For the initial meeting and the first follow up meetings the field research team was composed of a facilitator (TA), a translator proficient in the local language (Acholi) and English, and a senior researcher (EC). For the second follow up meetings the field research team was composed of a facilitator (TA) and a notetaker.

Selected participants were invited to the initial meeting in the form of a FGD in the six selected villages. The meetings started with assurances about confidentiality and obtaining written consent to take photographs and make voice recordings. Discussions followed a topic guide (see Appendix 1). The discussions were conducted in the local language, Acholi, guided by the facilitator, translated simultaneously into English, and the translations recorded. Detailed notes were taken and the recordings were kept as back-up but not transcribed *ad verbatim*. A brief presentation about ASF was given as an introduction to the study. Subsequently, participants were asked whether they would be willing to

change their biosecurity routines to improve ASF prevention while taking part in a study that would include repeated interviews and adapted implementation support. Following this, two subgroups were created based on the participants' main role in the value chain: farmers and other stakeholders (referred to below as traders). The trader subgroups included live pig traders, slaughterers, pork vendors and owners of "pork joints" (Ugandan English for a small restaurant serving grilled pork). Next, the subgroups were presented with a list of biosecurity measures (see Appendix 2). In the subgroups, each suggested measure was discussed, after which the subgroup was encouraged to take a common decision to implement some of the listed measures (or their own suggestions) for the duration of the study. The intention was that the selected measures should not already be implemented, and that all the participants in the group should be able to implement them. Finally, the subgroups were brought back together and a common community contract was created for both subgroups, stating which measures each subgroup intended to fulfil.

The first follow-up took place four months later and included FGDs with the farmer subgroups and interviews plus field observations in the form of visits to the places of business for the trader subgroups. The interviews with the trader subgroups were done with individual participants, or in groups of two to four participants, depending on their availability and place of business. FGDs and interviews followed the same topic guide (see Appendix 3). Only the biosecurity measures that had been selected by the respective group were discussed. A second follow-up took place six months later and included an open meeting with the invitation extended to all stakeholders in the value chain in the study villages and a discussion following a structured interview guide and covering biosecurity implementation and the community contract with the initial study participants (see Appendix 4). As before, only the biosecurity measures that had been selected for implementation by the respective subgroup were discussed. At this follow-up implementation was scored as "easy", "difficult" or "not applicable". The open meeting was held on the request of participants who had been approached by neighbours who were not included asking if they could also be part of the study. During the open meeting information about ASF as well as its prevention and control were shared, and a laminated poster on this topic handed out (Chenais et al., 2023).

In all interviews, the facilitator guided the discussion based on the topic guides while letting the participants lead the discussion. The facilitator further sought to encourage equal participation, recording different opinions without forcing consensus (Fischer et al., 2020). The decision on which measures to include in the community contract was however communal, with the decision reached through discussions, guided by the facilitator. The intention was that the selected measures should not already be implemented (i.e. representing a change) and be implementable for all participants.

2.3. Data analysis

For each of the three sets of interviews, master field notes were created and imported into NVivo qualitative data analysis software (QSR International Pty Ltd. Version 12, 2018). Data referring to discussion around the biosecurity measures from all three interviews were summarised for each measure. On the first meeting, data concerning the implementation of the measures prior to the study was recorded at group level as "already implemented" or "not". On the two follow-up occasions, data on the implementation of the biosecurity measures agreed in the community contract were recorded at group level as an implemented measure, a partly implemented measure or a non-implemented measure. The second category included measures that had been successfully implemented by some but not all the participants, measures that turned out to have already been implemented prior to the first meeting (i.e. no change had occurred), or measures not applicable at this follow-up due to no pigs being bought, becoming sick or dying for example (making measures depending on such events non-relevant). Field observations from the first follow-ups were used during the analysis to enlighten, confirm or question the interview data. Data from the second follow-ups were further summarised per additional discussion topic (community contract, effects of the COVID-19 pandemic and associated restrictions). With the aim of capturing the participants' perspectives on the implementation, a thematic analysis was performed. This analysis comprised repeated reading of the data allowing for themes to emerge inductively.

3. Results

In total, 65 (average 11, min 9, max 12) participants attended the first FGDs in the six study villages (villages A-F). Each FGD was attended by eight participants who were farmers and by between one and four participants who were traders. Many of the traders also kept pigs but identified themselves mainly as traders in live pigs/slaughterers/pork traders/pork joint owners and therefore chose to join the trader subgroup. The first follow-up was attended by in total 59 participants: all originally participating farmers from three of the villages, all but one to three of the originally participating farmers from the other three villages and all originally participating traders apart from one butcher in village E. Fifty-four of the original participants attended the second follow-up. In total, 155 (average 26, min 21, max 32) people attended the open meetings during the second follow-up. At the time of the first follow up, an ASF outbreak reportedly occurred in the vicinity of village B, and one pig death that might have been due to ASF was discussed among participants in village C. Apart from this, no outbreaks were reported during the study period.

3.1. Community contract

The farmer subgroups selected a minimum of six and a maximum of nine measures each (average 7.2) (Tables 1a and 1b). One subgroup added a suggestion of its own. The measure "Create a farmers/village group with common standards for pig-keeping" was chosen by all farmer subgroups. The measure "Always contact the vet if pigs are sick" was rejected by all farmer subgroups. Several other measures were chosen by only one farmer subgroup. The trader subgroups selected a minimum of three and a maximum of eight measures each (average 5.6). No measure was chosen by all these subgroups and two measures ("Make sure that items that have been in contact with meat, pig products or blood (axes, knives, buckets) never come into contact with pigs" and "Issue a health declaration of pork for sale" were rejected by all subgroups. In the following section, the discussions during the three sets of interviews are summarised per measure and per subgroup.

3.2. Biosecurity measures suggested in the farmer subgroups

3.2.1. Only buy healthy-looking pigs

Overall, this measure was seen as feasible by groups B-F. It had already been implemented by participants in villages C-F. Participants from village B thought that they could start implementing the measure, suggesting that the local veterinarian or the slaughterer could assist in identifying healthy pigs. At the first follow-up, only one participant from this village had bought new pigs since the last interview. This participant had changed his biosecurity behaviour regarding trade: he had bought from a seller known to keep the pigs confined and had asked a veterinarian for a health check of the new pigs, both actions representing a change. At the second follow-up, four participants had bought pigs. They described it as generally easy to see if pigs were healthy and make an informed choice, but that this was more difficult if the seller was unknown to them. However, participants from village A thought this measure was impossible to implement, mentioning that many people sell their sick pigs, that it is difficult to visually separate healthy pigs from unhealthy ones, and that they would need to visit the market with the veterinarian to assure the pigs' health status.

Table 1a

Biosecurity measures included in a community contract and their reported implementation at two follow-ups, four and ten months after the initial intervention. Results refer to farmer subgroups in a biosecurity implementation study performed in Northern Uganda between October 2019 and October 2020. Grey cell in the column "first meeting"=measure already implemented at the first meeting. Unfilled cell in the columns "first follow up" and "second follow up"=measure not included in community contract, filled cell in the columns "first follow up" and "second follow up"=measure included in community contract. Green=successfully implemented at the respective follow-up, yellow=partly implemented, red=not implemented. E = implementation perceived as easy, D=implementation perceived as difficult, N = not applicable, undecided or not answered.

Farmer subgroups	Village A			Village B			Village C			Village D			Village E			Village F		
Biosecurity measures/village/follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up
Only buy healthy-looking pigs						E, D												
Keep new pigs away from the rest for 14 days			E			E, D			E, D						E			E
Keep pigs confined at all times and in all seasons									E, D									E, D
Do not let others touch my pigs without washing hands, changing clothes and clean their boots			E												E			E
Wash hands, change clothes and clean my boots after handling other peoples' pigs			E												E, D			E, D
Make sure that items that have been in contact with meat (axes, knives, buckets) never come in contact with pigs			E															
If I borrow spray pumps or other equipment, clean it before bringing it onto farm			E			N			N			E			E			
Use only my own boar			E															
Separate healthy and sick pigs												E, D						
Wash hands, change clothes and clean boots after handling sick pigs						E			N			N			E, D			E
Tell each other if pigs are sick and confine sick pigs			N												E, D			
Remove carcasses of dead animals and aborted foetuses from the pigs and bury them						E, N			N									N
Always contact the vet if pigs are sick																		
Don't feed pigs hotel/restaurant swill or cassava leaves from pork joints without cooking first															E			
Create a farmers/village group with common standards for pig keeping			E			N			N			D			D			N
Create a farmers/village savings group as village insurance to be used in case of outbreaks for those that follow the						N						N			N			
contract																		
Other											**	N						
No. measures already implemented	4			6			11			8			7			7		
No. measures included in contract		8			7			6			6			9			7	
Success rate (implemented/agreed)		4/8	5/8		3/7	3/7		0/6	2/6		1/6	0/6		3/9	5/9		4/7	5/7

* As the selection of measures was done on group level, some participants were sometimes already implementing measures that were selected. Implementation of these measures were scored as "partly implemented".

* *hold regular meeting to update fellow farmers.

3.2.2. *Keep new pigs away from the rest for 14 days*

This measure was perceived as possible for most participants, mainly dependent on how the pigs were kept (confined/tethered/free range) and the households' possibility of constructing pig enclosures. Some of the participants from villages A and B were already practising this measure. Participants from villages C and F were not previously aware that this practice could be useful in preventing disease. At the first follow-up, very few participants from the villages that had selected this measure had bought new pigs and the measure had thus not been relevant. For those who had, all but one had changed their biosecurity routines regarding the introduction of new pigs. Different implementation models were described, such as tethering new pigs in a separate place or keeping new pigs in an abandoned hut. Participants who had sold pigs had also informed the buyers about the benefits of keeping new pigs isolated from the rest of the herd. At the second follow-up, more participants had bought new pigs, and separation of new pigs from the existing herd was generally reported. Participants stated that if new pigs were kept enclosed, providing enough feed for the pigs was problematic.

3.2.3. *Keep pigs confined at all times and in all seasons*

The perceived feasibility of this measure depended on the farmers' varying possibilities for investing in pig enclosures and/or sties. In villages B-D and F the discussions revealed that the measure was perceived to be an option for some but not all, mostly depending on the households' possibilities to organise confinement and feed, especially in the dry season. Those who already confined sows generally did not manage to keep piglets enclosed. Participants from villages A and E reported that they already practised the measure and participants in village C were not previously aware that confinement was useful for preventing disease transmission. At the first follow-up, most participants from the villages that had selected this measure reported that confinement was challenging, mainly because of the need to feed pigs if they were prevented from scavenging. Those who already managed to keep their pigs confined had continued to do so, but only one participant had managed to change pig confinement practices. At the second follow-up the participants had varied experiences, reporting implementation as both easy and difficult. Several participants had been able to construct pigsties, and a change was thus reported. Providing feed was repeatedly reported to be a problem while keeping pigs enclosed.

3.2.4. *Do not let others touch my pigs without washing hands, changing clothes and clean their boots*

Participants from villages B and C were not aware that such a practice could be useful for preventing ASF and therefore it was not practised. In the other villages, some participants were already restricting visitors' access to pigs, while some were not. The measure was perceived as impossible to implement if pigs were kept on free range. Difficulties were also reported in terms of acquisition of disinfectants and instructing neighbours and veterinarians not to touch the pigs, whereas it was perceived to be easier to give this advice to potential

Table 1b

Biosecurity measures included in a community contract and their reported implementation at two follow-ups, four and ten months after the initial intervention. Results refer to trader subgroups in a biosecurity implementation study performed in Northern Uganda between October 2019 and October 2020. Grey cell in the column "first meeting"=measure already implemented at the first meeting. Unfilled cell in the columns "first follow up" and "second follow up"=measure not included in community contract, filled cell in the columns "first follow up" and "second follow up"=measure included in community contract. Green=successfully implemented at the respective follow-up, yellow=partly implemented, red=not implemented. E = implementation perceived as easy, D=implementation perceived as difficult, N = not applicable, undecided or not answered.

Trader sunbgroups	Village A			Village B			Village C			Village D			Village E			Village F		
Biosecurity measures/village/follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up	1st meeting*	1st follow-up	2nd follow-up
Never enter villages or where pigs are kept, but instead let the farmers bring the pigs out to me			E			E			E, D			E, D						
Wash hands, change clothes and clean boots after handling pigs before handling another pig			E, D						E			E			E			
Don't take live pigs back from market/slaughter slab to my own village						E									E			
Only buy healthy-looking pigs			E			E			E									
Don't buy pigs from villages with outbreaks			E			E			E			E						E
Report to the vet if I hear about sick pigs			E															
Only slaughter "walking pigs"															E			
Take care that blood, offal and other leftovers are safely disposed of so that pigs, dogs, rats and birds cannot get to it during and after slaughter			E									E						E
Don't take equipment used for slaughter/grilling home									E									
Make sure that items that have been in contact with meat, pig products or blood (axes, knives, buckets) never come into contact with pigs																		
If I know that the pig was unhealthy - heat treat pork before sell or dispose it safely															E			D
Issue a health declaration of pork for sale																		
Create a village group with common standards for pig and pork handling			D			E			D			E						
Create a village savings group as village insurance to be used in case of outbreaks for those that follow the contract						D			D			D			E			
No. measures already implemented	4			5			5			6			7			6		
No. measures included in contract		7			6			7			6			5			3	
Success rate (implemented/agreed)		4/7	5/7		4/6	5/6		2/7	3/7		2/6	4/6		0/5	0/5		2/3	2/3

*As the selection of measures was done on group level, some participants were sometimes already implementing measures that were selected. Implementation of these measures were scored as "partly implemented".

pig buyers. At the first follow-up, the measure was reported to be practised by almost all participants from the villages that had selected it. The implementation had required some investment (building a fence, fixing a gate) but this was reported to be feasible. Several participants stated that it was necessary to explain to others why this measure had been introduced, but that the explanations were received positively and implementation made easier as butchers, for example, were included in the study. One participant mentioned that it was difficult to buy disinfectants for cleaning boots because of the cost.

3.2.5. Wash hands, change clothes and clean my boots after handling other people's pigs

Participants from villages A and D were not aware that such a practice could be useful for preventing ASF. In villages B-E, the discussions revealed that the measure was perceived as achievable for some, but not for all, and that implementation was particularly challenging if pigs were not confined. Having a change of clothes was mentioned as a specific hindrance to implementation. At the first follow-up, most participants from the villages that had selected this measure said they had started to implement it and that it was feasible, although sometimes explanations were required when interacting with people who were not part of the study.

3.2.6. Make sure that items that have been in contact with meat (e.g. axes, knives, buckets) never come into contact with pigs

Participants from villages B-F reported that items used for pigs were already kept separate from other household items. Participants from village A reported that all such items were currently not kept out of reach of free roaming pigs, but that this could easily be changed. At the first and second follow-ups, participants from the village that had selected the measure reported that it had been implemented without difficulty. Several participants reported at both follow-ups that they had extended this practice to never eating pork at home unless they had slaughtered their own pigs.

3.2.7. If I borrow spray pumps or other equipment, clean it before bringing it onto the farm

Most participants from all the villages were already doing this, or perceived it as easy to implement. Participants from village A stated that if it was the veterinarian bringing equipment, it would be difficult to comment on the need for cleaning. At the first follow-up, many participants from villages that had selected the measure reported actually never borrowing any equipment and the measure was thus not applicable. Some lent equipment to others and found it generally easy to clean the items after they were returned. Participants from village D had borrowed wheelbarrows and buckets and reported that it was easy to clean these before returning them, and that they used these moments as opportunities to talk to other community members about disease prevention and control.

3.2.8. Use only my own boar

Borrowing boars for breeding was seen as an unavoidable necessity

for people who did not have their own boar, which very few had. Some participants who needed to borrow a boar considered it possible to select the boar based on health information or geographical proximity. At the first follow-up, only one participant from the village that selected the measure had covered her sow and had chosen to use a boar from another participant in the group. At the second follow-up, two participants reported that they continued to borrow boars, but had started to isolate sows/boars upon their return to their herds after service.

3.2.9. Separate healthy and sick pigs

Participants from villages B-F were either already implementing this measure or perceived it as something they could start to do. Participants from village A did not previously perform this practice, believing that ASF virus could be transmitted by air and that separation would thus not prevent transmission. Separation was generally perceived to be difficult to implement if pigs were not confined. At the first follow-up, two participants from the village that had selected the measure had experienced cases of sick pigs since the first meeting and both had managed to implement isolation. No additional sickness had occurred at the second follow-up, but one participant had received pigs that looked unwell from a friend who could not take care of them. He had isolated these pigs from the rest of the herd, but reported that it was a challenge to keep them in isolation, especially during feeding.

3.2.10. Wash hands, change clothes and clean boots after handling sick pigs

No participants had been doing this before, but it was perceived to be possible by all the villages, with a reservation about not having a change of clothes. Participants from villages that had selected this measure and that had experienced sick pigs reported that they had (fully or partly) implemented the measure. Generally, hand-washing was performed, but a change of clothes and boots was more rarely implemented. At the second follow-up, no participants had suffered any cases of sick pigs. Except for village E, hand-washing was reported by most participants to be easy on this occasion.

3.2.11. Tell each other if pigs are sick and confine sick pigs

Participants from villages B-F reported that they already shared health information on most occasions, but that they did not always confine sick pigs. Participants from village A did not previously perform this measure, but saw no obstacle to its future implementation. It was specifically mentioned that implementation of the measure did not involve any costs and that it was important to have reciprocal information to avoid disease transmission. At the first follow-up, participants from village A reported quite a lot of interaction with the community: sharing information about their own sick pigs, being called to give advice on pig health, practising isolation of sick pigs, and explaining this and other preventive measures to the community. No participants from village E had experienced any sick pigs. At the second follow-up, participants from village E reported that community members who did not participate in the study had different knowledge about disease prevention and control, and therefore it was difficult for them to communicate on equal terms.

3.2.12. Remove carcasses of dead animals and aborted foetuses from the pigs and bury them

Participants from all villages reported that aborted foetuses were disposed of, but only participants from village F reported doing this safely in the form of burial. Participants from villages B and E perceived the burial of aborted foetuses to be feasible. Safe disposal of adult pigs by either burying or burning was perceived as difficult or even impossible by many participants due to a cultural taboo about burying animals, and to tradition and food security implications of discarding valuable protein. Participants in villages B, C and F, however, said it might be possible and that they would try to implement this measure. At the first follow-up, none of these participants had experienced any of their own pigs dying. Participants from villages B and F reported that they had managed to convince owners of pigs that aborted to safely dispose of the foetuses by burial. This had required some explanation but had been feasible. The burial of dead adult pigs was reported as unfeasible by participants from village C. At the second follow-up, only traumatic deaths (drowning and strangulation by the tethering rope) were reported so the measure had not been applicable.

3.2.13. Always contact the vet if pigs are sick

Participants from villages B-F reported always calling the veterinarian or the community animal health worker on such occasions, while participants from village A reported sometimes calling the vet and sometimes not. No village selected this measure.

3.2.14. Don't feed pigs hotel/restaurant swill or cassava leaves from pork joints without cooking first

Participants from villages A, B and E reported not having previously been aware that feeding swill was a risky practice, but that it would be possible to stop using this feed source. In village E, all the participants used market scraps to feed pigs. Participants from the other villages already did not feed swill sourced from outside the household, mainly because of the costs and fear of the swill containing too much salt or other food items that are not healthy for pigs. At the first follow-up, all participants from the village that had selected this measure had stopped feeding pigs market scraps. Participants rated this measure as easy to perform, reporting that they fed pigs home-grown maize and cassava instead.

3.2.15. Create a farmers/village group with common standards for pig-keeping

Participants from villages C and D reported that they were already in other farming groups that could be extended to also cover pig farming. All other participants were positive about forming new groups based on the community members present at the interview. The measure was chosen by all the villages, but at the first follow-up no villages had managed to start groups and they asked for support to facilitate the first steps in forming a group. The second follow-up was used to provide this guidance and the groups were formed during that meeting.

3.2.16. Create a farmers/village savings group as village insurance to be used in case of outbreaks for those that follow the contract

Participants from village C reported that the farming groups in which they were currently participating were already collecting funds. Participants from the other villages would consider the possibility of collecting funds in the groups that already existed, or that were to be formed. At the first follow-up, no villages had managed to perform this measure as the implementation was linked to the creation of pig production groups. Setting aside funds for this was perceived to be difficult.

3.3. Biosecurity measures suggested in the trader subgroups

3.3.1. Never enter villages or where pigs are kept, but instead let the farmers bring the pigs out to me

Participants from village E were already practising this measure, whereas the other participants were entering homesteads and/or pigsties on most occasions. All participants agreed that it was possible to implement this measure, especially if farmers were also made aware of the associated risks. At the first follow-up, participants from the villages that had selected the measure reported that it was widely implemented, some had been practising it before and for some this was a change. Participants reported sometimes being obliged to explain why they did not want to enter homesteads or pigsties but, despite this, implementation was perceived to be easy. Some farmers reportedly regarded this practice as suspicious, thinking that the traders had been in contact with infected pigs if they needed to take such special precautions, and others needed assistance to bring out the pigs, e.g. because of physical weakness. At the second follow-up the measure was still reported as

being mostly implemented.

3.3.2. Wash hands, change clothes and clean boots after handling pigs and before handling another pig

Some of the participants from villages A-E were already washing their hands and boots, some only their hands, and some neither. None of these participants were changing their clothes or overalls between handling pigs from different customers. Some of the participants had overalls that they used only while buying pigs, but did not change them between customers. Some of the participants considered this practice achievable and some did not, to a certain extent depending on how many pigs they buy per day and the geographic location of the customers relative to their homes and businesses. Participants from village F had overalls and only bought and slaughtered one pig a day, so perceived the measure to be feasible. At the first follow-up, most participants from villages that had selected the measure had started to wash their hands, but changed their clothes and boots much more rarely. This was reported to be due to not having a second set of clothes or not having time to return home to change or wash between customers. Several participants had however changed their practices since the first interview, e.g. procured a second pair of boots. At the second follow-up the practice was reported to have become routine.

3.3.3. Don't take live pigs back from market/slaughter slab to my own village

All participants from villages A, C, D and F were already keeping pigs brought back for resale separate from pigs in their own herds that were destined to be kept, whereas some of the participants from villages B and E mixed these two categories of pigs. Participants from all villages agreed that the measure was feasible to implement. At the first follow-up, traders from village E reported keeping pigs for the household and pigs for sale separately. Traders in village B did not manage to completely separate the two categories of pigs, but still reported taking more care, e.g. avoiding contact at feeding.

3.3.4. Only buy healthy-looking pigs

This measure was generally not perceived to be feasible, even if several participants reported that their intention was to always buy healthy pigs. Buying sick pigs was perceived to be unfavourable as they could not be resold, might be condemned on veterinary inspection, might transmit diseases and were considered to have less tasty pork. Participants mentioned that pigs might look healthy on inspection despite actually being sick, and also that it was difficult for traders to refuse to buy if farmers were desperate to sell their pigs. At the first follow-up, some participants from villages that selected the measures reported that they had already previously been practising this, while others reported a change in this regard. Fear of pigs dying before being resold and veterinary condemnation of the pork were mentioned as strong incentives for implementation.

3.3.5. Don't buy pigs from villages with outbreaks

All participants from village C reported that they were already practising this measure. In the other villages, the measure was practised by some participants and not by others, or at least not at all times. Some participants from village F reported buying pigs from areas with outbreaks, but only individuals that looked healthy. Particularly diverging perceptions were discussed regarding the feasibility of this measure. Outbreaks were reported to create chances to make a profit, but also to come with a risk for the pigs of the traders or their communities, as well as for the traders' business reputation and profitability, as the pigs might die before being sold. Traders also reported sometimes not being aware of outbreaks before arriving at the trade location, or to only be presented with pork (and not the entire carcass or a live pig). It was mentioned that farmers generally do not want to sell healthy pigs, but only pigs that are sick. At the first follow-up, the measure was generally reported to be implemented by participants from villages that had selected it, and that this constituted a change in their practices related to the first meeting. They mentioned that it was hard to refuse to buy sick, dead or dying pigs from farmers who were desperate to sell. However, participants were persuaded not to buy unhealthy pigs or go to outbreak villages to buy pigs. At the second follow-up, participants reported that no or few outbreaks had occurred since the previous interview, with the measure only partly applicable on that occasion.

3.3.6. Report to the vet if I hear about sick pigs

Participants from villages E and F were already practising this measure whereas none of the participants from village A and only some from villages B, C and D had reported disease events. Several participants thought that reporting was the responsibility of the farmer and that if they reported it, it would endanger their business relations. Participants from village A perceived the measures as feasible, and that reporting would protect their customers. At the first follow-up, one participant stated that she had reported a recent outbreak and another participant recounted that this was not a new practice for him. At the second follow-up, participants reported that no outbreaks had occurred since the previous interview and thus the measure was not applicable.

3.3.7. Only slaughter "walking pigs"

All participating slaughterers reported that they were already practising this measure and the participants selling cooked pork reported that they were not willing to buy pork from pigs that had been found dead. At the first follow-up, the participants who had selected the measure reported that they had now changed their practice and no longer bought dead pigs. However, they said that it was hard to refuse to buy dead pigs from farmers who were desperate to sell. At the second follow-up, the measure was described as having become routine.

3.3.8. Take care that blood, offal and other leftovers are safely disposed of so that pigs, dogs, rats and birds cannot get to it during and after slaughter

All participants were reportedly slaughtering in very unhygienic conditions, directly on the ground or on plastic sheets with literally no possibility of avoiding blood contamination of the environment or practising safe disposal of offal. This was confirmed during field observations at the first follow-ups. Water was used during the slaughter process. Most were slaughtering in rented or communal properties and paying fees to the community for using the space, market access and for services such as offal removal; others left blood and offal on the ground for the benefit of free-roaming dogs. Blood was described as most often being let out on the ground or in some cases collected in plastic bags or in a shallow hole dug in the ground. Some basic improvements, such as collecting blood and wastewater in buckets and disposing of blood and offal in pit latrines, were discussed and regarded by all as possible to implement. At the first follow-up, many participants who had selected the measure still experienced difficulties in implementation as there was a lack of infrastructure at the slaughtering facilities and they often did not own the properties, hampering investment in biosecurity. Some had managed to find preliminary solutions since the last meeting, and several had started constructing facilities that would enable safer handling of offal and blood. At the second follow-up, implementation was reported as continuing to improve. The use of public latrines for offal was a common solution.

3.3.9. Don't take equipment used for slaughter/grilling home

Participants from villages A, B and C were bringing slaughter equipment home at the end of the day, some after washing it and some directly without any precautions. Participants from villages D, E and F were already practising the measure. This approach was perceived as feasible, for example purchasing an extra axe to be kept at the workplace. At the first follow-up, one participant from the village that had selected the measure reported always having kept equipment for these two purposes separate, whereas another participant reported having changed his practices in this regard after the first meeting.

3.3.10. Make sure that items that have been in contact with meat, pig products or blood (axes, knives, buckets) never come into contact with pigs

Participants from villages B, D and F were already practising this measure. Equipment used for slaughter by participants from villages A and C was not protected from contact with pigs, but the measure was considered feasible to implement. However, no village selected this measure.

3.3.11. If I know that the pig was unhealthy - heat treat pork before sell or dispose it safely

This measure was not relevant for all participants, depending on their respective roles in the value chain. Participants in villages E and F reported previously selling fresh pork suspected as coming from diseased pigs, but that it would instead be possible to cook such pork before selling it. Participants from villages A and D reported previously having discarded or burnt entire carcasses or parts of them that did not look good. At the first follow-up, implementation varied, with some participants from villages that had selected the measure reporting that they had never slaughtered or bought pork from unhealthy pigs, while some reported that they continued to do this. No change was thus reported. Mention was again made that it is difficult to refuse to buy dead or unhealthy pigs as farmers are often desperate on such occasions. At the second follow-up, participants from village E reported that no outbreaks had occurred and they therefore had not been confronted with any unhealthy pigs. Participants from village F said that it was challenging to implement the measure because if pigs became sick after purchase but before slaughter, the trader must keep and feed them until they become healthy, thus incurring costs.

3.3.12. Issue a health declaration of pork for sale

An unofficial "self-declaration" was not deemed possible to introduce for any participants. Participants reported challenges with the existing official inspection, including low availability of veterinary inspection staff and inspections therefore being performed by other categories of officials, variation in the price of inspection between communities, and sometimes different prices depending on the inspection results. No village selected this measure.

3.3.13. Create a village group with common standards for pig and pork handling

Participants from villages A and E reported that they were already in other groups that could be extended to cover pig trade slaughter standards. The participant traders who were also farmers suggested forming a common group for farmers and traders. All participants were positive about forming new groups, seeing many added values from working together both as traders and as part of the wider community. At the first follow-up, participants from village B had started a group that also included farmers, while the others had not been able to initiate the groups. At the second follow-up, the group in village B was still active and participants from village D had also been able to form a group.

3.3.14. Create a village savings group as village insurance to be used in the case of outbreaks for those that follow the contract

Participants from villages D and E reported that funds were already being collected in other groups of which they were members. Other participants considered the possibility of collecting funds, if groups were formed, as positive. At the first follow-up, villages B and E had started a saving (but not insurance) scheme. The other villages had not managed to start one as intended. At the second follow-up, the group in village B was still active and had distributed the savings between members. Participants from villages C and D had not been able to start saving.

3.4. Implementation

None of the subgroups had fully implemented everything that had been agreed in the contract at the first follow-up, but all subgroups had changed some of their biosecurity routines. The reported success rate of fully implemented measures, counting only measures that were previously not implemented, in the farmer subgroups ranged from 0/6–4/7 at the first follow up, increasing to between 0/6 and 5/7 at the second follow-up. For the trader subgroups the success rate ranged from 0/5–2/3 at the first follow up, increasing from 0/5–5/6 at the second follow up (Tables 1a and 1b).

In the thematic analysis, three general themes emerged regarding reasons for rejecting the inclusion of a specific measure in the community contracts: feasibility, costs and losses, and social norms and traditions. Many measures were not deemed **feasible** for implementation by all group members. This was related to structural constraints such as a lack of infrastructure (e.g. pig housing, slaughter facilities, offal removal services) and the participants' personal experiences and livelihood situations. Some measures were further not perceived as relevant for pig-keeping, the disease reality or the activities performed by participants in the value chain (e.g. trade routines for farmers who had their own breeding stock or measures enabling safe slaughter for those who only handled pork). For many measures participants said that implementation was constrained by associated **costs** or potential **loss of income** or food sources (e.g. buying disinfectants or overalls, constructing a pig enclosure, discarding carcasses or pork), or by **social norms and traditions** (e.g. burying animals, wasting food, restricting neighbours' access to the homestead and the pigs).

The factors emerging as enabling or hindering implementation at the first and second follow-ups were often specific for each measure, but some general themes emerged in the analysis (see Fig. 1). These hindering factors were largely similar to those emerging from the data from the first meeting regarding reasons for rejecting measures, with the addition of factors related to the COVID-19 pandemic and restrictions, with a strong emphasis on access to and costs of commercial pig feed. Themes emerging as enabling factors were **feasibility,** where measures that could be directly and easily adapted to fit the local situations were perceived as more achievable (for example, suggested local adaptations were to take the veterinarian to the market for a health assessment, use of an abandoned hut for isolating new pigs, extending measures intended to limit indirect contact to encompass all consumption of pork bought outside the household and to dispose of offal in latrines), as were low cost-measures. Feasibility was further impacted by participants' livelihood situations, especially the possibility of constructing enclosures, which is a prerequisite for several other measures. As further elaborated on in a previous paper (Chenais et al., 2023), the **knowledge** gained during the discussions was described as empowering participants, helping them to explain their changed biosecurity behaviour to others, motivating changes in their own routines and instigating change in the wider community. For some measures participants mentioned that they had previously been aware of the specific biosecurity recommendation, and the discussion had been a reminder to again implement measures that had previously been in place. The broad **community approach** with the inclusion of several different stakeholders in the value chain further enabled implementation, especially for measures involving several stakeholders, such as the trade in live pigs.

3.5. The COVID-19 pandemic

Restrictions due to the COVID-19 pandemic, such as the complete cessation of all public activities and gatherings, closure of schools and markets, and limitations on transport, were in place in Uganda from March 2020 and throughout the rest of the study period (with some variations). This affected the study, with less intense follow-ups than anticipated, and had specific consequences for how the participants could implement the biosecurity measures agreed in the community contracts. The effect varied between villages and subgroups as well as between measures. Reported consequences for the farmer subgroups are detailed in Annex 5. Specific restrictions, such as the closure of schools, affected both farmers and traders, but in different ways: farmers

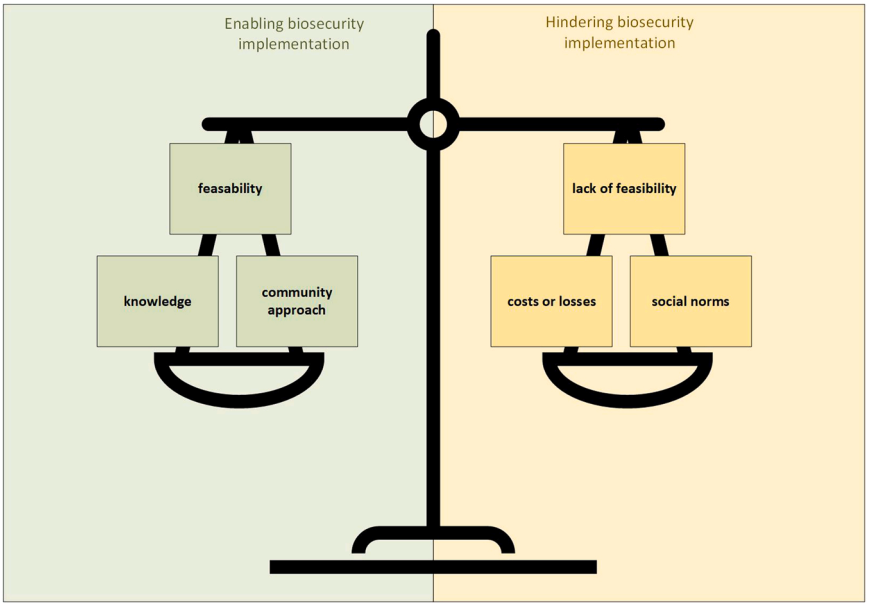

Fig. 1. Factors emerging as enabling or hindering implementation of biosecurity in a study carried out in Northern Uganda from 2019 to 2020.

reported that it was positive that the children stayed home and could help with farming activities, whereas traders reported that the closure of schools led to a reduction in pigs on the market as farmers generally sell pigs to pay for school fees. It was repeatedly mentioned that access to commercial pig feed had become difficult during the lockdown period as feed mills closed, transport was restricted, feed and transport prices increased, and participants lost income opportunities that would normally have raised money to buy pig feed. This was reported as negatively impacting on the possibilities of the farmer subgroups implementing the measures "Keep new pigs away from the rest for 14 days"," Keep pigs confined at all times and in all seasons" and "Don't feed pigs hotel/restaurant swill or cassava leaves from pork joints without cooking first". In the study area pigs are often transported on motorcycle taxis (boda-boda in Ugandan English), either tied to the seat behind the driver, or held over the knees of the passenger. During lockdown, boda-bodas were only allowed to transport goods, not passengers. Farmers and traders could thus only transport pigs by boda-boda if they were driving themselves. This was reported to negatively affect the possibilities of the farmer subgroups implementing the measures "Only buy healthy-looking pigs" as it was difficult to travel to find healthy pigs and also "Keep new pigs away from the rest for 14 days". The traders' possibility to buy pigs at all was equally negatively affected by the specific boda-boda transport restrictions, as well as by a restriction ordering a curfew and another closing pig markets. Traders were further negatively affected by travel and social contact restrictions, as these prevented them from visiting farmers and villages to buy pigs. Lockdown reduced the demand for fresh and roasted pork in the village centres when people mostly stayed at home or left the village centres as workplaces closed. However, the same restrictions affected the implementation of other measures in a positive way. Farmers reported that the measure "Don't let others touch my pigs without washing hands, changing clothes and clean their boots" was easier to implement as people were visiting each other less. Farmers reported that the increased attention to hand hygiene and the associated increased availability of hand-washing facilities and hand sanitiser simplified the implementation of the measures "Wash hands, change clothes and clean my boots after handling other peoples' pigs" and "Wash hands, change clothes and clean boots after handling sick pigs". Similar positive effects were reported by traders in relation to general hygiene. At the same time, both subgroups reported that the price of hand sanitisers and disinfectants increased during the restriction period, making implementation of these measures challenging. The negative effect of the increased cost of disinfectant was emphasised by traders who were requested to organise feet disinfection at the entrance to pork joints at the same time as they were requested to reduce the number of tables and number of clients per table, thus simultaneously increasing costs and decreasing business opportunities. Traders reported that they bought fewer pigs as demand decreased, which made it easier to slaughter pigs immediately without having to take them to the homestead and risk mixing pigs bought for slaughter with pigs from the permanent home herd. The reduced number of slaughtered pigs was likewise reported to have made it easier to render offal in a safe way. The social distancing restrictions made it impossible to hold meetings and implement measures that were based on group action ("Create a farmers/village group with common standards for pig-keeping", "Create a farmers/village savings group as a village insurance to be used in case of outbreaks for those that follow the contract", "Create a village group with common standards for pig and pork handling", "Create a village savings group as a village insurance to be used in case of outbreaks for those that follow the contract"). As resources were even more constrained during the restrictions, e.g. due to less income as well as higher feed and transportation costs, it was also reported to be more difficult to implement the savings scheme for the village insurance.

4. Discussion

Biosecurity measures used for ASF prevention are generally designed to reduce direct and indirect contact between infected pigs, their excretions and products, and naïve pigs (Costard et al., 2009). Most of the suggested measures in the community contracts fell into this category, with the addition of one measure designed to improve early reporting and some with the intention of improving communication and strengthening group and community identity. In the farmer subgroups, the measure "Always contact the vet if pigs are sick" was uniformly rejected and the measure "Use only my own boar" was selected by just one village. Both these measures are frequently included in ASF biosecurity advice, irrespective of the context or target group (FAO, 2009; Beltrán-Alcrudo et al., 2017; Jurado et al., 2018). Limited veterinary access, especially for poorer smallholders, low quality of veterinary services and difficulties encountered by smallholders in differentiating veterinary professionals from, for example, community animal health workers who might not have any animal health education at all have

previously been reported in the study area (Aliro et al., 2022; Arvidsson et al., 2022b). For smallholders to be able to have more frequent veterinary contacts and increase the chances of early reporting of ASF, this structural problem needs to be addressed and included in e.g. national development plans (Forman et al., 2012). Reproduction is necessary for livestock production, and in the study context few means to ensure reproduction other than borrowing boars were available to most of the participants. Notably, participants suggested and tested ways to decrease the risk connected with this unavoidable practice during the study period, such as using boars from people in the study or from people they knew had good pig management routines, or isolating the sows on return from service. Some participants mentioned artificial insemination, but it was discussed as being expensive and not possible to receive on credit, whereas use of the boar is normally paid for in the form of a piglet on delivery of the litter. These two examples of frequently recommended measures, yet largely rejected in this study, tell two important stories. First, successful implementation of biosecurity measures is connected to other structural constraints, such as access to veterinary and breeding services, and the quality of veterinary services. It is futile to recommend contacting a veterinarian if people do not have access to one and if the services are not of high quality. Second, co-creation, local adaptation and flexibility will increase the probability of successful implementation. Participatory approaches for improving pig management and biosecurity have previously been used in the Philippines and Timor-Leste with good results (Barnes et al., 2020a, 2020b). In both studies, the capacity of biosecurity to protect against several diseases and at the same time improve general animal management and herd health were included in the theory of change. This multi-functional quality of biosecurity makes it an ideal subject for participatory approaches and co-creation: even if farmers, veterinary authorities or project funding agencies have different animal health priorities (Ebata et al., 2020a), participatory principles can be respected and participants' priorities remain in focus while co-creating measures that fit under the general umbrella of improving the implementation of biosecurity (Chambers, 1983; Allepuz et al., 2017). A topic that has been mentioned as a priority by smallholders and that is closely connected to biosecurity while also being an important pig production factor is local access to pig feed (Mutua et al., 2012; Dione et al., 2015; Barnes et al., 2020a; Aliro et al., 2022). This subject needs further attention and innovation.

Previous studies in the same geographical area have found both farmers and traders to be generally knowledgeable about ASF as well as about its prevention and control (Chenais et al., 2017b), while studies from other areas in Uganda have reported knowledge gaps concerning the same topics (Dione et al., 2014; Nantima et al., 2016; Mutua and Dione, 2021). In the present study, villages and participants were purposively selected for having experienced ASF. Nevertheless, participants were not aware that several very basic and rather simple biosecurity measures (confining pigs, isolating new pigs, separating sick and healthy pigs, hand hygiene, change of clothes and footwear, not feeding swill, having separate equipment for business and home use) could prevent the spread of ASF. Similar results have been observed in a study on biosecurity with cattle farmers in western Uganda (Wolff et al., 2019). The present study did not consider the time that had passed since the previous outbreaks, if the individual participants had been personally affected by previous outbreaks or investigate what information the participants had received in connection with previous outbreaks in their villages. The identified knowledge gaps might therefore be due to recall or selection bias, and just as likely signs of limited veterinary contact even during outbreaks, as of low quality of veterinary service delivery (Aliro et al., 2022; Arvidsson et al., 2022b). It is further possible that these knowledge gaps are not specifically related to ASF, but demonstrate a more general difference between local and scientific knowledge regarding causes of disease (Chenais and Fischer, 2018; Seligsohn et al., 2020). As in the study by Wolff et al. (2019), many of the measures that participants did not previously consider as preventive or control measures were selected for inclusion in the community contract, their implementation was described as feasible, and several were successfully implemented. In the same way, seemingly impossible measures such as not borrowing boars were spontaneously adapted, based on the knowledge acquired during the study, in order to lower the associated risk of disease spread. The farmer subgroup in village B (where an ASF outbreak reportedly occurred in a neighbouring village at the time of the first follow-up) had high success rate for implementation. This might have been due to the outbreak making people more aware of the risks and paying more attention to disease prevention and control or to confounding factors that the study design did not control for. Some basic (and therefore also frequently recommended) biosecurity measures were rejected by some communities for cost reasons. These included confining pigs, with the difficulty of providing feed if pigs cannot roam freely and scavenge frequently underlined. Other measures, simpler than constructing housing or enclosures, and not requiring major investments in infrastructure or equipment that cannot be found locally, were also rejected on cost grounds. These included washing hands and boots and changing clothes before touching other people's pigs or between different customers. Not having or being able to afford to buy several sets of overalls or changes of clothes was repeatedly mentioned. That even minor cash expenses hinder biosecurity implementation highlights the level of general poverty in the studied communities, and the importance of poverty as a *specific* factor, connected to but separate and unique from other structural, social and political factors that also affect the implementation of disease control (Ebata et al., 2020b). In this regard, selling sick (or even dead) animals was an important coping mechanism for farmers, with traders reporting difficulties in refusing them. It has previously been described how traders benefit from outbreaks (Chenais et al., 2017b; Dione et al., 2017a). In this study too, traders described outbreaks as constituting both a business opportunity and a threat. For the measure "Create a farmers/village savings group as village insurance to be used in case of outbreaks for those that follow the contract" a difference could be observed in the success rate between farmer and trader subgroups (none out of three farmer subgroups versus two out of four trader subgroups). This difference might be associated to the difference between farmers and traders in terms of vulnerability and access to cash income.

One of the most frequently selected measures for both the farmer and trader subgroups was to "Create a farmers/village group with common standards for pig-keeping/pig and pork handling". A strong commitment to working together for the common good has been reported in relation to other topics in rural Uganda (Andersson and Gabrielsson, 2012; Bergström et al., 2012). In a previous study describing the methodology used here, "cooperation" also emerged as an important theme in the analysis of how the community contract was perceived (Chenais et al., 2023). This positive attitude to cooperation in the context of disease control is particularly interesting given the limited capacity of the national authorities for controlling animal diseases in Uganda (Ilukor et al., 2015; Ilukor, 2016), thus requiring other stakeholders to take ownership of disease control. Interesting to note in this regard is also that the positive perception of "cooperation" specifically refers to working together across stakeholder groups in the communities (Chenais et al., 2023). Making a north-south comparison and demonstrating a global similarity of challenges that might seem very local, in Sweden where many important infectious animal diseases have either never been reported or controlled and eradicated, the role of farmers, their organisations and cooperation between organisations as well as between the organisations and the authorities has been underlined as a success factor (Sternberg and Viske, 2003; Hult and Lindberg, 2005; Carlsson et al., 2009; Wierup et al., 2021).

In this study structural and systemic constraints, including a lack of infrastructure, particularly hindered biosecurity implementation for participants in the trader subgroup. To be able to run their business they had to pay several different fees: for renting premises in the trading centres, for accessing markets, for slaughter inspection and in some

cases for offal removal. A common characteristic of these payments was that the sum varied considerably between the villages, and that the cost-benefit for the individual trader was questionable. Participant traders, for example, paid fees for communal slaughter facilities without basic hygiene, such as a surface for performing the slaughter that could be cleaned, without an available sewage system and running water, as well as for veterinary inspection that was found during the study not to be performed by a veterinarian. Veterinary inspection is obligatory at slaughter in Uganda, mainly aimed at detecting cystisercoid cysts due to infection with *Taenia solium,* but district veterinary offices are not sufficiently staffed to cover all remote slaughter slabs (Kungu et al., 2017). These structural and systemic constraints and lack of transparency seemed to affect biosecurity negatively (Ilukor, 2016; Ebata et al., 2020c). In the smallholder pig value chain in the study area and in similar settings, slaughter constitutes the activity with the highest potential for ASF spread (Costard et al., 2013). This is based on the epidemiology of ASF, with high viral titres present in the blood of viraemic pigs (Davies et al., 2015; Gallardo et al., 2017), in combination with slaughtering of in-contact as well as visibly sick pigs being a common risk mitigation strategy for many smallholders (Nantima et al., 2015b; Thomas et al., 2016; Dione et al., 2017a), ante-mortem veterinary inspection not always being performed, and the slaughter infrastructure having very limited possibilities to prevent blood contamination of the environment and render offal safely (Ouma et al., 2013). The biosecurity improvements seen concerning slaughter in this study were thus very positive, indicating that the methodology can be effective for instigating changes despite structural and systemic challenges.

Safe carcass-handling is another important aspect for breaking the transmission chain during ASF outbreaks (Costard et al., 2009). In low-income contexts, the options for safe rendering of carcasses are limited to burning or burial, and the organisation and costs of carcass-handling are largely left to the individual farmer. Burning carcasses incurs costs for fire wood, while burial requires labour and can carry a risk of carcasses being exhumed for the purpose of human consumption (Coffin et al., 2015). These negative aspects of safe carcass-handling were mentioned in this study, as was the food security aspect of destroying important protein and the cultural taboo related to burying the remains of animals. These social norms seemed to be strong in some villages and for some participants and possible to overcome for others, indicating heterogeneity between and within communities.

As burying animal carcasses is an even more important measure in other animal disease outbreaks, such as anthrax (to avoid contact with air and activation of spores), this social norm should be addressed more broadly as part of improving livestock management and disease prevention among animals and people.

The original study design had to be adapted due to the COVID-19 pandemic; the participants received less support than intended and the follow-ups were delayed. Nevertheless, implementation was generally successful. The restrictions affected how participants could implement the selected measures, in most cases reportedly making implementation easier. The main negative COVID-19-related hindrance to biosecurity implementation was the reported increase in prices of commercial feed and the heightened issue of accessing commercial feed. The participants lost to follow up during the study were not equally distributed among men and women, with only female participants being lost at the second follow-up. This might reflect that women often have more households chores than men and might find it challenging to devote time to activities without a direct livelihood benefit (Smith, 2012). Data concerning prior implementation of the suggested measures as well as implementation success rate was recorded on group level. In the studied communities the epidemiological unit is the village, with pigs free-roaming and many resources being shared. A community approach to biosecurity was hence deemed appropriate despite that most of the suggested measures are executed by individuals. The mix between individual actions and communal responsibilities might have influenced the results. Some measures were for example selected despite being recorded as "already implemented". In these cases, the measures might have been recorded as "already implemented" due to some participants already performing the measure, which served as an inspiration for the rest of the group to do the same. Measures recorded as "already implemented" at the first meeting was counted as "partly implemented" at the follow-ups, and the success rate was based on "implemented/agreed measures". This rate could thus represents an under-estimation compared to the true biosecurity change. Another way of recording the data could have clarified these potential biases. Recording the discussions (and not the translations) might also have contributed to a deeper information level in this regard.

In conclusion, it appears that the participatory methodology applying co-creation to community contracts for improved biosecurity facilitated implementation. Critical aspects of co-creation such as encouraging discussions, flexibility, local adaptation of measures and the option to reject measures seemed important for success. The positive tendency for implementation extended also to measures that appeared controversial in the discussions. Application of a community approach involving different stakeholders in the study further appeared to facilitate implementation as both sets of partners in pig transactions were included in the study and thus aware of the community contract.

Ethics approval and consent to participate

The study was approved by the School of Health Sciences Research and Ethics Committee, Makerere University, Kampala, reference number 2019–062.

Author contributions

EC, KF, KS and SSL designed the study. EC and TA performed the fieldwork. EC analysed the data and drafted the manuscript. All authors contributed to the final analysis and writing.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2023.105902.

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