Value Chain Analysis of Delivery of Artificial Insemination Services in Kenya: A Case Study of the Western Kenya Region

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Authors' contributions

This work was carried out in collaboration among all authors. Author SNM conducted the key informant interviews and farmer interviews, conducted the gross margin analysis and wrote the first manuscript. Author JOO conducted the key informant interviews and farmer interviews, conducted the value chain mapping and participated in writing the manuscript. Author EJM coordinated the study, conducted the key informant interviews and farmer interviews. Author HA coordinated the funding, conducted the key informant interviews and farmer interviews. Author RNW conducted the key informant interviews and farmer interviews. All authors read and approved the final manuscript.

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ABSTRACT

The aim of the study was to map out value chains for transmitting genetic material, estimate gross margins and value added by each artificial insemination (AI) service providers, and recommend ways of improving AI services. Regulators, agents, trainers in artificial insemination and dairy farmers were interviewed in nine counties, namely Kisii, Nakuru, Uasin Gishu, Nandi, Kakamega, Bungoma, Nyamira, Bomet and Trans Nzoiafor three weeks in the year 2017. Ninety AI inseminators, 32 regulators, 18 distributors, 6 trainers, 10 para-veterinary officers and 10 importers of genetic material were interviewed through key informant interviews. A total of 114 farmers were

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interviewed through a semi-structured questionnaire. Descriptive statistics (percentages, means) were used for data analysis. Results show that the Kenya Animal Genetics Resource Centre (KAGRC) handled 70% of the genetic material. Bull service had about 16% of the market share. The main challenge for farmers was repeat cases of insemination thus questioning the quality of artificial insemination. The AI trainers with better technical skills such as KAGR Conly trained 1% of the farmers interviewed. Gross margins for inseminators were Kenya shilling (KES) 163/dose for local semen and KES 660 for imported semen, thus making it difficult to earn a decent living from distribution of local semen. Transport cost was 37% of the total cost. To increase gross margins, inseminators should give veterinary services andencourage farmers to use AI services. County governments should reduce cost of transport. Traceability of inseminators and of semen distribution should be done to reduce exploitation of farmers.

1. INTRODUCTION

The livestock sector in Kenya contributes 12% of Kenya's national gross domestic product (GDP) and 42% of agricultural GDP [1]. According to a report published by the United States Agency for International Development [2], dairy production contributes about 4-8% of GDP, 14% of agricultural GDP and 40% of livestock GDP, thus depicting a significant part of the Kenyan agriculture economy. Other reports have also confirmed the importance of dairy farming activities in the generation of employment opportunities. For instance it is reported that for every 1,000 litres of milk produced daily in Kenya, approximately 23 full-time jobs for the self-employed are created in addition to 50 permanent jobs and three casual labour jobs [3], and that for every 1,000 litres of fresh milk processed approximately 13 jobs are created in the Kenyan economy. Dairy farming practices also supply the domestic requirements of meat and meat products, milk and other dairy products.

However, milk production still falls short of its demand. In the year 2018, milk production was projected to be 6.72 billion litres, giving a deficit of 1.28 billion litres by 2022 [2]. To meet the deficit, there should be a 79% increase in milk production. Most of the increase should be from increased productivity because increase in livestock numbers is unsustainable. Although the dairy sector has a significant contribution to the national economy, smallholder farmers face a myriad of constraints to increased productivity, and one of the constraints is limited access to artificial insemination (AI) services of good quality.

As reported by [4], as part of the economic structuring in Kenya, AI was liberalized by the government in 1991, leading to decline of semen demand because of the government's withdrawal of the subsidy to dairy farmers. After liberalisation, private AI service providers entered the value chain to offer the service, but due to poor regulation and supervision, there was a significant reduction in the quality of services, where malpractices were reported including distribution of poor quality semen or sometimes local semen being offered as imported in order to get higher gross margins.

The Kenya Animal Genetics Resource Centre (KAGRC) was formed in 2011 to address the decline of semen demand and quality due to withdrawal of the subsidy from the government. According to [5], KAGRC has been the main supplier of semen for AI, increasing production from 40,000 straws in 1996 to 1 million straws annually. Nonetheless, KAGRC's market share fell from 90% to 70% between the 1980s and 2017, while the market share for imported semen increased. All these changes have brought to the fore issues of accessibility and cost of semen to the smallholder dairy farmer. Some regions practicing smallholder dairy production have failed to attract adequate private investments due to lack of economies of scale (most AI providers mainly operate around urban areas), forcing farmers to use the natural service (bulls). The trend has compromised the quality of AI services given to smallholder farmers in most parts of Kenya. The questions addressed in this study are fourfold:

- What are the channels used for transfer of genetic material to smallholder farmers?
- What is the market share for each channel used?
- What are the gross margins and value added for the AI service providers?

- What can be done to improve AI service delivery for smallholder farmers?

Answering the four questions explains the observed behaviour of service providers and generates information that will inform stakeholders on how to increase availability and affordability of AI services for smallholder dairy farmers.

Several studies have reported the costs and benefits of different breeding methods in different areas. A study by M' Ikiugu et al. [6] has reported that natural service has been proven to have a higher net cost than AI, and that the advantage of timed AI depended on cost to feed bulls, price of semen and quality of semen, while Okeno et al.[7] reported that smallholder farmers in Kenya preferred AI to bull service but they used the latter because it was cheap. The economic merits of breeding strategies by use of cost benefit analysis for over 25 years was studied by [8], and the study indicates that the use of continuous semen importation is not economically viable under Kenyan production conditions. Imported semen has more superior quality than the local semen but its (imported semen) interaction with the local environment may not achieve the desired results [4]. The underlying message in these studies is that even if AI is superior to bull service, other factors can contribute to it not being economically viable, and farmers may opt for bull service. The information generated in this study gives a pointer on how AI can be made affordable to smallholder farmers.

Semen used by smallholder dairy farmers is obtained either locally or imported. The AI service providers (mostly private service providers) are mainly driven by gross margins from services rendered, meaning that they will supply semen that gives higher gross margins. This means that the service providers are a major determinant in the provision of the type and quality of semen. This study therefore sought to quantify gross margins for different service providers for local and imported semen in order to understand the preference for certain value chains. An understanding of incentives/disincentives for the different AI service providers through gross margin analysis would contribute to increasing efficiency in AI service delivery**.** In a study by [9], on factors affecting adoption of embryo transfer technology in dairy cattle in Kenya, there was a positive correlation between adoption and availability of the technology as well as between adoption and availability of technical experts in AI. In addition, there was a negative correlation between adoption and lack of awareness as well as between adoption and cost of the technology. The AI, a similar technology to embryo transfer may also have the same correlations. The service providers are the technical experts who increase awareness of the semen available and determine the cost of the technology, meaning they are strong determinants in adoption of AI. Therefore identifying and addressing their incentives and disincentives would increase adoption of AI.

The general objective for the study was to carry out a value chain analysis (VCA) of AI service providers while the specific objectives were to; map out the value chains used for transmitting genetic material, estimate the gross margins for, and value added by each AI service provider, and recommend ways of improving AI service provision.

Different studies have defined VCA in different ways. The VCA can be used in tracing product flows, showing the value adding stages, identifying key actors and their relationships with other actors in the chain, thus revealing the bottlenecks in the value chain for remedial action [10]. In addition [11] states VCA as the quantitative analysis of inputs and outputs, prices, value added and margins of the different agents under different policy scenarios. In the value chain analysis study of seaweed in Kwale County Kenya, the [12] conducted a mapping of all chain actors, size and economic importance of value chains, role of actors, chain power, gender mainstreaming, market linkages, gross margins, weaknesses and strengths. The VCA can also be used in tracing product flows, showing the value adding stages, identifying key actors and their relationships with other actors in the chain [10], thus revealing the bottlenecks in the value chain for remedial action. From the literature, it is apparent that VCA has moved from the initial analysis of merely describing the flow of a good or service from production to consumption, to including all the economic activities undertaken between these phases, and assessing the value these activities add to the chain, a concept that is essential for decision making. The East Africa Dairy Development project [13] used VCA to map the dairy value chains for both the formal and informal milk markets in Kenya as well as determine the number of players, their cost structures, prices and gross margins at each stage of the value chain, while [14] used VCA to

assess and document the factors limiting trade in the livestock export market. This study will use both concepts of VCA; mapping the value chain by tracing the flow and market share of genetic material up to the consumer, determining the gross margins for each AI service provider and the value added at each node of the value chain. Thisgross margins explain the behavior of the value chain actors in AI service provision.

The government of Kenya developed the Big Four agenda (manufacturing, food security, universal health care and housing) in 2017 [15]. This information generated in this study is a precursor of increased livestock productivity, which will go towards enhancing food security as the second pillar of the Big Four agenda. In the veterinary policy [16], the government recognizes that poor genetics in livestock, inadequate uptake of modern breeding technologies, weak infrastructure, diseases and inadequate extension services are the major challenges in livestock productivity, and promises to support AI together with other interventions to increase livestock productivity. This study will therefore contribute to facilitating the government's intervention in increasing AI services to smallholder dairy farmers, thus increasing productivity.

2. MATERIALS AND METHODS

2.1 Areas of Study

The research was carried out in nine counties in the year 2017, where the Smallholder Dairy Commercialization Programme (SDCP) were running dairy improvement projects and these counties were identified by SDCP to be regions with high poverty levels; where over 42% of the populations were living below the national poverty line [5]. These counties were:

1. Kisii County-Keumbu, Mosocho, Kiogoro-Bogiakumu regions
2. Nakuru County in Kabazi, rongai, Ngata, Subukia regions
3. UasinGishu County in Sugoi, Moi's Bridge and Kapsaret regions
4. Nandi County- Kapsaret-Kipture, Sigot-Kabisanga, Lolkeringet-Kabiemit
5. Kakamega County-Lugari, Likuyani, Lwandeti
6. Bungoma-Ndalu, Ndivisi, Bukembe
7. Nyamira-NyansiongoMekenene, Ekerenyo-Bonyamatata, Nyamira-Peri-urban
8. Bomet-Ndarwta, Kembu and Sugumerga
9. Trans-Nzoia-Endebess, Waitalluk, Kiminini

2.2 Selection of Study Units

The study units included dairy farmers, AI technicians, regulators of the dairy sector, semen distributors, agents for distributing genetic material, training institutions of AI technicians and companies importing genetic material into the country. The regulators, distributors and agents for distributing semen in the study counties and training institutions were very few and known, therefore the study targeted to interview all. Dairy farmers were purposively selected from beneficiaries of the SDCP dairy improvement programme, representing 10% of the beneficiaries in each county. The AI technicians interviewed were all beneficiaries of the SDCP dairy improvement programme.

The specific sample sizes for each category of study participants are included in Table 1. From each selected region, participants including livestock farmers, AI technicians, and representatives of regulators and distributors of genetic materials were invited to participate in the study.

Table 1. The category and number of AI service providers interviewed

No.	AI service providers	No. Interviewed per County	Total number Interviewed
2.	Inseminators	10 per county	90
3.	Regulators	3 per county	27
4.	Distributors/agents	2 per county	18
5.	Training institutions	National	6
6.	Kenya Veterinary Board/Kenya Veterinary Association, Para Vets	National	10
7.	Regulators	National	5
8.	Genetic importers	National	10
9	Farmers		114

Nos. 5,6,7 and 8 were national institutions in the sense that they servedthe whole country.The number of farmers in the nine groups were selected as follows; Kisii 12, Nakuru 13, UasinGishu 13, Nandi 14, Kakamega 12, Bungoma 12, Nyamira 13, Bomet 12, Trans-Nzoia 13.

2.3 Data Collection

To map out the value chains a review of documents which were available at KAGRC, public libraries at the Directorate of Veterinary Services, the University of Nairobi and other online resources was done to map out the flow of genetic material. Key informant interviews and semi-structured questionnaires were used to determine the semen value chains (and their share) and associated actors, determination of the actors' role and their activities along the value chain value chains, the number of registered AI services providers, their areas of operations as well as the challenges they were facing as regulators of the breeding sector. A semi-structured was used to collect the data from farmers on the challenges faced and the source of training on AI.

For gross margin analysis, the following primary data was collected from AI service providers.

 i) Buying and selling price of semen;
 ii) Transport costs;
 iii) Costs of labour
 iv) Cost of Liquid Nitrogen.
 v) Marketing costs

Secondary data from KAGRC was used to calculate the cost of depreciation of the AI kit by use of the Straight-Line Depreciation method. This is a simple and commonly used method [17]. The annual depreciation amount is obtained by subtracting a fixed residual value from the cost of the fixed asset and dividing the result by the estimated useful life.

2.4 Data Management and Analysis

Descriptive analysis was done to map the value chainswhile percentages of farmers were used in determining the challenges farmers faced as well as the type of trainers they used for AI services. Gross margin analysis was computed from 5 distributors of semen and 10 AI technicians. In order to increase the reliability of the data, not all data from distributors and AI technicians were used for gross margin analysis. The information used was only from the distributors and technicians who understood most of the operations in the value chain. Means and percentages were used to obtain gross margins and value added at each node of the value chain. Gross margin analysis seeks to highlight the incentives and disincentives in AI delivery,

but not at the overall benefit of local and imported semen to the smallholder farmers.
After identification of the main value chains the associated costs and revenues; gross margins for every actor along the value chain; comparing and assessing the factors affecting the different value chain actors. Additionally, the analysis involved determination of the economic value added along the semen value chains.

3. RESULTS AND DISCUSSION

3.1 Value Chain Mapping

The market share for animal genetics supply was as follows: KAGRC 70%, imports 14.5%, natural service 15% and embryo transfer 0.5% (Fig. 1). Embryo transfer had lower success rates compared to other breeding technology and had very few skilled personnel to carry out the embryo transfer technology.

Natural insemination (bull service) had about 16% of the market share, but its disadvantage is that bulls are expensive to maintain, there is the risk of spreading disease, and lack of records may cause inbreeding. The advantages with natural insemination are that there is no need for heat detection, reliability of conception and low cost of natural service (KES 200-500 per service). At the time of the survey, KAGRC was training farmers on how to manage the bulls. Embryo Transfer had <1% of the market share, had lower success rates compared to other breeding technologies and had very few skilled personnel to carry out the embryo transfer technology.

3.2 Farmers' Challenges

The smallholder farmers experienced different challenges with AI, and Fig. 2 shows that the main challenge was repeat cases after insemination (69%, n=114). This result is corroborated by M'Ikiugu et al. [6] who estimated 87% of smallholder farmers interviewed citing repeat cases with AI as a major constraint. Other challenges were unavailability of inseminators, deaths of calves and farmers only getting bull calves.

3.3 Farmers' AI Trainers

Fig. 3 gives the different trainers for farmers interviewed. Livestock officers were the

main trainers (40%, n=73) followed by SDCP (30%).

Heifer (Heifer International)- is an international organization that supports and trains livestock farmers.

3.4 Gross Margin Analysis

Gross margin analysis was done for two channels; semen from KAGRC and imported semen. The analysis started with identifying all the cost items of AI, from which the variable costs and prices were delineated to be included in the analysis as follows:

i) Price of semen;
ii) Depreciation of AI kit;
iii) Transport;
iv) Labour;
v) Marketing costs; and
vi) Liquid nitrogen

a) Gross margin analysis of agents/ distributors

The agents/distributors distribute semen to AI technicians, who then deliver to individual cows in smallholder farms. Table 2 shows the agents/distributors costs and returns for 35 doses of semen. Gross margins for imported
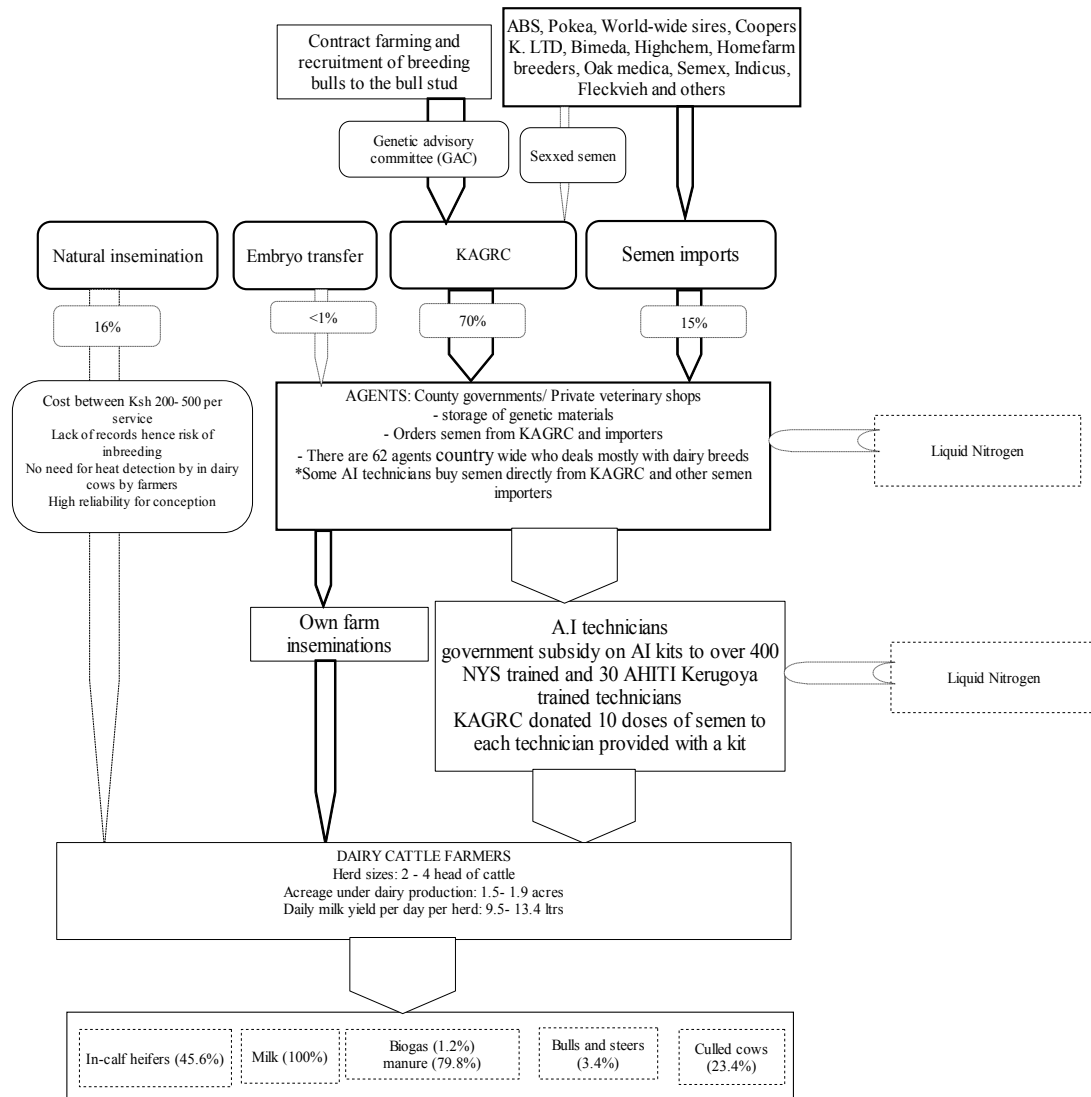

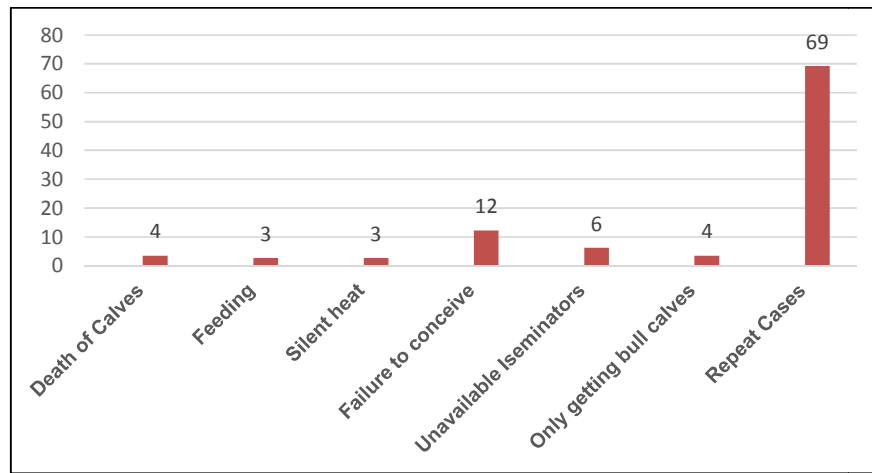**Fig. 1. Value chain mapping for local and imported animal genetics**

Fig. 2. Number and proportion (%) of farmers with different challenges faced with AI service
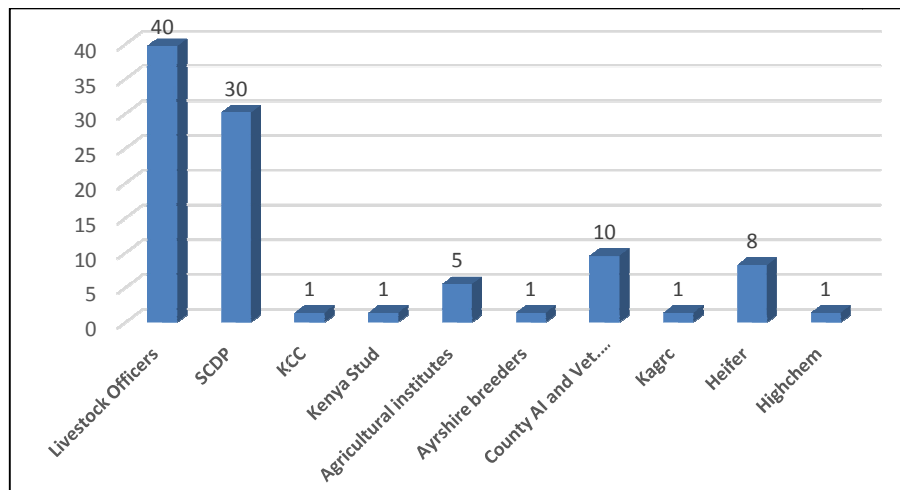

Fig. 3. Number and proportion (%) of farmers with different trainers

semen were about 13 times more than those of local semen, and the percentage gross margin (% of value added) was 13% for local semen and 55% for imported semen, meaning that the agents were getting 13% and 55% of the value added in local semen and imported semen respectively. This analysis shows that agents had a strong incentive to stock and sell imported semen.

b) Gross margin analysis for inseminators

Table 3 show the costs and returns to one artificial inseminator for one dose of semen. The analysis was based on one dose per day because the survey showed that on average, most inseminators made one insemination per day.

The Straight-Line Depreciation method was used to calculate the cost of depreciation. The cost of a 35 litre AI kit was about KES 115,000 (KAGRC data), with a lifespan of 5 years (20% depreciation rate). The salvage value is estimated at KES 50,000 (price at which kit can be sold as second hand after 5 years-personal communication). The net price (less salvage value) multiplied by the depreciation rate gives a depreciation value of KES 13000, in a year, therefore giving a depreciation value of KES 36 per day.

The total cost incurred per dose of local semen was KES 537. The largest share of the cost was the price of semen and transport at 47% and 37% respectively, with other costs consisting of about 16%. The significant cost of transport is in

Table 2. Agents/Distributors costs and returns for 35 doses of local and importedsemen

Item	Cost for 35 doses per day(KES)		% cost share		Data source/Remarks	
	Local Semen	Imported Semen	Local Semen	Imported Semen	Local Semen	Imported Semen
Purchase of semen	7,000	12,250	66	78	Survey data. Semen from KAGRC bought at 200 per dose. The average number of doses in the year 2016 was 12,500, translating to 35 doses in a day	Survey data. Used the price of KES 350 per dose
Labour for distribution	500	500	5	3	Survey data.	
Transport	200	200	2	1	Survey data.	
Marketing costs	200	200	2	1	Survey data.	
Liquid nitrogen	2,630	2,630	25	17	Survey data. The average number of litres used in the year 2016 was 4800 litres, translating to KES 13.15 per day. The cost of one litre of nitrogen was KES 200	
1.Total cost	7,913	15,780				
2.Sale price of 35 doses to Inseminator	8,750	31,500			Survey data. Used KES 250 per dose	Survey data. KES 900 per dose
3.Sale of nitrogen	3,288	3,288			Survey data. North Rift distributor in Trans Nzoia County used 4800 litres in 2016, translating to 13.15 litres per day at KES 250/litre	
4. Total Revenue	12,038	34,788				
5.Gross margin	1,508	19,008				

Note: KES 100= 1 US $; The percentage gross margin is = (gross margin/gross revenue)*100, which amounts to 13% for 35 doses

Table 3. Artificial Inseminators' costs and returns per dose of local and imported semen

Item	KES/dose		% Share of cost		Data Source/Remarks
	Local semen	Imported semen	Local semen	Imported semen	Local semen
Price of semen from distributor/agent	250	250	47	74.51	Survey data
Transport	200	200	37	17.53	Survey data
Price of Liquid Nitrogen per dose	2.19	2.19	0.4	0.19	KAGRC A 35 litre can of liquid Nitrogen has a capacity of 4000 doses. There for 1 dose uses 0.00875 litres. With a price of 1 litre of nitrogen being KES 250, this translates to KES 2.19 per dose
Price of one Sheath	12	12	2.2	1.01	KAGRC KES 600 for 52 pieces, and each insemination uses 1, giving KES 11.53 per dose
Price of one glove	9	9	1.7	0.79	KAGRC KES 900 for 100 pieces, each piece used for one dose giving a cost of KES 9 per dose
Price of lubricant per dose	29	29	5.3	2.50	KAGRC Lubricant for KES 400 used for 14 days, therefore 1 dose is KES 29
AI kit depreciation per day	36	36	6.7	3.16	Calculated from KAGRC data*.
1. Total cost 2. Sale price of semen to farmer 3.Gross margin	537 700 163	1141 1800 660			 Survey data

tandem with remarks from most inseminators who decried the poor state of road infrastructure. This explains why some smallholder farmers decried unavailability of AI services and why most of the services are concentrated around urban areas [5]. The cost of liquid nitrogen may appear insignificant per dose of AI but there can be no insemination without it. There was shortage of liquid nitrogen at the time of the survey, where some inseminators had to suspend their operations.

The study used KES 700 as the price of local semen sold to farmers, but the price was quite varied ranging from KES 500-1500. At a price of KES 700, the inseminators had a gross margin of KES 163, translating to a margin of 23%, meaning that inseminators were getting KES 23% of the value added when they sold local semen to farmers. At the time of the survey, the inseminators said that it was difficult to make a decent living from KES 163 per day.

For imported semen the study used KES 1800 as the price of imported semen sold to farmers, but this price was quite varied, going to as high as KES 6000. The gross margin (KES 660) from sale of imported semen was more than four times that from sale of local semen, where the inseminators were getting 37% of the value added. From the survey, imported semen consist of 22% of all the semen in the market [4] quotes 20% as the market share for imported semen), meaning that inseminators were quite limited in getting higher gross margins from imported semen. Therefore with poor supervision in the study area and with farmers' limited knowledge to identify local and imported semen, it was easy for unscrupulous inseminators to sell local semen as imported. According to MOALF & I [4], technicians (inseminators) exploit farmers by supplying local semen but charge the price of imported semen.

4. CONCLUSION AND RECOMMENDA-TIONS

Regarding the channels for transfer of genetic material and the market share for different players, the three modes of transmission of genetic material was the natural service (16%), embryo transfer (less than 1%) and semen transmission through AI. The KGRC was the largest suppliers of semen, mainly sourced locally. Imported genetic material constituted only 15%. Agents sourced the genetic material from KAGRC, who then supplied to AI technicians. A few farmers bought directly from agents to conduct their own AI.

A point to note is that KAGRC as well as AI and veterinary officers (who have the AI technical skills to impart to farmers) had trained a very small proportion of farmers. Therefore, this situation should change with KAGRC and veterinary officers getting more involved in training. The challenges faced by farmers point to the fact that the quality of AI services was quite wanting and that farmers had low dairy herd management levels. The regulatory authority should ensure that quality service is rendered.

On the question of gross margins, the inseminators had a gross margin of KES 163/insemination using local semen. Most inseminators said they conducted one insemination per day. This margin made it difficult to make a decent living from KES 163 per day. To increase their gross margins, the inseminators should encourage farmers to take up AI services and give veterinary services in addition to AI services.

The cost of transport was 37% of the total cost incurred by inseminators. This cost can be reduced by the county governments reducing the cost of transport by improving the road network. The analysis shows that agents/distributors were getting higher gross margins than inseminators. As an incentive to the inseminators, the agents/distributors can lower their prices, which would increase their sales therefore getting more returns. To avoid exploitation by inseminators, traceability of the inseminators as well as of the semen used should be increased and farmers given information on how to differentiate between the local and imported semen.

CONSENT

As per international standard, farmers' written consent has been collected and preserved by the author(s).

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4. Farmers in the nine counties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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