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Assessing Artificial Insemination Service Effectiveness and Evaluation of Semen Quality in West Arsi Zone of Oromia Region, Ethiopia

Diribi Mijena[1*], Aman Getiso[1], Jemal Felecho[2]

[1]Ethiopian Institute of Agricultural Research, Wondogenet Agricultural Research Center, Shashemene, Ethiopia
[2]West Arsi zone, Dodola District Livestock and Fishery Office, Dodola, Ethiopia
[*]Corresponding author: E-mail: jibatdm@gmail.com

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***Abstract*— *This study was conducted to assess the effectiveness of artificial insemination and semen quality in the Dodola district of the Oromia region of Ethiopia. A cross-sectional survey with structured questionnaires and a stratified sample approach was used to gather data from 264 smallholder dairy households (168 rural and 96 peri-urban households). Furthermore, 32 frozen semen straws were collected using a random sampling approach to assess the quality of the frozen semen based on handling effectiveness. Additionally, the number of services per conception, non-return rate, and conception rate were determined using retrospective data spanning two years (2020–2021). The survey results show that,30.7% of the dairy farmers in the study area regularly and uninterruptedly receive artificial insemination services, while 69.3% do not, citing a lack of inputs, a shortage of artificial insemination technicians, and service interruptions on weekends and holidays. The overall mean numbers of services per conception, non-return rate, and conception rate in the study area were 2.16, 42.9%, and 45%, respectively. Improper management of liquid nitrogen containers, improper semen deposition in the reproductive tract, neglecting basic AI equipment, and improperly dried straw after removal from warm water thawing were the main issues with semen handling in the study area. The average motility and viability of frozen semen from Source: Laboratory result (2022) was 67.3 ± 5.82 and 78.9 ± 5.77, respectively, but in the district, they were 49.9 ± 5.3 and 59.8 ± 7.4, respectively. According to the results of the survey and experiment, the overall success rate of artificial insemination services was unsatisfactory, with conception failure and improper handling of semen being particularly critical issues that need urgent attention. Therefore, it is important to provide artificial insemination technicians with regular training and sensitization to advance their expertise. However, robust structural integration between logistics centers and supply chains for artificial insemination inputs is necessary to optimize the effectiveness of these services.*

Keywords*— *Conception rate, peri-urban, rural, Motility, Number of services per conception, non-return rate, Viability

I. INTRODUCTION

An estimated 66.26 million cattle are existing in Ethiopia, of which 56.69% are female. Only 1,094,645 (1.65%) and 168, 175 (0.25%) of all female cattle are hybrid and exotic breeds, respectively, and only 3.87 billion liters of milk were produced annually during the 2021/22 production year, with an average lactation length of six months and an average daily milk yield of 1.45 liters per cow [1]. However, the country 's per capita milk consumption is only 19 kg per year [2], suggesting that production levels are insufficient to fulfill consumer demand.

Despite the presence of large and diverse animal genetic resources, Ethiopia is characterized by low livestock production and productivity [3] owing to several complex and interrelated factors, such as inadequate feed and nutrition, widespread diseases, and poor genetic potential of indigenous breeds [4, 5]. The selection of the most promising breeds and crossbreeding of indigenous breeds with highly productive exotic breeds have been considered practical solutions to improve the low productivity of local cattle [6].

Artificial insemination (AI) is the most popular and promising biotechnological technique to increase the reproductive capacity of farm animals. It is the process of collecting, processing, and storing sperm from a male animal and then manually or artificially inserting it into the female reproductive tract to conceive [7]. It plays a significant role in increasing the yield capacity of cows and is an appropriate method of genetic improvement. The realization of breeding programs must be well organized and excited in a very reliable way [8]. Nonetheless, several studies have noted that its use is less common in developing countries and the results are far from satisfactory [9]. The performance of AI is mainly affected by the heat detection efficiency, effectiveness and efficiency of the inseminator, fertility of the cow, and semen quality [10]. The efficiency of AI services in Ethiopia is very poor, with the conception rate of the first service being as low as 27.1% [11]. According to [12], a breeding strategy to achieve "one calf per cow per year" calving interval needs to be minimized. In the study area, research has not yet been conducted on the effectiveness of AI services, semen quality, or how these factors affect the conception rate of inseminated cows. The objective of this study was to assess the effectiveness of AI, the quality of semen, and their impact on the conception rate of inseminated cows in the study area.

II. MATERIALS AND METHODS

1.1. Study site description

Six rural and three peri-urban peasant associations (PAs: smallest administrative unit of the country) from the Dodola district participated in the study. Dodola district is located in the West Arsi zone of the Oromia regional state (Figure1). The district is approximately 75 km from Shashamene, the zonal town, and 320 km southeast of Addis Ababa, the capital city of the country. It is located at 06°59′ N and 39°11′ E, with an altitude range of 2362–2493 m above sea level [13]. The district occupies a total of 145, 246 hector land with 244,540 people living there. It contains 23 rural and six peri-urban peasant associations. According to information from the Dodola District Livestock and Fishery Office, there are 391,669 cattle in the district, of which 91.5%, 7.5%, and 1.2% are indigenous, hybrid, and exotic breeds, respectively. The climate of the district is characterized as highland (95%) and midland (5%). Rainfall was usually intense and medium in duration, with an average of 805–1260 mm per annum. The main rainy season in the district is between June and October (the long rainy season), while the short rainy season is from March to April, and the season lasts until May.

1.1. Research Design

This study consisted of three components (a cross-sectional survey, semen quality analysis, and a retrospective study). To collect the required evidence relevant to the aims of the study, different data were collected at a time (June 2022 to December 2022). Both qualitative and quantitative data collection instruments (questionnaires) were well-developed and employed. Semen quality was assessed using slandered laboratory techniques. Secondary data were collected from the District Livestock and Fishery Development Office documents, AI certificates, and case books. Each sampled straw was labeled with all the necessary information, such as the production batch code, collection date, and code of artificial insemination technicians. To prevent thermally induced semen damage, the semen straws were transported from the Dodola district to the semen laboratory in Kaliti using three-litter liquid nitrogen-containing containers. Finally, the frozen semen was thawed and examined to estimate sperm motility and viability (live and dead cell count) defects. To calculate and analyze the number of services per conception (NSPC), non-return rate (NRR), and conception rate (CR), two years (2020–2021) of data from the AI service center were used.

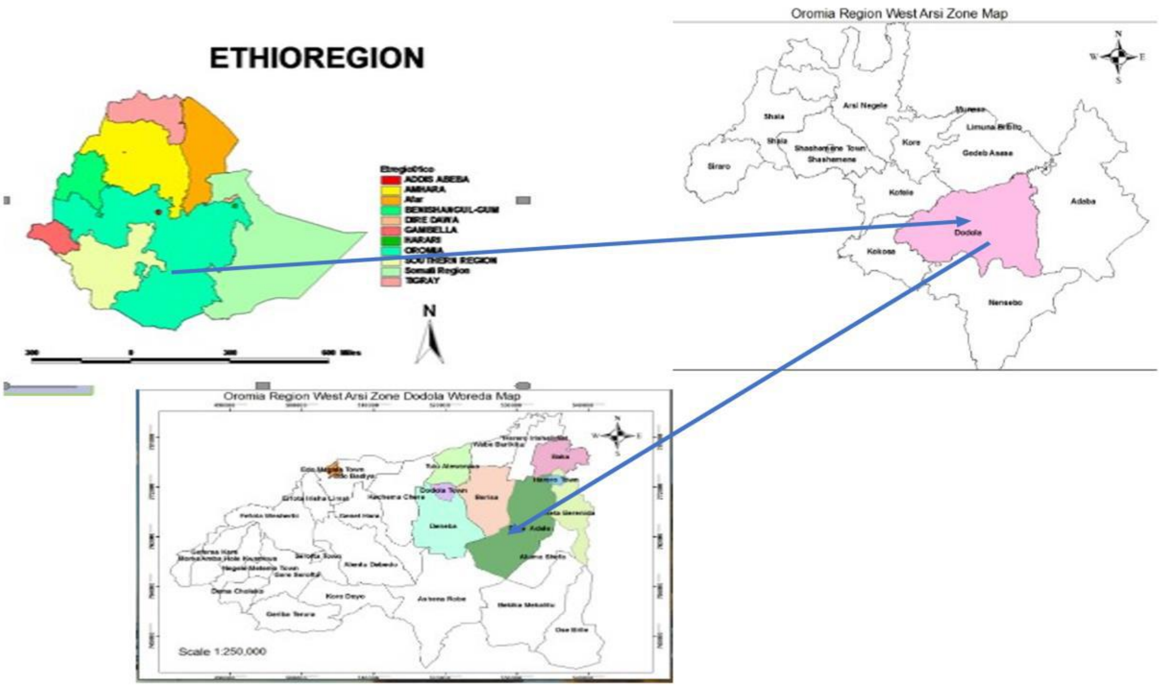

Fig.1:Map of the study area

1.2. Sampling techniques and sample size

Multi-stage sampling techniques were employed to select the target households. In the first stage, the Dodola district was purposely selected from the West Arsi zone owing to its dairy cattle potential, and the AI service was widely exercised. In the second stage, the district was stratified based on smallholder dairy production in the rural and peri-urban systems. In the third stage, nine PAs were selected purposively based on smallholder dairy production system representation, dairy production potential, number of AI service beneficiary, and accessibility out of 29 kebeles (six for rural and three representing peri-urban) from the district. In the fourth stage, 264 representative households (168 from rural and 96 from peri-urban) that owned a minimum of one crossbred (50-75% blood level) dairy cow and one local breed were selected from lists of identified dairy producers using a simple random sampling technique, based on the proportion of the population size of selected PAs (Table 1). The sample size was determined based on the absolute desired precision of 5% at a confidence level of 95%, according to the formula provided by [14], from the total number of AI beneficiaries (780) in the study area. Accordingly, 264 target households were selected using a probability proportional sampling technique, while four artificial insemination technicians, 14 livestock extension workers, and 12 animal health professionals as key informants (KI) were purposively selected and interviewed using separate questionnaires and checklists, respectively. This value was calculated using the following formula:

$n = N/(1 + N(e2))$ Where, n = Represent sample size,

N=Stands for the total number of the targeted population size

e= Represent maximum variability (5%), and

1=Stands for the probability of an event occurring.

For semen quality assessment, random sampling techniques were used to select sample straws for semen quality assessment and evaluate quality loss due to transportation and handling. Accordingly, 32 straws of frozen semen were randomly selected and used to analyze the frozen semen quality. The frozen semen was collected from two breeds (100% Holstein-Friesian and 100% Jersey). This implies that 16 straws from each breed were used for assessment. Data on sperm quality at the production and processing sites were collected from the record book of the National Animal Genetic Improvement Institute (NAGII). To compute the NSPC, NRR, and CR, two years of data (2020–2021) were employed, whereas five years of data (2017-2021) were used to analyze the trends of AI services in the study area.

Table 1:Peasant Associations and contact households covered in the study district

Smallholder dairy type	Selected PAs	Target Population size	Sample size
Rural	Adele	62	21
	Baka	54	18
	Barisa	96	32
	Denaba	72	24
	Kata	102	35
	Tullu	111	38
	Total	497	168
Peri-urban	Anole	94	32
	Eddo	102	35
	Heraro	87	29
	Total	283	96
Total		780	264

PAs=Peasant Associations

1.3. Method of data collection

Prime information relating to the demographic, social, and attitude of farmers towards the management of dairy cattle, breeding practices, mating systems, and AI service efficiency was collected from respondents using an open-ended survey interview guide. Moreover, other data such as the number of cows inseminated by year, number of calves born each year, conception rate in the study area, and related information were collected from secondary sources such as AI center record books, district-level assessments, and performance reports. For AI trends in the study area, five years (2017-2021) of recorded data were used, whereas two years (2020-2021) of recorded data were used for the retrospective study. For semen quality assessment, frozen semen (sperm motility and viability) data were used to estimate the fertility.

1.4. Data management and method of data analysis

The collected qualitative and quantitative variables were cleaned, edited, and entered into a statistical program for social science computer software version 20 (SPSS-20), and coded for analysis. Numerical data were analyzed using an independent t-test, whereas the chi-square test was employed for categorical data. Data on the purpose of keeping cattle and the constraints of AI in the study were analyzed using ranking index analysis. Change or loss of sperm quality is estimated as the difference between the quality measurements before and after semen is disseminated to the insemination center. Retrospective data were obtained from the district livestock office and AI service-recording book. Data of two year (2020 to 2021) were used to estimate and compute the following parameters:

1. **The number of services per conception (NSPC)** was determined as the number of services required for successful conception [15].
2. **Non-Return Rate (NRR)** is the percentage of inseminated cows that are not inseminated again for a set period (usually between 30 and 60 days) [16].

$$\text{NRR} = \frac{\text{Cow not return for 1st insemination}}{\text{Total 1st inseminated cow}} \times 100$$

3. **The conception rate (CR)** was estimated by computing the percentage of conceived cows and number of inseminated cows [17].

$$CR = \frac{\text{Number of pregnant cows}}{\text{Total inseminated cows}} \times 100$$

The following model was used to analyze semen quality:

$$Yij = \mu + ti + eb + eij$$

where Yij =frozen semen quality (sperm motility and viability), μ= overall mean, ti = artificial insemination technicians (with codes 01,02,03, and 04), eb= breed (Holisten-fersian and Jersey), and eji is the random residual error.

For the ranked variables, the data were computed using the following index formula:

Index $=\sum R_n{*}C_1 + R_{n-1}{*}C_2 \ldots + R_1{*}C_n$ for individual variables/$\Sigma Rn\,{*}C_1 + R_{n-1}{*}C_2. + R_1 \times C_n$ for all variables.

where R_n = Value given for the least-ranked level (e.g., if the last rank is 5th, Rn = 5, R_{n-1} = 4, and R_1 = 1). C_n= percentage of households for the last ranked level and C_1 = percentage of respondents ranked first.

III. RESULT AND DISCUSSIONS

3.1 Demographic characteristics

The average age of the households in the rural smallholder dairy (39.1±10.9) years was significantly (P<0.001) higher than the mean age (34.8 ± 8.3) years in peri-urban smallholder dairy types (Table 2). The current average age (36.9 ± 9.6) years of respondents in the district was lower than that of [18] and [19] who stated the average age of household 38.47±1.31 and 45 years in Bench Maji and West Shewa zone of Ethiopia, respectively. The average family size of rural smallholder dairy (7.1 ±2.9) was higher than that of peri-urban smallholder dairy (4.4±1.8). The average family size (5.7±2.3) reported in this study was in line with the finding of [20], that was 6.02±2.52 in Jimma town, Oromia, Ethiopia. Concerning gender, in rural smallholder dairy farms, approximately 81% of the respondents were male and 19% were female. In the peri-urban area, 68.6% and 31.4% of the respondents were male and female, respectively. From this finding, it can be observed that in both smallholder dairies, males were more responsible than females. This result is slightly similar to [21], who noted that males were headed by 92.7% of the family in Haramaya district, Ethiopia, and [22] reported 95% male and 5% female household heads in Southern Ethiopia.

The interviewees' educational levels ranged from illiteracy to completion up to the degree level. This may be the result of growing educational coverage, which makes it easier to implement better dairy-husbandry practices. Overall, 79.2% of the respondents had completed various levels of formal education, 16.3% could read and write, and only 4.5% were illiterate. The percentage of illiteracy reported in the current study was lower than that reported in [19], in which 46.1% of respondents were illiterate in the western Shewa zone of the Oromia region, Ethiopia. This might be due to the accessibility of the study area to educational centers and the awareness of the farmers in the study area on education.

Table 2: Demographic characteristics of the households

Variables	Smallholder dairy		Overall mean	P-Value
	Rural (N=168) Mean ± SD	Per-urban (N=96) Mean ± SD	(N=264)	
Age of the households in year	39.1 ± 10.9	34.6 ± 8.3	36.9 ± 9.6	0.001
Family size of the households by number	7.1 ± 2.9	4.4 ± 1.8	5.7 ± 2.3	0.000
Gender of the households				
Male	136(81 %)	66(68.6%)	202(76.5%)	
Female	32(19 %)	30(31.4%)	62(23.5 %)	
Educational status of the households				
Illiterate	12(7.1%)	-	12(4.5%)	
Read and write	40(23.8%)	3(3.1%)	43(16.3%)	

Primary education (1-4)	48(28.6%)	28(29.2%)	76(28.8%)
Junior education (5-8)	53(31.5%)	41(42.7%)	94(35.6%)
Secondary education (9-10/12)	15(9.0%)	17(17.7%)	32(12.1%)
Certificate/Diploma/Degree	-	7(7.3 %)	7(2.7%)

3.2 Dairy cattle herd size and experience of the households in dairy farming

There was a significant difference ($p < 0.05$) in dairy cattle herd size and period of involvement in dairy farming between rural and peri-urban smallholder dairy production communities in the study area (Table 3). By the most farmers (93%) experienced with dairy farming, the average herd size per household of the study area (6.2±2.9) was comparable with the finding of [23] that was (5.8) in Wondogenet district, southern Ethiopia

Table 3:Dairy cattle herd size per households and the households experience in dairy farming

Cattle number (Mean±SD)	Smallholder dairy		Overall mean	
	Rural (N=168	Peri-urban (N=96)	(N=264)	P-value
Number of local breed cattle/hh	5.4±3.0	1.7±0.9	3.6±1.9	
Number of crossbreed cattle/hh	2.3±0.9	2.6±1.0	2.5±1.0	0.000
Total cattle/hh	7.7±3.9	4.3±1.9	6.0±2.9	
Experience with dairy activities in percentage				
< 3 years	25(14.8%)	11(11.5%)	36(13.6%)	
4-6 years	43(25.6%)	17(17.7%)	60(22.7%)	
7-9 years	54(32.1%)	22(22.9%)	76(28.7%)	
≥10 years	46(27.5%)	46(47.9%)	92(34.8%)	

N=Number of respondents, SD=standard deviation, hh= households

3.3 Dairy production system and purpose of keeping dairy cattle in the study area

The study showed that people with different occupational and economic backgrounds undertook dairy farming for home consumption of milk in rural farmers and a source of supplementary income from milk sales that was used to meet the costs of various expenses in the case of peri-urban dairy households. According to the current study, mixed crop-livestock farming is practiced by 73.8% of rural and 74% of peri-urban smallholder dairy households, whereas only 17.3% and 23% of rural and peri-urban households exclusively produce livestock, respectively. Similar to the current findings, [24] also reported that 91.1%, 6.7%, and 2.2% of the respondents in the central zone of Tigray, Northern Ethiopia, practiced mixed, livestock, and crop production in farming systems, respectively. This suggests that smallholder dairy farming in the study area has the potential to enhance respondents' welfare and could help reduce poverty. In contrast, the majority of respondents (58%) kept dairy cattle for milk production (home consumption) in rural households, whereas 76% did so to generate income (from milk and milk products) in peri-urban households (Table 4). Information from the FGD indicates that households with local-breed dairy cows kept their animals for home consumption, whereas those with crossbred dairy cows kept them to generate income from milk and milk products. In rural smallholder dairy, the majority of the milk produced was used to make butter, which was then sold in the local market, indicating that the rural farming system was not market oriented.

Table 4: Purpose of keeping dairy cattle and major livestock farming systems

Variables		Smallholder dairy Rural (N=168)	Smallholder dairy Peri-urban (N=96)	Overall mean (N=264)	X^2	P-value
Major farming system	Mixed(crop-livestock)	124(73.8%)	71(74%)	195(74.1%)	4.029	0.133
	Livestock	29(17.3%)	22(23%)	51(19.1%)		
	Crop	15(8.9%)	3(3%)	18(6.8%)		
Purpose of keeping dairy cattle	Income	71(42%)	73(76%)	144(55.0%)	8.926	0.003
	Milk production/home consumption	97(58%)	23(24%)	120(45.0)		

3.4 Dairy cattle management practices in the study area

3.4.1 Feed resources for dairy cattle

The top five dairy feed resources in the study area are listed in table (5). According to the respondents' responses, crop residue, industrial byproducts, private pasture, communal pasture, and improved forage crops were identified as the top five dairy cattle feed resources in the study area, respectively. Crop residue, private pasture, industrial byproducts, communal pasture, and improved forage crops were ranked first through fifth, respectively, in rural smallholder dairy farms, whereas communal pasture, private pasture, crop residues, industrial by-products, and improved fodder were ranked first through fifth, respectively, in peri-urban smallholder dairy farms. These findings are consistent with those of [25], who documented the contribution of these feed resources to agro-ecology, the types of crops grown, and the production systems of urban and peri-urban dairy production in southern Ethiopia.

Table 5:Top five dairy feed resources in the study area

Variables	Rural N=168 Index	Rank	Peri-urban N=96 Index	Rank	Overall mean N=264	Rank
Crop residue	0.392	1st	0.259	2nd	0.326	1st
Industrial by product	0.154	3rd	0.345	1st	0.250	2nd
Private natural pasture	0.245	2nd	0.129	4th	0.187	3rd
Communal natural Pasture	0.126	4th	0.176	3rd	0.151	4th
Improved Forage	0.082	5th	0.094	5th	0.088	5th

Index = ∑ (5 for rank 1) + (4 for rank 2) + (3 for rank 3) + (2 for rank 4) + (1 for rank 5) divided by sum of all weighted

3.4.2 Dairy cattle housing system in the study area

The goal of housing is to protect cattle from theft, predators, and extreme weather conditions. The findings of the current study revealed a significant difference ($p<0.05$) between rural and peri-urban smallholder dairy cows in terms of their housing arrangements (Table 6). In the rural smallholder dairy sector, the majority of the respondents (41%) housed their dairy cows in shelters with walls, roofs, and earth floors, while 61% of the peri-urban households kept their dairy cows in houses with walls, roofs, and concrete floors. This result is consistent with that of [26], who stated that 65% of dairy farmers in the Sayo district of the West Wollega zone, Ethiopia, used separate houses with roofs from the main houses. Cattle houses were determined to be suboptimal on the basis of visual observations, including inadequate space, poor ventilation, and inadequate hygiene and drainage facilities.

Of the 264 responders, 129 (49%) and 118 (45%) primarily supplied their dairy cows with pipe water and river water, respectively (Table 6). In rural smallholder dairy farms, respondents used rivers, pipes, and springs as significant sources of water for their animals at proportions of 60%, 30%, and 10%, respectively, whereas in peri-urban areas, this proportion was 82% and 18% for pipes and river water, respectively. These data are similar to previous findings [27], which showed that tap water accounted for 84.4% of the water used by animals in Mekelle, Tigray, whereas 15.6% of farms used river water for their livestock.

Table 6: Types of dairy houses and source of water used for dairy cattle

Variables	Smallholder dairy				
Type of house	Rural (N=168)	Peri-urban (N=96)	Overall mean (N=264)	X^2	P-value
Having wall, roof and concrete floor	57(34.0%)	59(61.5%)	116(44.0%)		
Having wall, roof and earth floor	69(41.0%)	26(27.1%)	95(36.0%)		
No wall, but has roof and concrete floor	25(15.0%)	9(9.4%)	34(12.9%)	20.78	0.000
No wall, but has roof and earth floor	17(10.0%)	2(2.1%)	19(7.2%)		
Source of water					
River	101(60.0%)	17(18.0%)	118(45.0%)		
Pipe	50(30.0%)	79(82.0%)	129(49.0%)	57.209	0.000
Spring	17(10.0%)	-	17(6.0%)		

N=Number of respondents

3.5. Reproductive Management Practices

3.5.1. Farmers' awareness on estrus detection

According to the interviewees' responses, mucus discharge (37.5%) and attempts to mount other animals (27.6%) were among the well-known heat signs identified and easily understood by dairy owners. Additionally, silent heat (14.7%), bellowing (10.4%), restlessness and loss of appetite (7.8%), and swollen red vulva (2.7%) were among the heat signs identified by respondents. The current results are in line with [28], who showed signs of estrus, such as mounting other cows (55.5%), restlessness and nervousness (20.0%), loss of appetite (15%), and redness and mucus of the vulva (9.2%), which were identified as well-known symptoms of dairy cows in Debretabor town, Ethiopia.

Table 7:Signs of estrus used to identify cows on heat

Sign of heat	Smallholder dairy		
	Rural N=168	Peri-urban N=96	Overall (N=264)
Silent heat	23(13.7%)	16(16.7%)	39(14.7%)
Mucus discharge	58(34.5%)	40(41.7)	98(37.1%)
Attempt to mount other animals	49(29.2%)	21(21.9%)	70(26.5%)
Bellowing	16(9.5%)	12(21.5%)	28(10.6%)

Swollen red vulva	7(4.2%)	1(1.0%)	8(3.0%)
Restlessness and loss of appetite	15(8.9%)	6(6.3%)	21(8.0%)

N=Number of respondents, %=percentage

3.5.2. Farmers' awareness on timing of insemination

The dairy owner's decision regarding the time of insemination depends on the dairy cattle's signs of heat. As a result, when the cows/heifers go into heat in the morning, the majority (67.4%) of the respondents inseminated their cows/heifers in the afternoon of the same day, which was the proper time to do so, while the remaining (32.6%) did so at the incorrect time (Table 8). Similarly, when their cows/heifers show signs of estrus in the afternoon or evening, 70.68% of the households inseminate on the morning of the next day, which is the right time to inseminate, while the remaining (29.32%) inseminate at the incorrect time. The results show that about two-thirds of dairy owners in the area are aware of the right time for insemination, implying that this is not a major problem. This study was in line with [29], who reported that in cows, maximum fertility was achieved if inseminated from mid-estrus to the end of estrus. The lifespan of the ovum is approximately 12-18 hours and its viability decreases over time. If insemination occurs too early, sperm cells will die before fertilization of the ovum. Conversely, when insemination is overdelayed, the ovum loses its capacity to be fertilized. According to [30] next to estrus detection, the second step in getting a cow pregnant is insemination at the correct time. The present findings confirmed a previous study by [31], who showed the common practice of breeding cows according to the am-pm rule, which requires that cows are observed for estrus five times per day; those commencing estrus in the morning are inseminated in the evening, and those commencing estrus in the afternoon are inseminated the next morning.

Table 8: Awareness of dairy owners on timing of insemination during heat period

Variables	When cow show heat in the morning	When cow show heat in the afternoon/evening
As soon as heat sign is seen	33(12.5%)	27(10.2%)
Afternoon of the same day	178(67.4%)	34(12.9%)
Morning of the next day	41(15.5%)	187(70.8%)
Based on the availability of AITs	12(4.5%)	16(6.1%)

AITs=Artificial insemination technician

3.5.3. Breeding practice in the study area

In the study area, the majority of smallholder dairy owners (64.1%) used AI services, compared to 22.9% and 13.0% of the respondents who used natural mating and both AI services and natural mating, respectively (Table 9). The results of the current study were in agreement with those of [32], who found that 56.67% of smallholder dairy farmers in Adigrat, Tigray, Ethiopia utilized AI services, while the remaining 43.33% mated their dairy cows naturally. The current finding is consistent with that of [24], who found that breeding practices had a tendency to change from natural mating to AI services in the central zone of Tigray, Northern Ethiopia.

3.5.4. Source of breeding bulls in the study areas

Smallholder dairy owners in the study area had different sources of bulls for mating (Table 9). The majority (71.0%) of smallholder dairy owners obtained breeding bulls from the village, and the remaining 15.4% and 13.5% were from neighbors and their own farms, respectively. The present findings are inconsistent with the study of [24] in the central zone of Tigray, Northern Ethiopia; 61.4% of smallholder dairy owners obtained breeding bulls from neighbors, while the remaining 21.3% and 17.3% obtained bulls from their own farm and village, respectively. This inconsistency could be explained by the presence of communal grazing land in the current study area, where numerous cattle were kept together for free grazing during the day. In the case of peri-urban areas, bulls from neighbors and villages were employed for a fair fee, whereas it was both free and possible to pay for it in rural smallholder dairies. Despite the way dairy cows mate, none of the respondents chose the best bull for breeding purposes.

Table 9:Breeding practices and source of breeding bull for matting

Variables		Smallholder dairy					
		Rural (N=168)	Peri-urban (N=96)	Overall (N=264)	mean	X^2	P-value
Breeding practice	AI service	102(61.0%)	69(72.0%)	169(64.1%)		2.296	
	NM	48(28.0%)	12(13.0%)	61(22.9%)			0.010
	Both	18(11.0%)	15(15.0%)	34(13.0%)			
Source of bull	Own farm	22(13.0%)	14(14.6%)	36(13.5%)		0.706	
	Village	129(77.0%)	67(69.8%)	187(71.0%)		71.0	0.702
	Neighbor	17(10.0%)	15(15.6%)	41(15.4%)		15.4	

AI=Artificial Insemination, Both = AI service and natural matting, NM=Natural mating, %= Percentage

3.5.5. Artificial Insemination service in the study area

Only 81 (30.7%) of the 264 households interviewed regularly received AI services (Table 10). According to the responses from smallholder dairy owners, the lack of AITs (35.6%), lack of inputs such as liquid nitrogen and semen (20.8%), and unavailability of AITs due to weekends and holidays interrupted the AI service in the study area. These findings are similar to those of [33], who indicated that 47% of AI beneficiaries used services regularly and 53% did not use it due to discontinuation of service on weekends and holidays, shortage of artificial insemination technicians, shortage of input, and long distance to get the service in and around Adama town.

Table 10: Causes of AI service interruption in the study area

Variables	Smallholder dairy				
	Rural (N=168)	Peri-urban (N=96)	Overall (N=264)	X^2	P-value
Not available on weekends and holidays	22(13.1)	12(12.5%)	34(12.9%)		
Limited number of AITs	62(36.9%)	32(33.3%)	94(35.6%)	2.418	0.029
Shortage of inputs	30(17.9%)	25(26.0%)	55(20.8%)		
There is access of service regularly	54(32.1%)	27(28.1%)	81(30.7%)		

AITs=Artificial insemination technicians, %= percentage,

3.5.6. Repeated Breeding/Inseminations

The majority (58%) of households with repeat breeding issues utilized AI repeatedly, followed by natural matting (23%), although a sizeable proportion (19%) of the households in the study area engaged in culling (Figure 2). [12] stated that following insemination, cows must become pregnant, maintain pregnancy to term, give birth after approximately 270 days, and then wait 40–50 days before successful insemination. However, this is not always possible, and cows must be reinseminated over multiple cycles. The timing of insemination, proper insemination techniques, semen quality, proper handling of semen, and skills in pregnancy diagnosis have all been reported as management factors contributing to repeated inseminations [34].

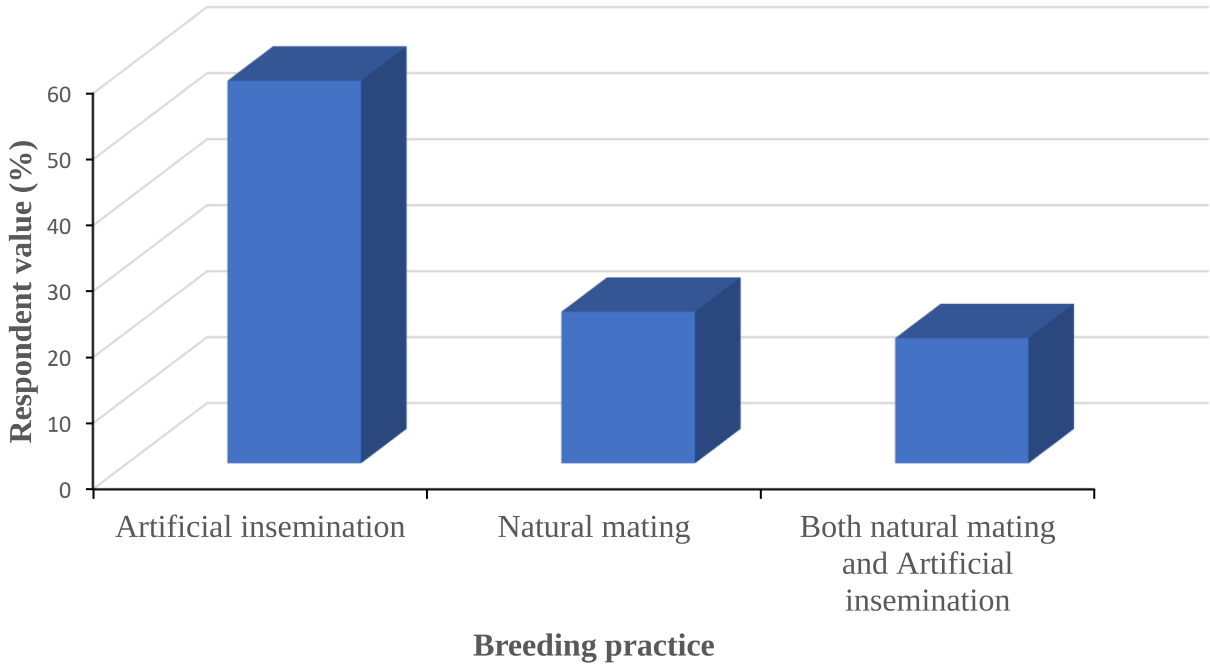

Fig.2:The percentage of alternative solutions for households during repeated breeding

3.6. Semen Evaluation

3.6.1. Individual motility of frozen semen

The proportion of all sperm cells in semen samples that are actively moving is known as individual semen motility. At the time of collection and processing at the National Animal Genetic Improvement Institute (NAGII) for the current study, the individual progressive motility of fresh semen was 80% for all samples. However, at the same center (NAGII), the overall motility of the same semen sample after freezing was 67.3% (i.e., there was an average loss of 12.7% owing to freezing). The average motility of frozen semen was further decreased to 50.0% (i.e., a 17.2% loss) after transportation and additional storage at the district AI service center. The average results revealed that semen motility of the four AITs varied significantly ($P<0.05$). A lower rate of motility was observed in AITs-04 (26%), followed by AITs-01 (19.6%), both of which showed a loss of motility. This shows that semen motility from frozen-thawed semen was significantly lower for AITs-04 and AITs-01 than for AITs-03 and AITs-02 at 9.4% and 13.5%, respectively. This might be due to experience and adequate work training between AITs. In addition, the loss might have occurred as a result of poor handling practices by AITs and the transportation of semen from the National Animal Genetic Improvement Institute to the local AI service center, for instance, timely top-up of liquid nitrogen before the liquid nitrogen level drops and possible thermal exposure of straws during the transfer of straws between containers. The current overall mean result was matched with the 51.7% and 51.5% reported by [35] and [36], in Bishoftu town and Western Gojjam zone of Ethiopia, respectively. However, similar to the 49.4% reported by [37] and higher than the 44.5% reported by [38] in the Eastern Tigray and Harari regional states of Ethiopia, respectively.

Table 11: The percentage of alternative solutions for households during repeated breeding

AITs code	Bull ID	Batch code	Production date	FS at NAGII	FS at NAGII (before)	FS at district (after)	Loss of motility (%)	P-value
01	B1=2618	12/339	Febr.10/2021	80	65.9±2.7	46.3±4.2	19.6	0.004
02	B2=9777	01/29	Febr.12/2021	80	66.8±9.0	53.3±4.1	13.5	0.019
03	B1=2618	12/339	Febr.10/2021	80	67.9±5.3	58.5±5.6	9.4	0.060
04	B2=9777	01/29	Febr.12/2021	80	67.8±6.3	41.8±7.4	26.0	0.002
		Overall		80	67.3±5.8	50.0±5.3	17.3	0.000

AITs=Artificial insemination technicians codes (01, 02, 03,0 4), FS=Frozen semen, M±SD = Mean plus/minus standard deviation and NAGII (National Animal Genetic Improvement Institute)

3.6.2. Semen viability

Sperm viability was defined as the proportion of living sperm in a semen sample. Sperm viability refers to the percentage of live sperm in the semen samples. The average viability of frozen semen was dropped by 19.1% from 78.9% at NAGII to 59.8% at district level. The proportion of viable spermatozoa found in the current study (59.8%) was lower than the (67.0%) reported by [36] and slightly similar to the result suggested by [38], which was 57.6% in the Western Gojjam zone of the Amhara and Harari regional states of Ethiopia, respectively. Each straw was initially packed with 30 million spermatozoa, and at least half of this number (15 million) is expected to be alive, according to [39], so that normal reproductive function can occur. Regardless of the various influences, the sperm viability observed in this study was higher than the minimum threshold of 50%.

Table 12: Viability of frozen semen in the study area

AITs Code	Bull ID	Batch code	Production date	Frozen semen at NAGII (before)	Frozen semen at district (after)	Loss of viability (%)	p-value
01	B1=2618	12/339	Febr.10/2021	78.9±3.3	55.3±7.7	23.7	0.004
02	B2=9777	01/29	Febr.12/2021	77.3±8.8	64.0±4.5	13.3	0.020
03	B1=2618	12/339	Febr.10/2021	80.2±5.1	69.0±8.4	11.2	0.070
04	B2=9777	01/29	Febr.12/2021	79.3±5.9	51.0±9.1	28.3	0.002
		Overall		78.9±5.8	59.8±7.4	19.1	0.000

AIT (Artificial Insemmination); NAGII (National Animal Genetic Improvement Institute)

Source: Laboratory result (2022)

3.7. Artificial Insemination service efficiency

3.7.1. Number of services per conception (NSPC)

The efficiency of AI services in the area was evaluated based on the NSPC, NRR, and CR. For local and crossbreed dairy cows, the average mean NSPC was 2.30 and 2.02, respectively (Table 13). There was no statistically significant (*p>0.05*) difference in the NSPC between the two breeds. The current overall mean was almost within the threshold as [40] noticed that NSPC levels above 2.0, should be classified as unsatisfactory, and the average NSPC (2.0±1.1) of crossbreeds in the study area was similar to that in [41], who found that the mean average NSPC for all crossbred cows was 2.14 in the West Shewa zone of Oromia, Ethiopia. But, [42] confirm that exotic pure-bred of Holstein Friesian cattle and their 3/4 hybrid with Fogera breed cattle perform with an estimated value of 1.4 and 1.3 NSPC in the central highland of Ethiopia, respectively. Participants in the focus group discussion highlighted that because local breeds have shorter heat cycles, silent heat, and exhibit aggressive behavior during insemination, they require more services per conception than crossbreeds do.

Table 13:NSPC across a breed in both production system

Variables	Breed	Mean +SD (N=264)	Overall mean	P-value
NSPC	Local	2.3+1.1	2.2	0.087
	Cross	2.0+1.1		

N = Number of sample size, NSPC= Number of services per conception and SD = Standard deviation

3.7.2. NRR and CR

Other reproductive markers that might be used to evaluate AI efficiency include NRR and CR. The average NRR and CR percentages for local and cross breeds were 39.4%, 40.0%, 46.2%,51.4%. However, the overall NRR percentage was 45.0% compared to the overall CR percentage of 50.6% (Table 14). The mean NRR results from the current study were lower than those reported by [43] and [38], who reported 84.03% in North Gonder, 48.1% in North Shewa, and 75% in the Harari regional state of Ethiopia.

The current CR result (50.6%) falls short of the required value. It waslower than the most recent study by [44], who found that in and around the Haramaya town of Eastern Ethiopia, 59.1% and 69.15% CR for multiparous cows and primiparous cows, respectively. These findings support the hypothesis put forth by [45], who claimed that the smallholder production system's influence on CR in dairy cows depends in part on the cows, farms, and AITs in the Sirajgonj District of Bangladesh.

Table 14: NRR and CR in the study area

Service year	Breed type	TAIS	1st Insemination	1st PD+	TPD+	NRR (%)	CR (%)
2020-2021	Local	312	208	82	125	39.4	40.0
	Cross	4062	906	419	2087	46.2	51.4
Total		4374	1114	501	2212	45.0	50.6

TAIS=Total Artificial Insemination Service, 1stPD+=First Pregnancy Diagnosis, TPD+=Total Pregnancy Diagnosis NRR= Non-Return Rate and CR= Conception Rate

3.8. Main reason for the low CR of dairy cows in the study area

The overall percentage of this result reveals that low CR in dairy cows in the study area was caused by estrus detection (47.0), absence of AITs on weekends and holidays (20.5%), ineffectiveness of AITs (18.2%), distance from the AI service center (7.5%), and disease problems (6.8%) (Table 15). Although there has been a tendency to neglect aspects related to AITs most of the time, they can have a significant impact on how successfully AI is used in the dairy industry. The current findings concur with a recent report by [46], who noted that the main variables influencing CR and application of AI in the North Shewa Zone were insemination time, AITs proficiency, heat detection, distance from AI service center, and semen quality.

Table 15:Reasons for the low CR of dairy cows in the study area

Variables	Smallholder		Overall	X^2	P-value
	Rural (N=168)	Peri-urban (N=96)	(N=264)		
AITs effectiveness problem	32(19.0%)	46(47.9%)	48(18.2%)		
Estrus detection	80(47.6%)	15(15.6%)	124(47.0%)		
Absence of AITs	22(13.1%)	31(32.3%)	54(20.5%)	22.5	0.000

Distance from AI service center	20(11.9%)	-	20(7.6%)
Disease problem	14(8.3%)	4(4.2%)	18(6.8%)

3.9. Artificial insemination service trend in the study area

Figure 3 shows the number of inseminated cows/heifers and calves (male and female) born in the study area over the last five years. According to retrospective data from the AI service centers' record books, the number of inseminated dairy cows increased from 2017 to 2020, but declined by 2021. Similarly, with the exception of 2021, the number of calves born each year increases with the number of artificially inseminated dairy cows. According to the respondent's hypothesis, the challenge of COVID-19 and an unstable political climate during the country's transition era are to blame the low performance that was witnessed in 2021. These have a negative impact on smallholder dairy producers' access to extension services and supplies of AI inputs. The current finding is in line with the [47] report's prediction that as a result of the COVID-19 impact, production may decrease by 30% if producers return to the extensive production system for cash crops and significant income losses in particular sectors, such as livestock and horticulture, as well as supply chain disruptions are an increasing possibility. The year 2020 had 3891 inseminated cows, whereas 2017 saw the fewest (2061). Each year, a greater number of male calves were born than female calves, with the largest number of calves (1520) in 2020 and the fewest (954) in 2017. From 2017 to 2021, only approximately 45.48% of cows gave calves in total. [48] found a continuous increase in the number of inseminated cows/heifers and calves born, in contrast to this finding. This difference could be the result of issues with the technicians and heat detection.

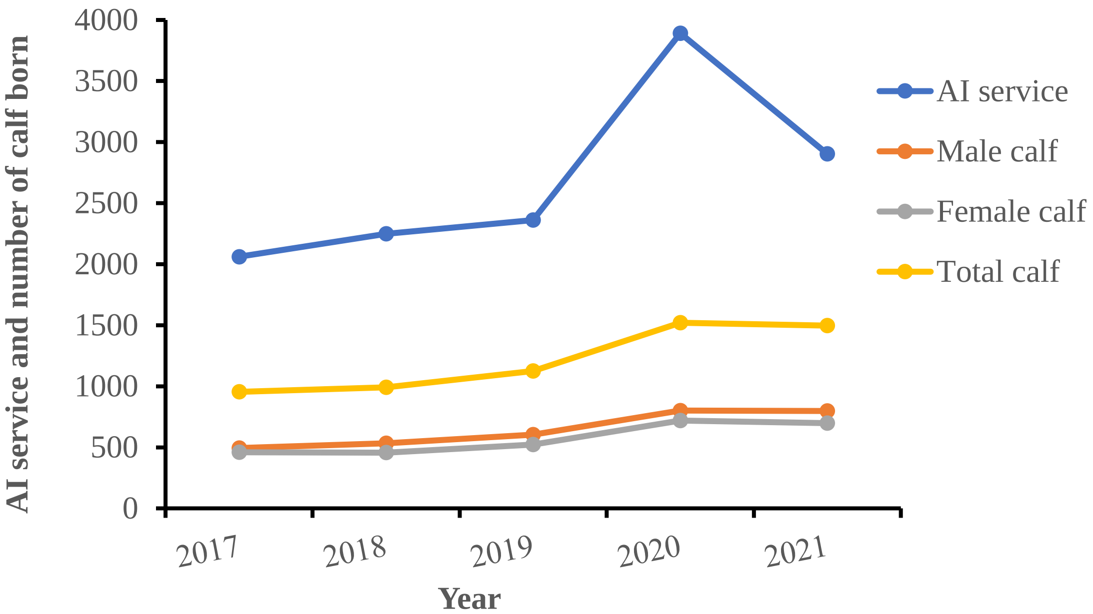

Fig.3:The trends of AI service for last five consecutive year in the study area

3.10. Constraints of artificial insemination service in the study area

According to the professional groups who participated in this study, the major challenges to AI services in the study area were a lack of AI inputs (33.3%), inadequate facilities for AITs (26.7%), poor AITs efficiency (20.0%), poor recording systems (10.0%), a small number of AITs assigned to a district (6.7%), and a lack of integration between stakeholders (3.3%). Similarly, evidence indicates that common barriers to the use of AI services by smallholder farmers in Ethiopia include the competency of AITs, farmers' knowledge of heat detection and the timing of insemination, dairy herd management systems, breed types, the absence of AITs, and distance from the AI center, even though the severity of each issue varies [19, 49],[50], and 51]. Furthermore, [17] pointed out that the majority of smallholder dairy cattle production systems in and around Negele-Arsi, Ethiopia, have poor reproductive efficiency, which causes cows to become infertile for a variety of reasons, such as management issues, nutrition, and semen handling practices. Additionally, the lack of record-keeping and reporting by AI service providers and farmers has adversely affected national data analysis and decision-making on progress, and it is also believed to have increased the incidence of inbreeding in the country [8].

Table16: Constraints of AI service delivery the study area

Variables	Value
Lack of readily delivery of AI inputs (Semen, liquid nitrogen)	10(33.3%)
Inadequate facility for AITs (protective close, motorcycle, car)	8(26.7%)
Performance of AITs (discontinue of training)	6(20.0%)
Poor recording system of AI service	3(10.0%)
A limited number of AITs assigned at district	2(6.7%)
Lack of integration with stock holders	1(3.3%)

AITs- Artificial insemination technicians

IV. CONCLUSION AND RECOMMENDATIONS

Low CR is a very serious issue that requires immediate remedy, and the efficiency of the AI service observed under the smallholder dairy cow management system in the study area was unsatisfactory. These issues were linked to a number of factors, including poor management, poor nourishment, poor inseminator ability, AI input delivery system, poor heat detection, and improper insemination time.

On the other hand, inadequate insemination techniques or improper handling of semen can significantly reduce the quantity of sperm cells available for fertilization, which lowers CR. For instance, semen stored at the district level is significantly reduced in quality. This suggests that the management abilities of AITs were connected to correct semen handling procedures.

- Training for AITs should emphasize improving their abilities, handling semen properly, and ensuring that semen is deposited in the reproductive tract at the proper site.
- To improve the efficiency of AI services, integrated supply chains for logistics and AI inputs should be strengthened.
- To avoid a negative impact on the quality of semen, liquid nitrogen should be provided on time in particular and AITs should monitor any changes in nitrogen concentrations within the tank before refilling the tank again
- Awareness creation for owners of dairy cows on heat detection, feeding, housing, and record-keeping with better healthcare management should go hand-in-hand to maintain the right efficiency of AI services.
- The number of services provided per conception should be considered when evaluating the efficiency of AI technicians.

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