

Effect of Supply-Chain Sourcing and Delivery of Liquid Nitrogen and Frozen Semen on the Quality of Public Animal Breeding Services in the Selected Cattle Corridor Districts of Uganda

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ABSTRACT

The study focused on the effect of supply-chain sourcing and delivery of liquid nitrogen and frozen semen on the public animal breeding services in selected cattle corridor districts (Mbarara, Mubende, Luwero & Soroti) of Uganda. The research adopted a cross-sectional survey with mixed methods that involved concurrently collecting both quantitative and qualitative data using a structured questionnaire, focus group discussions (FGD) guide, together with interviews of key informants in the case of the Uganda National Animal Genetic Resources and Data Bank (NAGRC&DB). Extant records review was deployed throughout. The study hypothesised that there was a positive relationship between supply-chain sourcing and delivery of liquid nitrogen and frozen semen and the quality of animal breeding public services in selected cattle corridor districts of Uganda. The findings showed a positive relationship between sourcing ($\chi^2 = 13.895$, $p = 0.003$, $\chi^2_{critical} = 7.815$), delivery ($\chi^2 = 20.900$, $p = 0.013$, $\chi^2_{critical} = 16.919$), and animal breeding services in selected cattle corridor districts of Uganda. This research contributes to theory through improving business dexterity, bolstering hierarchical learning objectives, and improving operational engagements for chain actors. In practice, it helped put in perspective the genetic centre's evaluation of operational engagements, and contrasting organisational execution with benchmark information. The study concludes that sourcing and delivery are pivotal segments in supply chains that determine the associated dynamics for the key breeding inputs in the animal resources sector. The study recommends the interplay of value-chain actors working in a coordinated system facilitated by some level of knowledge, skills, and interests, operating within acceptable standard operating procedures (SOPs). The research recommends further studies to examine the effects of supply-chain collaboration performance and organisational capabilities on the delivery of animal breeding services in Uganda. Likewise, top management commitment of the animal genetic centre to Total Quality Management (TQM) and organisational supply-chain ambidexterity in the delivery of animal breeding services in Uganda needs further empirical investigation.

Keywords: Public Animal Breeding Services, Artificial Insemination, Cattle, Cattle Corridor, Supply Chain, Supply Chain Management

INTRODUCTION

Vital services that become too costly for private provision often attract public investment. Governments take part in mobilization of resources to enhance service delivery. Assisted reproductive methods such as artificial insemination is one of such services. Planned artificial insemination (AI) dates back to about 1322 CE, when an Arab chieftain induced planned artificial insemination (AI) dates back to about 1322 CE, when an Arab chieftain induced a coveted stallion to discharge semen for his

prized mare to conceive (Foote, 2002; Morell, 2011, Baruselli et al., 2012; Richard, (n.d)). Centuries later, recorded history cites various methods used to increase the quantity and preservation of collected semen to improve reproductive efficiency through AI (Foote, 2002; Baruselli et al., 2012), now well-established as one of the most successful biotechnologies. Adoption of this assisted reproductive procedure has greatly improved genetics of farm animals and economic returns, especially in cattle (Lagu et al., 2020a). Over 20% (150 million) of female reproductive cattle population are inseminated every year

(Tghibier, 2005).

While AI promises similar advantages and disadvantages to both developed and developing countries, contextual realities such as access to electricity, quality and quantity of roads, equipment, maintenance, supply of spare parts, nature of transport system, and availability of semen preservative substances can be prohibitive (Schuh, 1992; Lagu et al., 2020b). Liquid nitrogen is one of the most useful substances to protect the semen, eggs, developing lives, and requiring expensive equipment. For instance, liquid nitrogen can attain temperatures as low as -196°C , providing a powerful means for directing cryo-safeguarding of semen, ova, and embryonic organisms till utilisation (Dalton, 1985; Mugisha et al., 2014). Liquid nitrogen and associated inputs are mainly produced through public investments on the supply side. Nonetheless, on the demand side, consumers of AI services tend to own small to medium herds, producing low-quality stock that cannot compete favourably in the international markets.

In Uganda, where AI was first introduced in 1960s (Nakimbugwe, Sölkner & Willam, 2004), adoption slightly increased from about 5% in 2004 to 7% in 2008. The highest adoption of AI in Uganda is in the central parts closest to the National Animal Genetic Resources and Data Bank (NAGRC&DB), and only 2% in the northern parts of the country (Mbowa, Shinyekwa & Lwanga, 2011). The percentage increase in the demand and use of artificial insemination services are still less than 5% among households with livestock in selected cattle corridor districts of Uganda (MAAIF, 2016). Yet, livestock is a key source of livelihood for food security and household incomes among the communities keeping livestock in selected cattle corridor districts of Uganda. The very low percentage of demand for utilising the artificial insemination services is associated with high costs, scarcity of inputs, inadequate AI technicians, and fragility of off-springs to inseminated cows, which are too big for the cows to deliver (Mbowa, Shinyekwa & Lwanga, 2011). The fewer use of AI services could also be attributed to the inefficient supply-chain sourcing and delivery of breeding inputs in selected cattle corridor districts of Uganda. Supply-chain sourcing and delivery aims to set up business processes to deliver goods and services to users (Chopra & Meindl, 2013). However, there has been limited empirical research explaining the role of supply-chain sourcing and delivery in ensuring efficient and effective delivery of animal breeding services in Uganda. This study, therefore, fills the gap by examining the effect of supply-chain sourcing and delivery of liquid nitrogen and frozen semen on the quality of public animal

breeding services in the selected cattle corridor districts of Uganda.

UNDERPINNING THEORIES

The study adopted the Supply Chain Operations Reference Model (SCOR). The model is a management tool for discussing, developing, and communicating supply-chain management decisions within a company or organisation with a company's suppliers and clients. This model focuses on five supply-chain areas: preparation, origin, development, distribution, and return (Bolstorff & Rosenbaum, 2003; Christopher, 2005; Poluha, 2007; Johnson & Anna, 2015). In this study, the SCOR helps explain how the breeding inputs, including liquid nitrogen and frozen semen, can be sourced and delivered to the AI technicians, in order to facilitate quality safeguards of the frozen semen. Quality semen in the hands of competent technicians can ensure successful and efficient AI services at farmer levels. The SCOR helps underpin the theoretical explanation of production, storage, distribution, and use of the liquid nitrogen and frozen semen in the cattle corridor districts of Uganda, including actors in the value-chain and related users of the breeding inputs.

THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

The theoretical framework is hinged on the supply-chain operations reference (SCOR) model. In supply-chain management, the SCOR is an administrative instrument for examining, creating, and imparting gracefully, supply-chain management decisions within the executive's choices inside an organisation or association. For example, the National Animal Genetic Center, and with an organisation's providers and customers. This model spotlights on five flexibly chain zones: planning, inception, advancement, appropriation, and return (Bolstorff & Rosenbaum, 2003; Christopher, 2005; Poluha, 2007; Chopra & Meindl, 2013; Johnson & Anna, 2015). The study hypothesises:

H1: There is a positive relationship between supply-chain sourcing of liquid nitrogen and frozen semen and the quality of animal breeding services in the selected cattle corridor districts of Uganda.

H2: There is a positive relationship between supply-chain delivery of liquid nitrogen and frozen semen and the

quality of animal breeding services in the selected cattle corridor districts of Uganda.

In this study, supply-chain sourcing and delivery are independent variables, while the quality of animal breeding services is the dependent variable.

MATERIALS AND METHODS

The study adopted standard methods with the research design, study population, sample size, sampling techniques and procedure, validity and reliability tests, procedure of data collection, and ethical clearance detailed in earlier studies by Lagu et al. (2020a & 2020b). In the research, supply-chain sourcing was contextualised by the ease of access of technicians to offer the AI public services whenever called upon by the livestock farmers. The construct for supply-chain delivery was time taken by the AI technicians to reach the farmer's holding to offer the services when the animals are in estrus (heat). In addition, the study took other constructs to buttress the study variables, such as the forms of record keeping, records kept, and level of satisfaction with the AI services and the providers (Mugisha et al., 2014; Mwangi et al., 2019). Furthermore, the study looked into the number of inseminations on the farm, forms of communications used by the farmers to contact the technicians, percentage of breeding cows, conception rates, and animals returning to heat. The animal breeding services is measured through successful animal artificial insemination services by the technicians and conception rates of animals realised through AI services.

Data Analysis

The analysis involved data capture, data cleaning, data coding, and data entry. The detailed description of the qualitative data analysis is found in Lagu et al., (2020a & 2020b). The quantitative data were presented and analysed using descriptive and inferential statistics, respectively. Descriptive statistics involved the use of frequencies, percentages, and mean of the sourcing and delivery parameters. Inferences of the relationships between sourcing, delivery of liquid nitrogen, frozen semen, and animal breeding services in selected cattle corridor districts of Uganda was done using chi-square (χ^2) test, at 0.05 level of significance. The data analysis were performed using Statistical Package for Social Scientists (SPSS) version 21.

RESULTS AND DISCUSSION

Socio-Economic Demographic Characteristics of the Households and Related Issues in the Selected Cattle Corridor Districts of Uganda

A total of 129 questionnaires were administered to farmers using AI services (54.3% males; 35.7% females), covering 34 sub-counties, 55 parishes, and 81 villages, as detailed in Table 1.

Table 1: Tabular Representation of Socio-Economic Demographic Characteristics of the Households in Selected Cattle Corridor Districts of Uganda

District	Respondents	Gender			Sub-County	Parish	Villages
		Male	Female	Missing			
Mbarara	30	19 (63.3%)	11 (36.7%)	-	8	16	25
Mubende	30	12 (40.0%)	15 (50.0%)	3 (10.0%)	8	7	10
Luwero	30	19 (63.3%)	8 (26.7%)	3 (10.0%)	11	16	23
Soroti	39	20 (51.3%)	12 (30.8%)	7 (17.9%)	7	16	23
Total	129	70 (54.3%)	46 (35.7%)	13 (10.0%)	34	55	81

Source: Lagu et al. (2020a)

Simple random sampling technique was used to select the sub-counties, parishes, and villages.

From Table 2 it is clear that about 50% of the breeding cows (50-100) are served through AI services,

apart from the Soroti district that represents 32.4%. Over 65% of the animals served get conceived, apart from in Luwero, which stands at 42.3%.

Table 2: Representation of Breeding Cows Served through Artificial Insemination (AI Services) Per Annum, Conception, and Animals that Return to Heat

Parameter	Categories (Numbers)	Mbarara	Mubende	Luwero	Soroti
Per cent of breeding cows served through AI services per annum	1-5	2(6.7%)	5(17.2%)	2(7.7%)	10(27.0%)
	6-10	1(3.3%)		1(3.8%)	3(8.1%)
	11-29	2(6.7%)	1(3.4%)	2(7.7%)	5(13.5%)
	30-50	10(33.3%)	6(20.7%)	8(30.8%)	7(18.9%)
	50-100	15(50.0%)	17(58.6%)	13(50.0%)	12(32.4%)
Per cent of animals that conceive per annum once served through AI	1-5	-	1(3.4%)	3(11.5%)	1(2.6%)
	6-10	-	-	1(3.8%)	2(5.3%)
	11-29	1(3.3%)	1(3.4%)	1(3.8%)	-
	30-50	8(26.7%)	8(27.6%)	10(38.5%)	9(23.7%)
	50-100	21(70.0%)	19(65.5%)	11(42.3%)	26(68.4%)
Per cent of served animals that return to heat	1-5	18(72.0%)	4(14.8%)	12(41.4%)	21(63.6%)
	6-10	3(12.0%)	4(14.8%)	1(3.4%)	3(9.1%)
	11-29	1(4.0%)	4(14.8%)	9(31.0%)	1(3.0%)
	30-50	-	10(37.0%)	5(17.2%)	4(12.1%)
	50-100	3(12.0%)	5(18.5%)	1(3.4%)	3(9.1%)
	Other (None)	-	-	1(3.4%)	1(3.0%)

Source: Primary data

The percentage of served animals that return to heat ranged from 3.4% to 18.5%. In other words, for those who practice AI services, the results in terms of percentage being served through AI, percentage that conceive, and percentage that return to heat is within acceptable limits, with minor exceptions in terms of efficiency in the delivery of AI services. This is explained by the availability of liquid nitrogen, frozen semen, technicians, and promptness in calling AI technicians to serve animals that are in heat, coupled with the level of awareness on heat detection among the practicing farmers, including

the culture of record-keeping for decision making and retrieval as adduced in the subsequent results.

Table 3 illustrates that at least 89.3% of the farmers in the study districts keep records (AI records, health records, milk records, and financial records) on the farm. AI records ranked top, followed by health records, milk records, and financial records. Efficient and proper AI records are key for a successful breeding programme in triggering delivery of timely liquid nitrogen, frozen semen, and other consumables. Rank 1- highest/best; Rank 1 - lowest.

Table 3: Record-Keeping in Farms

Parameter	Responses	Mbarara	Mubende	Luwero	Soroti
Do you keep records on your farm?	Yes	29(96.7%)	26(92.9%)	25(89.3%)	36(94.7%)
	No	1(3.3%)	2(7.1%)	3(10.7%)	2(5.3%)
Form of records kept (average rank)	AI Records	2.21	1.78	1.69	1.69
	Health Records	1.97	1.54	2.04	2.18
	Milk Records	2.14	2.9	2.61	2.64
	Financial Records	3.57	3.74	3.95	3.31

Source: Primary data

Table 4 illustrates that over 93% of the farmers receive AI services on the farms. Most of this service (over 92%) is provided by AI technicians. Additional providers include animal husbandry officers (AHO), veterinary officers (VOs), field extension workers, and other service providers. These providers are trained and are skilled in the technology of providing AI services to improve the quality of breeds of the farmers for higher productivity per stock. The Heifer Project International (HPI) was

ranked topmost among other service providers for AI services, in addition to Send a Cow, NGOs, CBOs, and farmer organisations, as presented in Table 4. This aspect demonstrates that there are not many actors in the supply-chain of AI breeding services to supply inputs like liquid nitrogen and frozen semen. Rank 1 - highest/best; Rank 4 - lowest.

Artificial Insemination (AI) services provided by AI technicians to the farmers per district are presented

in Table 5. The study found that over 76% of AI technicians can be accessed when needed by the farmers. The most ranked form of communication to access AI technicians is the use of mobile phones in all the districts where the study took place. This is because

the use of phones is the easiest, quickest, and cheapest means of reaching the AI technicians. Other methods explored include using fellow farmers and extension workers within the locality. Rank 1 - highest/best; Rank 4 - lowest.

Table 4: Representation of AI Services Offered on the Farm and Providers of AI Services

Question	Response	Mbarara	Mubende	Luwero	Soroti
Do farmers receive AI services on the farm?	Yes	30(100%)	28(93.3%)	29(96.7%)	38(97.4%)
	No	0	2(6.7%)	1(3.3%)	1(2.6%)
If yes, who are the providers of AI services?	AI Technician	29(96.7%)	27(93.1%)	29(100.0%)	35(92.1%)
	AHO	1(3.3%)	1(3.4%)	-	-
	VO	-	-	-	2(5.3%)
	Field Extension Officer	-	-	-	1(2.6%)
	Other	-	1(3.4%)	-	-
Other AI service providers in your area (average rank)	Heifer International	1	2.5	1.5	-
	Send a Cow	4	1.43	2.5	-
	NGOs	2	2.5	2.43	1
	CBOs and Farmer Organisations	3	2.5	4.2	-

Source: Primary data

Table 5: AI Services Provided by AI Technicians to the Farmers Per District

Parameter	Categories	Mbarara	Mubende	Luwero	Soroti
Easy access to AI technicians once AI services are needed	Yes	30(100%)	23(76.7%)	28(96.6%)	30(76.9%)
	No	-	7(23.3%)	1(3.4%)	9(23.1%)
Form of communication used to access AI technician (average rank)	Phone calls	1.04	1	1	1.03
	Fellow farmer	2.36	3	3.14	3.48
	Extension worker	2.3	2	3.06	3.09
	Physical follow	4	4	2.33	2.08
Do inseminators respond in time?	Yes	29(96.7%)	23(79.3%)	22(78.6%)	28(73.7%)
	No	1(3.3%)	6(20.7%)	6(21.4%)	10(26.3%)
Time taken to arrive when you call AI technician	30 minutes – 1 hour	1(3.3%)	13(46.4%)	15(53.6%)	12(38.7%)
	1.5–2 hours	1(3.3%)	5(17.9%)	7(25.0%)	11(35.5%)
	2.5–3 hours	9(30%)	7(25.0%)	2(7.1%)	4(12.9%)
	4–6 hours	18(60%)	-	2(7.1%)	3(9.7%)
	Other	1(3.3%)	3(10.7%)	2(7.1%)	1(3.2%)
Number of inseminations on farm per year	1–5	9(30.0%)	28(96.6%)	16(61.5%)	31(83.8%)
	6–10	5(16.7%)	1(3.4%)	7(26.9%)	4(10.8%)
	11–20	10(33.3%)	-	2(7.7%)	1(2.7%)
	21–40	6(20.0%)	-	1(3.8%)	1(2.7%)
Satisfied with AI services provided by AI technicians	Yes	28(93.3%)	21(72.4%)	26(92.9%)	31(81.6%)
	No	2(6.7%)	8(27.6%)	2(7.1%)	7(18.4%)
Services offered by AI technicians that make you satisfied (average rank)	Timely service	1.52	2.23	2.73	2.8
	High conception rates	2.61	3.26	2.75	2.71
	Few return rates	3.25	2.91	3.04	2.97
	Quality offspring born	2.56	1.41	1.41	1.53
View on the performance of AI services in your area	Very good	8(26.7%)	-	9(31.0%)	5(13.2%)
	Good	8(26.7%)	20(69.0%)	10(34.5%)	17(44.7%)
	Fair	12(40.0%)	8(27.6%)	6(20.7%)	15(39.5%)
	Poor	2(6.7%)	1(3.4%)	4(13.8%)	1(2.6%)
Challenges faced in an attempt to use AI services (average rank)	Few AI technicians	1.44	1.52	2.96	2.24
	Irregular AI services	2.33	2.48	2.96	2.54
	Lack of liquid nitrogen & frozen semen	2.4	2.63	1.42	2.91
	Difficulty accessing AI technician	3.83	3.33	3.88	2.14

Source: Primary data

Quite a good number of AI technicians (85.7% and above) will respond within 30 minutes to three hours when called to serve cows in heat, except in Mbarara, where the percentage response is 36.6% (Table 5). A total of 63.4% of AI technicians in Mbarara will take more than three hours to respond when called to serve an animal in heat, while 10.7%, 14.2%, and 12.9% of AI technicians in Mubende, Luwero and Soroti, respectively will take more than three hours to respond to serve an animal. These may be due to the fact that AI technicians in the Mbarara area are located near to the farmers and the technicians usually have fixed farmers and experience in properly linking and timing farmer's phone calls to ensure that they conduct the AI services without missing the optimum correct time for effective insemination.

Timely response to AI service is key in ensuring success rates in conception and also having a matching response to when the animal is at its peak in heat for it to be served by the technician.

At least 88.4% of inseminations per annum on a farm is one to ten inseminations for other districts (Mubende, Luwero & Soroti), except for Mbarara, which constitutes 46.7%. In Mbarara district, 53.3% of the inseminations in a year range from 11 to 40 inseminations, compared to 11.5% in Luwero and 5.4% in the Soroti district. Most of the AI services were mainly provided by AI technicians to the farmers, as indicated in Table 4. The number of inseminations is a key factor in determining the frequency and reliance of success rates of AI. Infrequent insemination is a factor of inefficiency on breeding activities on the farm, unless it is programmed breeding using the synchronisation of the animals, i.e. ensuring that specific numbers of stock on the farm are bred during specific periods, to get calves and milk volumes in specific time periods.

The AI technicians respond on time when called for AI services (at least 73.7% responded positively) and at least 72.4% are satisfied with the service provided. The quality of offspring, timely services, high conception

rates, and few return rates offered by AI technicians are the key determinants of what makes the farmers most satisfied (Table 5). As a result, a minimum of a 53.4% of the respondents view the performance of AI services as at least good.

Despite the satisfaction of the farmers with the AI services, there were some challenges faced by AI services, such as few trained AI technicians, irregular provision of AI services, and lack of adequate supply of liquid nitrogen and frozen semen (Table 5). The need to train more AI technicians, equip them with kits, and provide transport facility and regular supply of liquid nitrogen, and ensuring that the contacts of AI technicians are shared with farmers are key to improving services of AI. This effort aims at deepening the decentralisation of supply-chain of AI services at the farmer level.

In a focus group discussion (FGD), the participants recommended the following as ways to improve the quality of delivery of animal breeding services in Uganda: training more AI technicians, creating satellite centres in the different regions, conducting refresher courses for AI technicians, reducing the cost of semen and liquid nitrogen, forming an association of AI technicians, and ensuring frequent distribution of semen and liquid nitrogen to the districts.

Other recommendations include training farmers on heat detection, reducing the cost of liquid nitrogen, provision of containers and AI kits, and using synchronisation protocols to ensure that big numbers of animals are served at the same time. Community-based breeding outreach programmes (CBBOP) can be carried out, along with establishing regional and zonal distribution centres for semen and liquid nitrogen, and reducing the farmer's cost of carrying out artificial insemination services.

The chi-square tests (Table 6) show significant positive associations between sourcing ($p = 0.003$) and delivery ($p = 0.013$) of AI services, and the quality of animal breeding services.

Table 6: Cross Tabulation of Sourcing and Delivery Parameters and the Quality of Animal Breeding Services in Selected Cattle Districts of Uganda

Sourcing									
Parameter	Options	Performance of AI Services				Chi-Square (χ^2) Test			
		Very Good	Good	Fair	Poor	χ^2	$\chi^2_{crit.}$	df	p-Value
Easy access to AI technician	Yes	22	51	32	5	13.895	7.815	3	0.003
	No	0	3	9	3				
Delivery									
Parameter	Options	Number of Inseminations on Farm Per Year				Chi-Square (χ^2) Test			
		1-5	6-10	11-20	21-40	χ^2	$\chi^2_{crit.}$	df	p-Value
Time taken by AI technician to arrive when called	30 minutes–1 hour	30	5	3	1	20.900	16.919	9	0.013
	1.5–2 hours	19	2	0	1				
	2.5–3 hours	10	6	5	1				
	4–6 hours	13	1	5	4				

Source: Primary data; $\chi^2_{crit.}$ = critical chi-square; df = degree of freedom

DISCUSSION OF THE RESULTS

Households had varying numbers of cattle presented for AI services. The services are currently more among cattle than goats, sheep, and pigs, and unnoticed in chickens, as earlier documented by Lagu et al. (2020a). There are varying figures on animals served through AI services that conceive and those that return to heat, and ease of access of artificial insemination (AI) technicians when they are needed by the farmers to offer services in various localities. This is in agreement with studies by Morell (2011), Eklundh (2013), Mugisha et al. (2014), Lijalem et al. (2015), and Engidawork (2018).

The key findings in the socio-economic demographic characteristics (Table 1) are that gender differences is a key worry at family unit levels with regards to land and animal possession. It is a typical patriarchal society in many of the community settings. It has effects on access to benefit-sharing for the livestock kept. Men always dominate and women do most of the work in terms of rearing, milking, and treatments for the animals that fall sick; yet, goals and priorities of men and women in the households differ (MAAIF, 2016; UBOS, 2017; Lagu et al., 2020a). This finding is in agreement with previous studies conducted by Mugisha et al. (2008) and Lagu et al. (2020a).

Farmers indeed recognise the vital roles of AI services (Table 4) in genetic improvement of stock to enhance production and productivity through genetic gain of traits from superior breeds; this is in agreement with previous studies by Nishikawa (1964), Morell (2011),

Eklundh (2013), and Engidawork (2018). However, the performance and perception of the farmers on AI services in terms of response, conceptions, and return rates are mixed, as documented earlier by Morell (2011), Ococh (2013), MAAIF (2016), and Engidawork (2018).

Farmers keep some form of AI records on their farms (Table 3). Record-keeping is one of the key animal husbandry, and breeding practices and activities on the farm. This agrees with previous observations by Mugisha et al. (2014). Farmers also keep health, milk production, and financial records. The extent to which record-keeping is practiced is dependent on the level of education, literacy among the households, the level of awareness, and how the farmers view record-keeping in terms of helping them to make decisions. This is in agreement with the observations made by Ococh (2013) and Chuang (n.d.).

The study established that farmers use mobile phones (Table 5) as the easiest way to access AI technicians. The major mobile phone service providers are Mobile Telecommunication Network (MTN) and Airtel Network. Assuming that the networks are available, farmers access the phone numbers of AI technicians and call them once their animals are in heat.

It was clear that in the countryside there are few AI technicians, and the trained AI technicians lack AI kits, field flasks, and adequate liquid nitrogen and frozen semen reservoir tanks. To make matters worse, the regular access and delivery of liquid nitrogen and semen to the various AI technicians has been a big constraint, as observed by the various reports by EPRC (2019), MFPED (2017), MAAIF (2016), and UIA (2016).

'The supply-chain operations reference model (SCOR) is a management tool for discussing, developing, and communicating supply-chain management decisions within a company or organisation such as the National Genetic Centre, and with a company's suppliers and clients. This model focuses on five supply-chain areas: preparation, origin, development, distribution, and return (Bolstorff & Rosenbaum, 2003; Christopher, 2005; Poluha, 2007; Johnson & Anna, 2015). The study observed the presence of organisations like Heifer Project International, Send a Cow, non-governmental organisations (NGOs), community-based organisations (CBOs), and other farmer organisations like Uganda Crane Creameries Cooperative Union (UCCCU), Reline, Dairy Farmer's Network (DAFAN), and so on, as other actors in the use of AI services.

Although the responsibility of the supply-chain for the sourcing and delivery of liquid nitrogen and frozen semen majorly lies with the genetic centre, the study observed that the centre has not put in place effective supply-chain measures and strategies to network with the various value-chain actors to distribute liquid nitrogen and frozen semen to the technicians and farmer's cooperatives to holistically conduct AI services. This is in agreement with observations by Christopher (2005), Ayers (2010), Rameshwar et al. (2018), Rameshwar et al. (2019a), and Rameshwar et al. (2019b).

The collaborative efforts with other supply-chain actors in the breeding industry will enhance sustainable supply-chain sourcing, address time lag in the supply, solve the bullwhip effects, and create a sustainable and resurgent supply-chain for the efficient and effective delivery of quality animal breeding services to attain production and productivity of quality animal resources in selected cattle corridor districts of Uganda. Similar studies by Rameshwar et al. (2018), Rameshwar et al. (2019a), Rameshwar et al. (2019b), Acosta et al. (2019), Rameshwar et al. (2020a), Rameshwar et al. (2020b), Samuel et al. (2020), and Mihelis et al. (2020) all point to the need for collaborative efforts in sustainable and resilient supply chains.

A total of 73.3% of the AI technicians respond on time when called for AI services; 72.4% are satisfied with AI services provided by AI technicians, while at least 53.4% of the respondents view the performance of AI services as good (Table 5). In other words, AI services as a technology is acceptable among the farmers, except that the modalities in facilitating its use, process, efficiency, and delivery are constraints affecting the higher impact expected from the adoption of the AI technology among the livestock farmers. These modalities are even more

constraining in AI services among small ruminants (goats, sheep) and pigs, because the technology has been limited in these groups of animals despite the numerous advantages it offers (Morell, 2011; Eklundh, 2013; Mugisha et al., 2014; Lijalem et al., 2015; Chuang, (n.d.)).

The study established that there was positive relationship between sourcing ($\chi^2 = 13.895$, $p = 0.003$, $\chi^2_{\text{critical}} = 7.815$), delivery ($\chi^2 = 20.900$, $p = 0.013$, $\chi^2_{\text{critical}} = 16.919$) of liquid nitrogen and frozen semen, and animal breeding services in selected cattle corridor districts of Uganda. In this study, sourcing is represented by the ease of access to AI technicians in the provision of AI services, while perceptions on AI services represented the delivery of quality of animal breeding services in selected cattle corridor districts of Uganda.

Sourcing strategy is a continuous process, not an isolated decision. It continuously balances internal and external activities and services. It further aligns business strategy, business process and product requirements, and balances the results that must be achieved and the future options available (Lysons & Farrington, 2016). Similar studies by Rameshwar et al. (2018), Rameshwar et al. (2019a), Rameshwar et al. (2019b), Acosta et al. (2019), Rameshwar et al. (2020a), Rameshwar et al. (2020b), Samuel et al. (2020), and Mihelis et al. (2020) highlighted critical efforts towards supply-chain sourcing and delivery for achieving lead times, on time performance, flexibility, delivery frequency, quality, pricing terms, coordination capabilities, design collaborations, and supplementary viabilities for key breeding inputs. These lead to resilient and sustainable supply chains hinging on supply-chain sourcing and delivery strategies for breeding inputs to farmers who are the ultimate users of the AI services in Uganda.

In order for AI technicians to deliver continuous animal breeding services, they must have the AI kits, field flasks, access to transport for mobility, and have mobile telephones so that they can be accessed by the farmers. In addition, they must have the appropriate skills, experience to undertake the pregnancy diagnosis, prepare the animals, and work closely with farmers as observed by Morell (2011), Mugisha et al. (2014), and Mugisha et al. (2008). Sourcing and delivery of AI services to the farmers is an intangible form of service. Unique features of this services are inseparability, perishability, variability, and heterogeneity of the AI services offered. Others include simultaneity, and fluctuating demand and pricing services (Gurjant (n.d.)).

Equally, the farmers have a role in preparing the animals, putting in place appropriate animal handling structures

like the crushes, labour to restrain and manage the animals, including health, nutrition, and record-keeping (Lijalem et al., 2015; Engidawork, 2018). By doing so, the results expected to deliver appropriate products due to the AI services sourced through the technician would be attained. Similarly, supply-chain collaboration, supply-chain networks, and supply-chain transparency among the supply-chain actors all lead to supply-chain resilience, as pointed out by similar studies by Rameshwar et al. (2018), Rameshwar et al. (2019a), Rameshwar et al. (2019b), Acosta et al. (2019), Rameshwar et al. (2020a), Rameshwar et al. (2020b), Samuel et al. (2020), and Mihelis et al. (2020).

Additionally, another important dimension of sourcing is integrating cross-functional teams consisting of staff from the Genetic Centre, Ministry of Agriculture Animal Industry and Fisheries (MAAIF), especially the Commissioner of Animal Production and representatives, the academia, livestock research and development institutions, and practicing farmer organisations to regularly assess the attitudes, dependability, state of morale, and atmosphere of harmony among the AI technicians or dissatisfaction among the farmers and the genetic centre (Lysons & Farrington, 2016). This is crucial to manage supply-chain risks in the provision of AI services, from the perspective of AI technicians. This agreement is supported by previous scholars such as Rameshwar et al. (2018), Rameshwar et al. (2019a), Rameshwar et al. (2019b), Acosta et al. (2019), Rameshwar et al. (2020a), Rameshwar et al. (2020b), Samuel et al. (2020), and Mihelis et al. (2020).

Furthermore, the degree of interest among the farmers for AI services, the degree of energy displayed, and the interest in getting things done by the farmers and the related costs are essential aspects in supply-chain sourcing and delivery. Others are competence and technological levels of the AI technicians, status of equipment and facility, and means of ensuring quality to realise the desired outcomes and results, which need to be regularly established to guarantee sustainable supply of AI services to the farmers in a coordinated and structured way, as pointed out by Ayers (2020).

Implications to Theory

The study expounded the gaps in the public delivery of goods and services from the animal breeding services perspective using the supply-chain operations reference (SCOR) model. This was in relation to how liquid nitrogen and frozen semen is produced, stored, distributed, and

utilised by the users in the animal breeding value chains perspective. The theory illustrates the linkages with actors to deliver sustainable liquid nitrogen and frozen semen supply chains (Rameshwar et al., 2018; Rameshwar et al., 2019a; Rameshwar et al., 2019b) rather than the limited scope of relying on biological sciences in explaining animal breeding services phenomenon. The model further explains the frameworks that can be used for breeding inputs, improve business dexterity for breeding inputs, quicken business process efficiency, improve stock turns and delivery, bolster hierarchical learning objectives, and improve operational engagements for animal breeding chain actors.

Implications to Practice

The study established that farmers use mobile phones as the easiest way to access AI technicians. The implication is that at the planning and budgeting levels, funds for airtime should be approved to facilitate AI technicians. In addition, training in AI is crucial, as is provision of AI kits, such as field flasks and liquid nitrogen and frozen semen reservoir tanks. This effort aims at deepening the decentralisation of the supply-chain of AI services at the local level.

The study has highlighted the importance of sourcing liquid nitrogen from the supply-chain perspective. In particular, practitioners may need to explore economies of scale, minimisation of purchasing cost, and how to benefit from collaborations or coordination with suppliers so as to assist in facilitating sustainable and resilient supply chains for breeding inputs to AI technicians and farmers in Uganda.

Furthermore, management of the genetic centre ought to focus on the procedures and objectives, and evaluate the operational execution with benchmark information. In practice, managers should link process, perform estimations, and follow best practices. Therefore, cattle farmer's associations' requests and exchanges for liquid nitrogen should be taken into consideration right from the supplier to the customer, including gear, supplies, save parts, mass items, programming and AI services, and so on.

Limitations and Future Research Directions

This study fell short of capturing information on supply-chain collaboration performance and organisational capabilities on the delivery of animal breeding services in Uganda. Likewise, the empirical investigation of top

management commitment of the animal genetic centre to Total Quality Management (TQM) and organisational supply-chain ambidexterity in the delivery of animal breeding services in Uganda needs further research.

CONCLUSION

The study reveals a structural and functional supply-chain sourcing and delivery dynamics for key breeding inputs in the animal resources sector. In addition, the study affirms that sourcing and public service delivery of efficient and effective artificial insemination services must be a factor of coordinated interplay among value-chain actors, including farmers who ought to have the necessary interest, knowledge, skills, and competence to work in an integrated and seamless manner to deliver AI services in compliance with biological and supply-chain requisites to create an impact on livestock production and productivity.

DECLARATION OF INTEREST

The authors have no conflict of interest, whatsoever, in the study and conduct of it. The authors have undertaken the study solely for academic purposes and to inform the key stakeholders in the supply-chain of animal breeding and genetic improvement of the animal resources sector.

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