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Structural analysis of Uganda's pig semen value chain: Actor networks, challenges, and opportunities

Isaac Kasoro [a,b,*], Donald Rugira Kugonza [b], Karen Marshall [c]

[a] *International Livestock Research Institute (ILRI), Kampala, Uganda*
[b] *Department of Animal and Range Sciences, College of Agricultural and Environmental Sciences, Makerere University, Uganda*
[c] *International Livestock Research Institute (ILRI), Nairobi, Kenya*

Abstract

Uganda's pig sector has expanded significantly, supporting households and value chain actors, and stimulating development in boar semen production. Despite this growth, the relationships and roles among actors within the boar semen production node remain unclear. This study conducted key informant interviews with six companies that were operating in Uganda between 2019 and 2023. These interviews examined a range of issues including the boar breeds reared and sourcing information, semen production and quality control practices, as well as constraints and opportunities. High-quality genetics enter Uganda through imported boars and gilts, with the six semen-production companies keeping a total of 23 boars (between two to six per company) predominantly of Duroc, Large White and Landrace breeds. Semen quality control involved both macroscopic (colour, temperature, smell) and microscopic (motility, concentration, viability) analyses, which conform to the set semen quality assessment methods. However, challenges remain in maintaining semen viability during storage, controlling storage temperature at 17 °C, the high cost of boar genetics, and the lack of clear standards and regulations. Despite these issues, opportunities exist with the growing demand for quality genetics and farmers' investment interests. Therefore, improved coordination and collaboration between actors along the boar semen value chain could streamline the sector and increase the productivity of Uganda's pig industry.

Keywords: boar semen-production, pig artificial insemination, pig genetic value chain, pig semen quality, smallholder pig production

1 Introduction

In Uganda, the pig sector continues to grow and supports over 2.2 million households and other value chain actors. In response to human population growth and demand for pork, the pig population rose from 3.2 million in 2008 to 7.1 million in 2021 (UBOS, 2024). Pig production is preferred by many smallholder farmers due to its relatively quick returns, limited land requirements, and ability to utilize agricultural waste (Marshall *et al*., 2023). In addition, pig production is increasingly contributing to improved nutrition and household incomes for smallholder farmers (Ouma *et al*., 2014). Therefore, if the sector is improved, it has the potential to alleviate poverty and contribute to improved food security and livelihoods.

Pig Artificial Insemination (pig AI) is a technology that has been recommended for improving smallholder pig production systems in most rural areas (Kadirvel *et al*., 2012). This technology is preferred because; (a) it is cheaper to pay for AI service than rearing a boar, (b) it provides farmers with a choice of boar breeds, (c) it allows for the use of superior boar genetics on many sows, (d) it reduces the spread of diseases in the herd particularly African Swine Fever (ASF), (e) it avoids injuries on smaller sows from bigger boars and (f) it offers similar litter size compared to natural service (Dziekońska *et al*., 2017; Knox, 2016; Marshall, 2020). In Uganda, this technology was successfully piloted by the College of Agricultural and Environmental Sciences (CAES) of Makerere University in 2011 (Mutetikka *et al*., 2011). Consequently, several initiatives and projects have been conducted to enhance its use and adoption in the country. However, the use and adoption of pig AI in the

* Corresponding author: isaackasoro@gmail.com

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country remains low (Niyiragira *et al*., 2018), with approximately 52 % of pig farmers in the central region still relying on communal boars for breeding (Bamundaga *et al*., 2018). Hence, increasing the use and adoption of pig AI technology by most smallholder farmers would result in increased production of the pig sector.

Whilst previous studies have analysed the overall pig value chain (Ouma *et al*., 2014, 2017; Nantima *et al*., 2015; Oba *et al*., 2022; Ngwili *et al*., 2023), the genetic component has not been fully analysed. Furthermore, the emergence of new actors in the breeding space, the increased importation of pig breeds and the emergence of boar studs, as well as the development of regulations to guide the breeding of terrestrial animals in Uganda, necessitate the study of the flow of genetics within the pig value chain. Characterising and assessing the challenges and opportunities faced by the different actors along the pig value chain would provide value insights into the adoption of pig AI. Understanding these dynamics can help identify key factors influencing its implementation and growth within the pig industry. This study aims to contribute to the increased efficiency of AI in Ugandan pig production by mapping stakeholder relationships, strengths, and weaknesses, and by describing the semen production, processing, and marketing practices of the different semen-producing companies in Uganda.

2 Materials and methods

2.1 Overall approach

Key informant interviews were undertaken with representatives of each of the six (6) currently operational boar semen-producing companies in Uganda. The information collected was used to generate a pig genetics value chain for Uganda (from the perspective of the company owners) as well as to explore the operations of the semen producing companies themselves.

2.2 Identification of semen-producing companies within Uganda

Using expert knowledge and the snowballing technique, a total of ten boar semen production companies were identified in Uganda to operate between 2019 and 2023. Only six (6) companies were still in operation at the time of this study, four had closed due to the outbreak of African Swine Fever (ASF), the costs of royalties paid to pig breeding companies for the further distribution of their genetics, and labour-related challenges. The locations of the six operational companies, which are in the districts of Mukono, Wakiso, Luweero, and Buikwe, are shown in Figure 1.

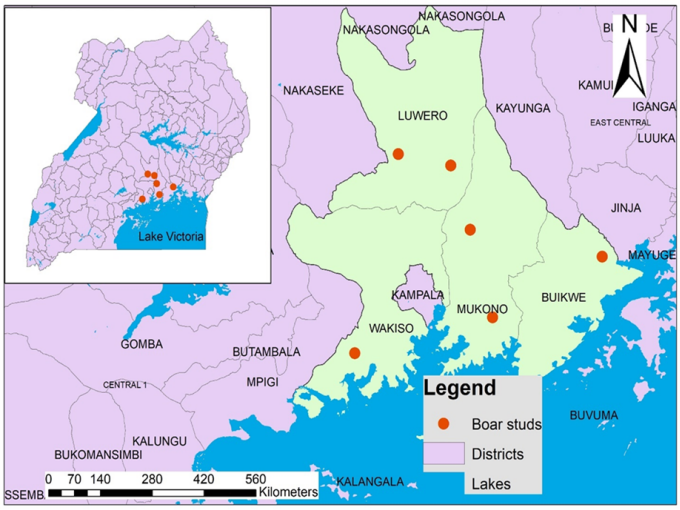

Fig. 1: *Location of the boar semen-producing companies in Uganda.*

2.3 Survey tool

A Key Informant Interview (KII) guide was developed to collect data relevant to the semen production node of the pig genetics value chain. The KII guide comprised sections on 1) the stud manager's demographics including sex, level of education, age group, business location, and role in the business enterprise; 2) The business operations' nature including the years in operation, products and services offered, major clients, number of employees, and any other business changes; 3) The boars kept for semen production including the boar breeds, why these breeds, selection criteria for the breeds, breeding programs, length in semen production, challenges sourcing the boars, and culling criteria; 4) The semen collection and preservation procedures including the collection frequencies, ejaculate volumes, collection techniques, semen analysis, input sources, training on pig AI, challenges in semen collection and analysis as well as records kept on semen production; 5) The semen demand and marketing process, and 6) Constraints and opportunities at the semen production node. Furthermore, the respondents were also engaged in activity to identify different nodes of the pig semen value chain and the actors therein, as well as actor roles at each of these nodes. The tool was pre-tested with two former managers of boar semen-producing companies, and feedback from this pre-test was used to refine the tool.

2.4 Data collection and analysis

The managers and directors of the six operational boar semen-production companies were the survey respondents. Interviews were undertaken in English at the companies' premises from August to September 2023, in English. The

interviews were audio-recorded using the sound recorder app on the phone and transcribed verbatim to Microsoft Word 365, with the assistance of the Microsoft Office speech-to-text transcription plug-in. The Word files were then coded to identify information on related themes, and information on the common theme was extracted and analysed further. Information on the actors, their roles, and relationships along the semen production node was used to generate a schematic for the node. The Cmaps® software version 6.04 (Institute for Human and Machine Cognition; A university affiliated Institute) was then used to draw the schematic.

2.5 Research approval

Research ethical review and approval for this study were obtained from the International Livestock Research Institute (ILRI) Research Ethical Committee (ILRI-IREC2022-41). Additionally, research clearance was granted by the Uganda Council of Science and Technology (UNCST-A303ES). Participation in the study was voluntary, with all respondents consenting to participate.

3 Results

3.1 Profile of the respondents

All six semen producing companies were privately owned and the respondents were either directors or managers of the companies. Of the six respondents, three had either a diploma or a degree in animal production and health, two had a bachelor's degree in veterinary medicine, and one had a master's degree in animal science. All respondents had received additional training on pig artificial insemination (Pig AI) from various institutions such as Makerere University, Nakifuma Farm, Kampala Capital City Authority (KCCA) Farm, IMV Technologies group, and Choice Genetics™. Only one respondent was female and the remaining five male. Three participants were youths (under 35 years) while the rest were non-youths (over 35 years).

3.2 The pig genetics value chain in Uganda

3.2.1 Overview

A schematic of the pig genetics value chain drawn from information provided by the respondents is given in Fig 2. Boars used for semen collection by most of the boar semen-producing companies are sourced from international breeding companies such as Choice Genetics™ in France, Pig Improvement Company™ (PIC) in South Africa, and Danbred™ in South Africa. Some Large-scale commercial farms also import boars from international breeding companies for breeding on their farms and sell replacement boars to some boar semen producing companies. The boar semen producing companies collect, process, and distribute semen doses to AI service providers and some pig farmers. Some boar semen producing companies also offer AI services to farmers. Additionally, breeding information regarding the best breeds to use is shared from the boar semennproducing companies to farmers and AI service providers. Old boars and those producing poor-quality semen are culled by the boar semen-producing companies and sold for slaughter for pork.

The AI service providers include veterinary practitioners, para-veterinary practitioners, and other personnel who are trained to conduct pig artificial insemination. These obtain extended semen doses from boar semen-producing companies and offer AI services to the different farmers in their locations. These also provide breeding advice to farmers regarding the best breeds for improving their productivity. The boar semen doses are packaged in either semen bottles or semen bags and transported using cooler boxes or improvised cardboards with ice packs. These are moved on buses and taxis for long-distance transportation, and on motorcycles (boda boda) for short-distance transportation. Generally, the pig genetics value chain was regarded as poorly organised with several independent actors operating in an unregulated, uncoordinated, and uncontrolled manner at all levels from production, processing, distribution, sale, and insemination.

Different actors and their roles along the pig semen value chain were identified by the respondents. These were categorised based on their node of operation in the chain. The actors identified included input suppliers, international breeding companies, AI service providers, farmers, regulators, and researchers.

The key input suppliers listed are AI equipment suppliers including private companies (Seminate Agri Solutions Ltd™ and CSVET™ South Africa) and pharmacies that supply catheters, microscopes, commercial boar semen extenders, collection bags, and chemicals for preparing laboratory-based boar semen extenders. International breeding companies such as Choice Genetics™ France, Pig Improvement Company™ (PIC) South Africa, and Danbred™ South Africa that export their genetics in form of breeding boars to the country were also identified as key actors along the production node. Additionally, local breeding farms that produce and sell both breeding gilts and boars were also listed as actors along the production node.

Boar semen-producing companies and AI service providers were the major actors identified along the production and distribution nodes respectively. The boar semen-producing companies mainly produce semen doses of different breeds and offer breeding advice to both farmers and AI

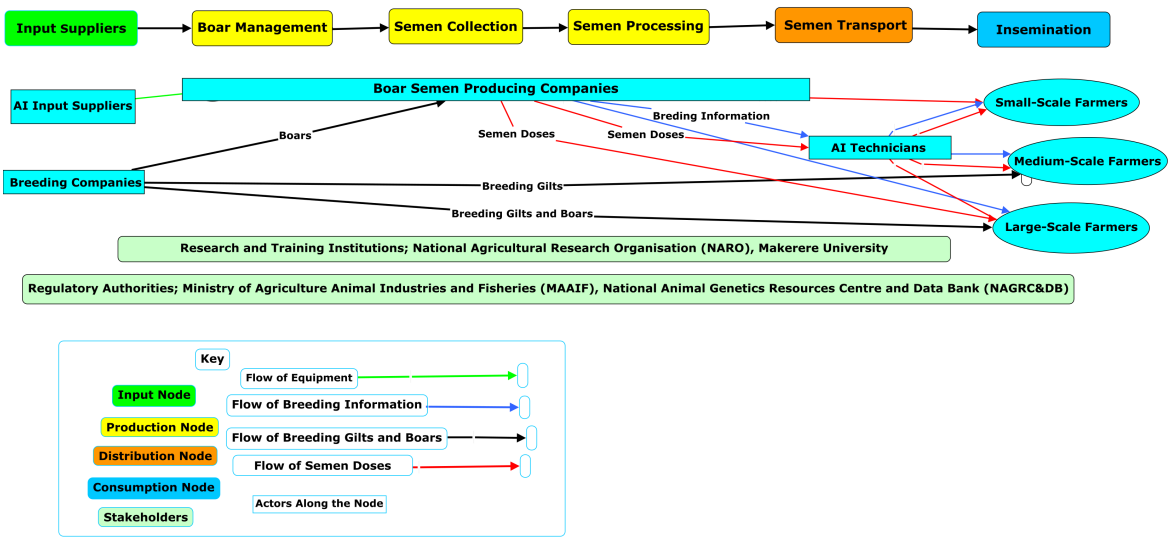

Fig. 2: *A schematic showing of the pig genetics value chain in Uganda. The arrows indicate the flow of pig genetics, equipment and breeding information. The colours represent the following: black – live animals; green – equipment; red – semen; and blue – breeding information.*

service providers. These pig AI service providers acquired semen doses from the semen-producing companies and delivered pig AI services to the local farmers.

According to the respondents, pig farmers were classified into three classes: smallholder, medium-scale, and large-scale farmers. Most respondents considered farmers with one to five sows to be smallholders, with five to ten sows to be medium scale, and with more than 10 sows to be large scale.

Regulatory bodies such as the Ministry of Agriculture Animal Industries and Fisheries (MAAIF) and the National Animal Genetics Resources Center and Data Bank (NAGRC&DB) were indicated to have a significant role in monitoring, evaluation, and control of importations and inseminations in the country. As stipulated in the Breeding Act of 2001, the commissioner of Animal Production and marketing in MAAIF is tasked with the registration, certification, and monitoring of both inseminators and semen collection premises. The National Animal Genetics Resources Centre and Data Bank (NAGRC&DB) on the other hand offers specialised training in insemination to technicians (Parliament of Uganda., 2001).

Researchers and research institutions such as the National Agricultural Research Organization (NARO) and Makerere University (MAK) were also identified by the respondents as major actors along the different nodes. These conduct research concerning the performance of the different pig genetics in the country.

3.2.2 *Strengths and weaknesses at the different nodes*

The strengths and weaknesses of the various actors along the value chain as suggested by the survey respondents are given in Table 1. In relation to the international breeding companies, better productive and reproductive performance of the improved pig breeds, and the breeding companies' vast experience in the business were seen as their major strengths. However, the requirement for a minimum of at least 40 animals for importation from some companies, delays in receiving animals due to lengthy transport distances and clearance processes, and the high cost of purchasing the animals (for example some animals range between Ugx 9,195,785.64 (US $2,362) and Ugx 9,226,931.4 (US $2,370)) were seen as the major challenges in obtaining breeding stock from the international breeding companies.

Relating to semen-producing companies, some indicated they lacked semen analysis equipment such as densimeters and photometers for semen concentration. They also had challenges maintaining the storage temperature at the required 17 °C. This was attributed to hydroelectric power load-shedding at their premises and the high cost of automated refrigeration units. Additionally, the semen-producing companies are challenged with loss of semen viability across the long distances to farmers.

The suppliers of equipment to artificial insemination service providers were concerned about equipment and product stockouts and delays in deliveries coupled with costly inputs. The local breeding farms provided improved genetics at a

Table 1: *Strengths and Weaknesses of actors along the value chain, according to semen company representatives interviewed.*

Actor	*Strength*	*Weakness*
International breeding companies	1. Better performing offspring in terms of productive and reproductive traits 2. Experience in breeding for over 100 years	1. Require a minimum number of at least forty (40) animals to make a full consignment for importation 2. Delays in receiving the animals arising from long distances of transport 3. Their genetics are expensive
Semen producing companies	1. They provide breeding advice to their clients 2. Avail maternal and terminal semen doses at affordable prices to farmers	1. Some lack equipment for conducting semen analysis and processing such as densimeters 2. Challenges in maintaining storage temperatures at 17 °C 3. Long distances to deliver semen to clients 4. Not all are certified with MAAIF
Artificial insemination equipment suppliers	1. Ensure availability of equipment such as cooler boxes and catheters 2. Some offer equipment on credit, enabling continued production	1. Delays in sending supplies and stockouts 2. Some inputs are too expensive
Local breeding farms	Cheaper and readily available within the country	Some farmers do not keep records, especially pedigree records
Semen producing farms	Sale of breeding gilts and boars at cheaper local prices	Some lack trained personnel for the collection and handling of semen
Training and certifying institutions	1. Offer training to technicians and provide breeding information 2. Have regionally accepted curriculum and competent trainers	1. Conduct few training sessions, resulting in fewer service providers 2. Currently lack a registry for pig artificial insemination technicians

cheaper price, though they are challenged by a lack of pedigree records. Large-scale commercial pig farms that also produced semen reported a lack of skilled personnel for boar semen collection and handling as major challenges. The certifying bodies didn't maintain an updated registry of all AI technicians and semen premises in the country, although the Animal Breeding Act of 2001 specifies so.

3.3 Characteristics of semen-producing companies

3.3.1 Stud and stud management

All six-boar semen-producing companies were in the central region in the districts of Mukono, Wakiso, Luweero, and Buikwe. The oldest company was established in 2010 with the latest- having been established in 2023. All these companies didn't have certification from either the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) or the National Animal Genetic Resources Center and Data Bank (NAGRC&DB) the mandated regulatory organisations.

Five of the six companies produced semen whilst also offering AI services. One company also offered animal nutrition supplements for both poultry and piggery farmers. Two companies sold breeding gilts and boars to farmers alongside semen. Three companies provided consultancy and agribusiness advisory services to their farmers.

Three companies had not made any changes to their business over the last two years, although they noted that clients were driving the business operations. Two companies started as pig breeding farms and later introduced semen production to provide semen doses to the farmers who bought breeding animals from them.

3.3.2 Boars and boar breeds

Three international breeding companies (Choice Genetics™ , Danbred™ , and Pig Improvement Company™), and Local farms such as Devenish Farms in Hoima were the major sources of breeding boars for the semen-producing companies. Breeding boars were mainly sourced at three to four months old and trained on the stud for semen collection. Two companies raised their replacement boars on their farm. These companies implemented traditional breeding techniques, involving the selection of sows from the same breeds and crossing using boars and semen from different breeds. The rest of the companies relied on the

importation of boars. The sources of boars were chosen based on the international breeding companies' experience in breeding, the performance of the pigs, the relationships established, and their prices.

Individual boars were selected based on the size of their testicles (two companies), their body condition score (two companies), their feed conversion ratio (two companies), their growth rate (two companies), and information on boar catalogues where available (one company). Two companies selected boars for maternal lines based on the breed's mothering and milk production.

The major challenges encountered with sourcing these boars were the high transportation costs from the importing country to Uganda (two companies), expensive genetics, and delays arising from attaining the required minimum number of animals for transportation per crate (two companies). Additionally, boars sourced locally required high transportation costs from source farms to stud (two companies), and some lacked pedigree records due to farmers' absence of recording systems. Four companies showed a willingness to increase their boar numbers and breeds in response to growing demands.

A total of 23 boars of predominantly Duroc, LargeWhite, and Landrace breeds were kept by the semen-producing companies. From the six companies, two reared two boars each, another two reared five boars each, one reared three boars and one reared six boars. Three companies kept Duroc, LargeWhite, Landrace, and Camborough™ boars. A further three companies reared Improved synthetic boars, and only one company reared Pietrain. These breeds were chosen owing to their growth and reproductive traits such as better performance of their offspring, faster growth rate, and good pork quality (five companies). Demand from clients was also a major driver for the selection of the different boar breeds by the semen-producing companies (four companies). The major records kept on the boars were semen quality (six companies), health records (three companies), and Daily feed intake (two companies). Some of the records such as growth rates and Feed conversion ratio (FCR) were shared with the clients alongside semen doses.

3.3.3 Semen collection, processing, and quality control

In all six companies, semen collection was done using the hand-glove technique. Both the macroscopic and microscopic boar semen analyses were conducted immediately after collection and daily before semen dispatch. The macroscopic analyses involved checking for the absence of blood and debris and checking semen colour and temperature. Analysis for sperm motility and concentration were the major microscopic analyses (subjective analysis) conducted in the six companies. These analyses were used as a baseline for accepting or rejecting semen for sale. The individual boars were collected at least twice a week for all companies and only used for semen production for between one and four years. The respondents noted that they make sure to collect at least twice a week from each boar even when they are not using the semen.

Both commercial and locally-made extenders were used for semen extension following different dilution ratios. Only one company used a calibrated machine (semen densimeter) for determining the dilution ratio while the rest relied on microscopic analyses. The extenders are able to maintain semen viability for between 5 – 10 days of storage, though the boar semen-producing companies only store semen for 2 – 3 days. According to the key informants, semen viability dropped drastically towards the set days of storage declared by the manufacturer of the different boar semen extenders. Additionally, they don't normally dispatch boar semen that has stayed for more than two days to minimize repeats owing to the failed conception of sows and gilts due to loss of semen viability. The respondents indicated that the

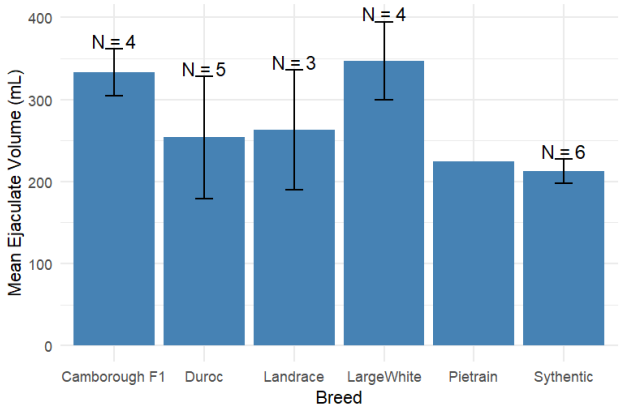

Fig. 3: *The mean ejaculate volumes per breed type, based on information from the respondents.*
Note: For Pietrain, only one observation (N = 1) was recorded, so no error bar is shown.

ejaculate volumes ranged from 125 ml to 500 ml (Fig. 3) and these were extended using warmed extender solutions and analysed for motility and sperm concentration. After this analysis, the extended semen is packaged in semen bags or bottles ranging from 80 ml to 100 ml for sale as doses. The packaged semen doses are maintained in semen cabins at a temperature of 17 °C, although some companies encountered challenges in maintaining this storage temperature. This is attributed to hydroelectric power-load shedding and the high cost of purchasing automated cabins and refrigerators. The individual semen doses were labelled with stickers and in some semen companies, semen dyes were used to differen-

tiate semen from different breeds. Additionally, information such as semen batch number, date of collection, expiry date, and boar breed were also included on the stickers.

3.3.4 *Boar semen marketing, distribution, and sales*

Boar semen marketing was mainly done through digital platforms such as WhatsApp and YouTube (three companies), client referrals (three companies), agricultural shows, and print media such as Newspapers. Three semen companies noted that semen demand was consistent throughout the year due to growing demand. However, the other half stated that the demand wasn't consistent since sows came on heat in different seasons. Three companies had separate semen sales points where semen doses were kept awaiting dispatch while the remaining three sold semen from their farm gate. The semen dose sale price was between Ugx 20,000 (US $5.14) and Ugx 35,000 (US $ 8.99) for a single dose and Ugx 60,000 (US $ 15.42) for a double dose. According to some respondents, a semen dose is two bottles/bags thus used for double inseminations per female animal; while for some, the dose is one bottle/bag, thus used for a single insemination. Therefore, a double insemination dose attracts a relatively higher price than a single insemination dose. Boar semen was majorly transported using portable cooler boxes with ice packs, and only one company had imported automated semen incubators (cabins) for long-distance clients. The semen was mainly kept at 17 °C in the automated cabins, while the temperature varied within the cooler boxes.

The major clients for all the semen-producing companies included trained AI technicians and small-holder farmers. Schools and cooperatives were also highlighted as key clients for some companies. The clients' preferences for breeds differed based on their level of production. According to the respondents, commercial farmers and farmers selling their pigs for slaughter mainly requested Camborough™, Duroc, and Pietrain semen doses. However, smallholder farmers didn't have clear choices on semen doses from different breeds and were always guided by the AI technicians on which breed to use.

Most of the clients for the boar studs were in the central region, in the districts of Wakiso, Mukono, Masaka, and Kampala. Other districts such as Kamuli, Jinja, and Gulu also had clients for the different studs. Fig. 4 shows the geographical distribution of the different clients.

3.3.5 *Challenges and opportunities along the boar semen production node*

The major challenges encountered by the boar semen-producing companies are shown in Fig 5. The loss of semen viability during storage and transport to clients in far

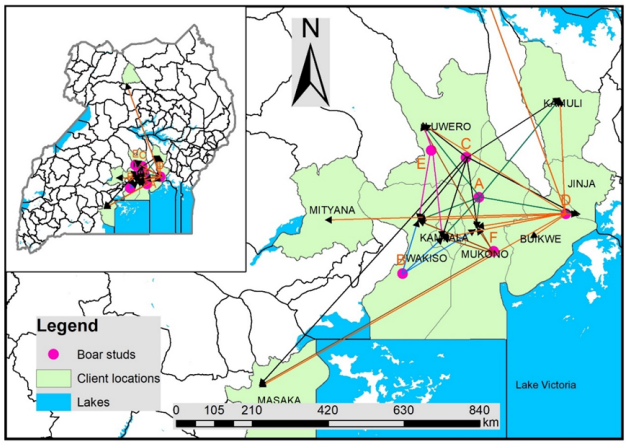

Fig. 4: *Geographical distribution of boar semen client locations from the different semen producing companies in central Uganda. The map indicates the spatial network linking boar semen producing companies (magenta circles) to client locations (light green) across the selected districts in the central and eastern regions. The coloured arrows represent semen distribution routes from each semen producing company to the respective clients. The inserted map provides a national overview, contextualizing the major semen markets within the broader Ugandan context.*

locations were some of the major challenges noted by all the respondents. Some respondents also added that they lacked some equipment for semen analysis such as photometers and densimeters. Diseases such as African Swine Fever and Parvovirus also had major impacts on herd structures and conception of sows respectively. They also lacked clear standards, regulations, and certification procedures for running the boar studs in the country.

The boar semen industry presents several opportunities for growth and development. Four semen-producing companies reported a growing demand for semen doses and high-quality genetics locally and throughout the East African region. One company noted an increase in semen doses sold per month from 80 to 400 doses, with a projected rise to 1000 doses. Additionally, two companies emphasised the industry's rapid growth and untapped potential. Another two companies recognised boar semen production as a valuable source of employment. Furthermore, the industry is viewed as a platform for advancing research, fostering innovation, and creating networking opportunities for industry players.

4 Discussion

This study gives a current characterisation of Uganda's pig genetics value chain, which has evolved significantly over the last decade. Stratification of the breeding system has been observed in the country with the emergence of different actors along the pyramid. The boar studs (semen-producing

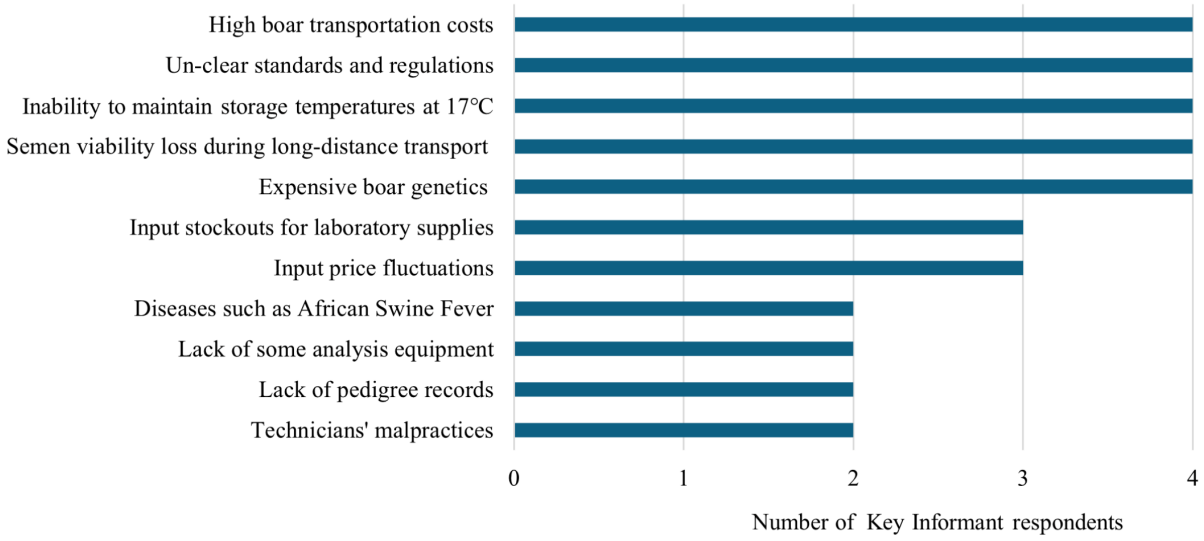

Fig. 5: *Challenges encountered by the boar semen-producing companies.*

companies) are the key actors within the multiplier tier, and large-scale farms now play a significant role in the commercial tier. These mainly rely on importations and in-country sourcing of dam lines such as LargeWhite and Landrace, and specific sire lines such as Duroc and Pietrain for boar semen production. Additionally, there has been an increase in the use of assisted reproductive technologies (ARTs), especially pig artificial Insemination.

The different actors identified along the semen production node operated independently making the value chain disorganised, a characteristic of many value chains in low-income countries. Unlike the pig genetics value-chain actors in Rwanda, whom the government supports (Marshall & Hirwa, 2024), there is still limited government support and initiatives for semen-producing companies in Uganda. Most boar studs relied on the importation of breeding boars from international breeding companies for semen production and breed multiplication. Despite this continued importation, the country still lacks a clear pig breeding program. To overcome the high cost of importing improved genetics and losses due to African Swine Fever (ASF), public sector support is required. This could be, for example, establishing additional multiplier farms through public and private sector partnerships, a strengthened enabling environment for the importation of breeding stock, or enhanced public sector support to the control of ASF. Further support in obtaining semen analysis and storage equipment, and capacity building of personnel is crucial in enhancing the development of boar semen collection, processing, and distribution. Additionally, the public sector should foster the delivery of pig breeding information through community extension workers and institutions.

Adoption of Pig Artificial Insemination (pig AI) in the country is still low (Tatwangire, 2014; Bamundaga & Natumanya 2018; Niyiragira *et al*., 2018). Consequently, all boar semen-producing companies are close to their clients in the central region. A recent livestock census showed that the pig population in other areas is growing steadily. The western, eastern, and northern parts of the country now account for close to five million pigs (2,285618 in the western, 1,396,397 in the eastern, and 1,039,415 in the northern) (UBOS 2024). Given this, there is a need to establish semen depots or more semen-producing companies in other areas of the country.

Intracervical AI (CAI) or traditional AI is the main insemination method used with semen doses packaged in 80–100 ml packaging materials. This method consists of semen deposition in the cervix's lumen using a catheter placed in the posterior cervix (Bortolozzo *et al*., 2015; Waberski *et al*., 2019). A new procedure, Intrauterine Artificial Insemination (IUAI) or Post Cervical Insemination (PCAI) that consists of the deposition of the extended semen within the uterine body using an inner cannula can be adopted. Since IUAI reduces sperm transit through the cervix, the dose volume and number of sperm cells can be reduced without impairing reproductive performance (Bortolozzo *et al*., 2015; Waberski *et al*., 2019). However, some level of difficulty can be observed in inserting the inner catheter, especially in first parity sows (Sbardella *et al*., 2014). Therefore, with IUAI, the semen producing companies can package semen doses in 40-50 ml packaging with 1-2 billion spermatozoa. This

allows for the production of more semen doses per ejaculate, reduces the time for insemination, optimises the use of high-index boars, and reduces boar maintenance costs (Gonzalez-Pena *et al*., 2016; Mellagi *et al*., 2023; Suárez-Usbeck *et al*., 2019).

Diseases such as ASF and parvovirus are still major challenges in the pig value chain (Dione *et al*., 2014; Ouma *et al*., 2018; Aliro *et al*., 2023). ASF has been proven to be transmissible through the sperm of infected boars (Sehl-Ewert *et al*., 2023). Furthermore, porcine reproductive and respiratory syndrome virus (PRRSv) infection in boars may result in sperm abnormalities, reduced motility, and lowered ejaculate volumes (Schulze *et al*., 2013). Therefore, strategies such as biosecurity and vaccination that are focused on the prevention of their transmission should be enforced. Vaccination against parvovirus, PRRSv, or porcine circovirus type 2 may help reduce the shedding of the virus following infection (Opriessnig *et al*., 2011). The design of the boar stud should allow for minimum contact and movement between the boars and personnel. Additionally, the design of the stud should accord a forward movement of semen from the collection, through processing and dispatch with no backward movement as suggested by Thibier & Guerin, (2000).

Maintenance of boar storage temperature at the recommended 17 °C (Knox 2011; Waberski *et al*., 2019) during transport and storage was a major challenge encountered by the boar semen-producing companies. A study by Henning *et al*., (2022), indicated that boar semen storage temperature can be increased to 25 °C with minimum effect on the spermatozoa quality within five days of storage. Therefore, this can be exploited by the boar semen-producing companies to maintain semen viability during short-distance transport from their depots to the farmers. In Rwanda, semen is delivered by drones, with the public sector subsidizing the costs, helping to overcome transportation challenges. Alternatively, the boar semen companies can be supported with automated cooler boxes to facilitate the maintenance of boar storage temperatures in the desired range of 15 – 17 °C.

Generally, Uganda's pig genetics value chain is growing, with increasing participation from the private sector actors and expanding access to high-quality genetics. Furthermore, a growing demand for artificial insemination services presents opportunities for further development within the value chain. Despite this recorded growth, the value-chain still faces several challenges. Key among these include a disorganised value chain, limited public sector support, high dependence on imported genetics, limited infrastructure for boar semen collection, and disease outbreaks that still hinder it's growth. Therefore, to optimise the value chain, public and private sector support in establishing multiplier farms and infrastructure, strengthening biosecurity measures and vaccination programs, and improving regulatory frameworks to combat malpractices will be crucial. Additionally, adopting advanced techniques like intrauterine artificial insemination (IUAI) can reduce the semen dose required per insemination, optimise the use of boars, and lower production costs. Investments in semen storage and transportation technologies such use of drones and automated cooler boxes are also required to maintain semen quality during distribution.

Conflict of interest

Authors Donald Kugonza and Karen Marshall have no financial interests. Author Isaac Kasoro has a business supplying artificial insemination equipment in Uganda that serves artificial insemination technicians, boar studs, and pig farmers.

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Author contributions

This study was conceptualised by Isaac Kasoro, Donald Kugonza, and Karen Marshall. Data was collected and analysed by Isaac Kasoro, with the support of Donald Kugonza and Karen Marshall. The original draft of the paper was written by Isaac Kasoro, with a review by Donald Kugonza and Karen Marshall. Karen Marshall obtained funding for this work.

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Data availability

The data associated with the manuscript are available from the corresponding author upon reasonable request.

Statement of animal rights

This study did not involve any animal subjects.

Ethics

Permission to carry out this research was granted by the International Livestock Research Institute (ILRI) Research Ethical Committee (ILRI-IREC2022-41), and the Uganda Council of Science and Technology (UNCST-A303ES).

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