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Factors affecting the success rate of artificial insemination in smallholder dairy production in selected regions of Rwanda

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Abstract

Accessibility of improved dairy genetics in Rwanda is still limited, mostly, by poor success rate of artificial insemination (AI) and dairy management practices. The present study was conducted to assess factors affecting the effectiveness of AI in smallholder dairy production systems in Gicumbi, Nyanza, and Rwamagana districts. A total of 257 cows and heifers from 234 farmers were assessed and recruited for artificial insemination. Information on health and production statuses of the animals was recorded and a trans-rectal ultrasonography was used to test conception rate (CR) from 60 to 80 days after artificial insemination. Collected data were analyzed using Statistical Package for Social Sciences Version 26. Factors with Chi-square, and p-value ≤ 0.05 were included in multiple logistic regression to identify factors with higher association with CR. Results showed that average AI success rate in the study area stands at 45.1%. Age between three to six years (p-value 0.002) and natural estrus (p-value 0.000) showed higher conception rate in this study. Similarly, the presence of three estrus signs and time for artificial insemination showed a positive association with conception rate. The findings of this study showed that natural heat detection, age of the cow, proper time for insemination, heat signs management, and breeds would be taken into consideration in breeding programs to increase AI success rate.

Keywords: Artificial Insemination, Conception rate, estrus induction, smallholder dairy farming

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Introduction

In Rwanda, bovine artificial insemination (AI) technique has been practiced at the farm level since 1987 (Bizimungu, 1991) and rolled out across the country after 1995. The AI service delivery capability was particularly reinforced in 2006 to accompany the one cow per poor family program, known locally as "Girinka"(Nilsson *et al.*,2018) to ensure that a smallholder is receiving a good dairy cow under the program and also passing on to the next beneficiary a good genetic merit dairy heifer offspring.

The bovine AI program, coupled with the Girinka, has significantly increased the number of crossbred dairy cows and, subsequently improved milk productivity and milk production. It was reported in the 2017 Rwanda livestock master plan that around 51% of the national cattle herd are crossbreds, 6% pure exotic, and 43% indigenous cattle (Shapiro *et al.*, 2017). Despite the rising prevalence of dairy genes in the current cattle population, milk productivity per cow remains notably low. According to estimates from the 2020 Agricultural Household Survey (NISR, 2023), this productivity is measured around 7 liters per cow per day for improved breeds.

The low dairy cattle productivity is attributed to, among others, poor genetic potential of indigenous breeds and low-grade crossbreds, low quality and quantity of feeds afforded to animals, poor husbandry practices, and lack of financial stability of dairy farmers to cover production costs (MINAGRI, 2022; Manzi *et al.*, 2019; Nishimwe *et al.*, 2015; EADD, 2013 and EADD, 2008).

The Government of Rwanda has put in place a number of policies, infrastructures and initiated different interventions to improve cattle farming in general and bovine AI in particularly (Manzi *et al.*, 2019; NISHIMWE *et al.*, 2015). Despite its potential and investments carried out, the delivery and adoption of bovine AI are still challenged by many factors including; lack of records, poor herd management, irregular supply of AI consumables, limited availability of qualified technicians and uterine infections that lead to low success rate of AI (Nishimwe *et al.*, 2015; Makuza *et al.*, 2016; Mushonga *et al.*, 2017; Rugwiro *et al.*, 2021). Studies carried out to assess cow conception rate (CR) following artificial insemination reported an average CR ranging from 37.16% to 58.7% (Nishimwe *et al.*, 2015; Sibo *et al.*, 2019) at farm level, and as high as 67% for inseminations carried out on station farms (Manzi *et al.*, 2019). On-farm studies conducted to identify factors affecting the conception rate of bovine

AI have depended on surveys as methods of data collection which rely on respondent's memory to recall past events on cow reproduction history. This on-farm experimental study was conducted to investigate the conception rate following artificial insemination. Therefore, the objective of this study was to evaluate factors affecting the on-farm success rate of bovine artificial insemination in dairy cattle of smallholder farmers in Gicumbi, Nyanza, and Rwamagana districts of Rwanda.

Materials and Methods

Study area

This study was conducted in Gicumbi, Nyanza, and Rwamagana districts of Rwanda (figure 1) from June to December 2021. Gicumbi district experiences rainfall ranging from 1,200 mm to 1,500 mm with average annual temperature of 15^{o} C (FONERWA, 2020). Generally, rain deficits have been observed in Southern and Eastern provinces while Northern province receives increased rainfall (World Bank, 2021). Gicumbi, Nyanza and Rwamagana districts have higher percentage of households rearing cows compared to the national average of 7.5% (NISR, 2023). Cows are, respectively, reared by 26.2%, 12.3% and 8.6% of households in Gicumbi, Nyanza and Rwamagana districts (NISR, 2023). Cattle population in the study area account for 63,219 heads of cattle in Gicumbi district, 29,867 heads of cattle in Nyanza district and 23,137 heads of cattle in Rwamagana district (NISR, 2023). The study population of dairy cows and heifers was under zero grazing farming.

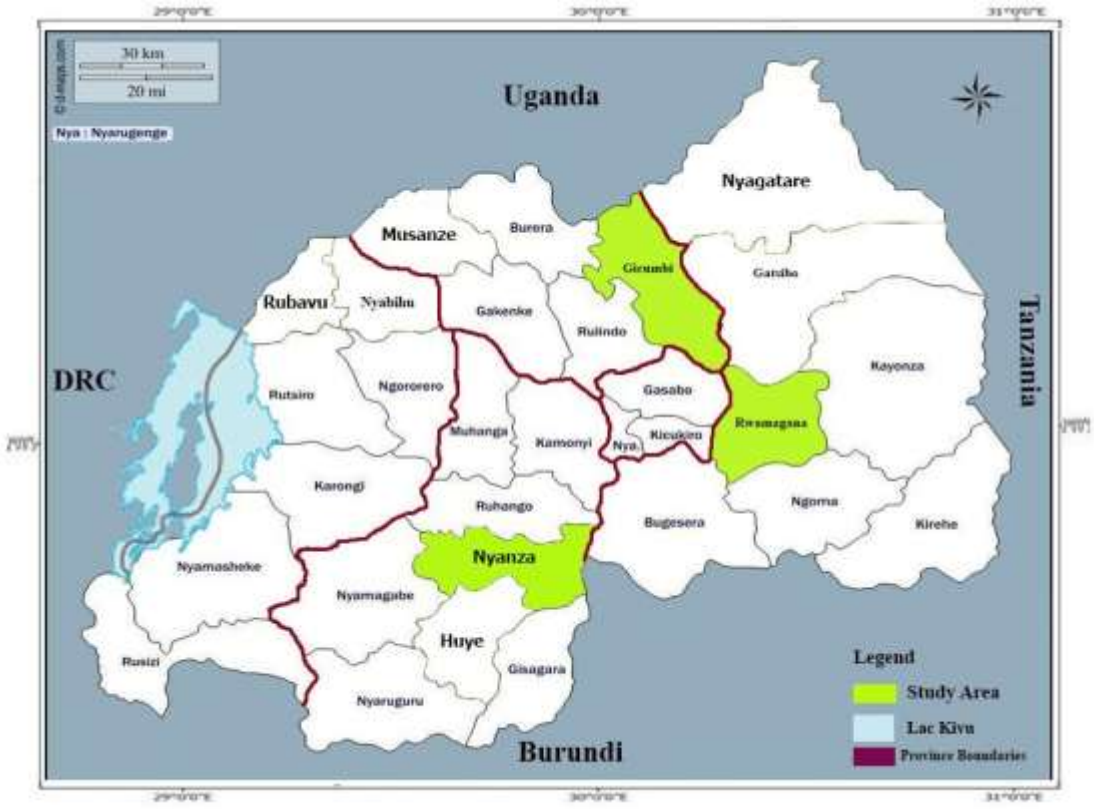

Figure 1. Map of Rwanda showing study areas (https://prodesigntools.com/adobe-cs6-direct-download-links.html)

Data collection

A total of 257 healthy and non-pregnant crossbreed cows and heifers from 234 smallholder's farmers were selected for the longitudinal study from June to December 2021 using reproductive records in selected regions. Of the total number of animals, 109 were inseminated after natural estrus while 148 cows were inseminated after estrus heat induction using a progesterone-based protocol (PRID delta + PGF_{2a} + GnRH) protocol (Demir & Ari, 2018). Holstein-Friesian and Jersey breed frozen semen that were produced and kept in Rwanda Agriculture and Animal Resources Development Board (RAB) store; were used to artificially inseminate all cows and heifers in this study. A team of experienced inseminators carried out AI to all cows and heifers in this study.

The ultrasound machine diagnosis was used to examine conception at 60 to 80 days after bovine artificial insemination. The Conception rate was determined by the following formula:

$$CR = \frac{P\ X\ 100}{NI}$$

Where:

CR: Conception rate

P: Cows tested positive to pregnancy diagnosis;

NI: Number of cows inseminated (Belay *et al.*, 2016)

The reproductive-associated factors such as estrus signs, body weight (BW), body condition score, and cervix status during insemination were recorded. The BW and body condition score (BCS) were measured with a tape measure and observation of bony and musculature of the animal, respectively. A structured questionnaire was used to collect information related to cattle breeds, age, parity, average daily milk production, the duration of post-partum anestrus, observed heat signs, the timing between the first estrus sign and AI, bull breed, and bleeding after AI. Ethical considerations were considered while designing the questionnaire and animals for treatment. Farmers' consent form was acquired before data collection. Furthermore, no details of farmers appeared throughout the study to ensure confidentiality.

Statistical analysis

The collected data were recorded and cleaned using microsoft excel spreadsheet. The cleaned data were imported and analyzed using statistical software for social sciences version 26 (SPSS, 26). The difference was considered as being statistically significant when the p-value is less or equal to 0.05 ($p \leq 0.05$). The multiple logistic regression analysis was used to identify factors with higher significant association with conception rate.

Results

Success rate of Artificial Insemination in the study area

In this study, the overall conception rate (CR) of AI was 45.1%. Age of a cow, observed heat signs, time for AI, type of heat, cow breed and bull breed significantly affected CR. Whereas milk yield per day, body conditions score, parity and body weight had no significant effect on conception rate (Table 1). There was no variation in conception rate in the selected regions possibly due to similar management of semen, the protocol used, handling of liquid nitrogen containers, and use of the same inseminators across the selected regions.

Table 2. *Reproductive associated factors influencing bovine AI in the selected areas*

Variables		Frequency	CR %	Chi-square	*P-Value*
Age (Years)	<3	52	57.7	8.320	0.016 *
	3 to 6	169	44.4		
	>6	36	30.6		
Observed heat signs	Silent	26	11.5	40.910	0.000 *
	Clear Mucus	59	28.8		
	Restlessness	30	40		
	Mounting	22	36.4		
	Restlessness and Mounting	26	53.8		
	Clear Mucus and Mounting	39	59		
	Clear Mucus and Restlessness	32	68.8		
	Clear Mucus, Restlessness and Mounting	23	73.9		
Time for Artificial Insemination (Hours)	**≤ 6**	45	24.4	27.340	0.000 *
	7 to 10	75	60		
	11 to 14	66	53		
	>14 Hours	71	35.2		
Types of heat	Induced	148	25.7	57.420	0.000 *
	Natural	109	71.6		
Breed	Cross Friesian	225	40.4	12.660	0.000 *
	Cross Jersey	32	78.1		
	Heifer	48	58.3		
Milk yield/Day	Cows producing 4 to 8 litres/day	112	46.4	6.190	0.103
	> 8 litres to 12 litres/day	79	35.4		
	Above 8 litres/day	18	44.4		
Body Conditions Scores	2.5	75	38.6	3.170	0.205
	3	158	45.6		
	3.5	24	62.5		
Parity	Heifer	48	58.3	6.770	0.080
	cows with one parity	65	43.1		
	2 and 3 parities	113	45.1		
	cows with four and over parities	31	29		
Body Weight	250-300kgs	29	48.3	7.300	0.199

Variables		Frequency	CR %	Chi-square	*P-Value*
	301-350kgs	48	41.7		
	351-400kgs	81	57.3		
	401-450kgs	71	39.4		
	451-500kgs	15	33.3		
	501-550kgs	13	23.07		
Bull breed	Friesian	207	42.02	3.880	0.049*
	Jersey	50	58		
Overall		**257**	**45.1**		

CR: conception rate

Seven of fourteen variables had been identified as significant: cow breed, age, body weight, types of estrus, signs of estrus, time between estrus onset and AI, and bull breed.

Table 3. ***Multiple logistic regression analysis***

Associated factors	Reference categories	Categories with significant association	Odds ratios	95%CI	*P-values*
Age	0 to 3 years	3 to 6 years	0.28	0.13-0.61	0.002
		Over 6 years	0.21	0.07-0.62	0.006
Types of estrus	Induced estrus	Natural estrus	7.67	3.61-17.06	0.000
Heat signs	Clear mucus only	Clear mucus + Mounting + Restlessness	7.42	2.25-27.15	0.001
		Clear mucus + Mounting	2.91	1.08-8.10	0.037
Timing of AI after estrus onset	1 to 6 hours	> 14 hours	5.15	1.32-22.02	0.022
		10 to 14 hours	4.46	1.23-17.15	0.025
		6 to 10 hours	6.66	1.81-26.67	0.005

***CI:** Confidence Interval

Based on calculated odd ratios and p-values, the study's findings showed significant factors with the strongest associations, including types of estrus, the number of heat signs, the timing of

insemination, and age (Table 2). The odd ratio was directly proportional to the number of heat signs observed and indirectly proportional to the age of cow inseminated. The more the odd ratio is obtained, the greater the influence. The factor was considered statistically significant when a p-value is <0.05.

Discussion

In this study, the overall conception rate in the selected regions was 45.1% in both dairy cows and heifers. The conception rate in this study was closer to the findings reported in earlier studies conducted by Kouamo *et al*. (2012) and Tebug *et al*., (2011) in tropical areas. A higher conception rate was reported in Ethiopia by Yehalaw *et al.* (2018) and Belay *et al*. (2016) in which the conception rate of inseminated cows was 64.8% and 60.4%, respectively. The conception rate of 29.0% was reported previously in Pakistan by Anzar *et al.* (2003) in cattle and buffalos from different study locations.

The conception rate of bovine AI was 78.1% in Jersey crossbreeds, and 40.4% in Holstein Friesian crossbreeds. The study conducted by Bansal *et al.* (2019) reported a conception rate of 51.92% in Jersey and 45.57% in cross of Holstein Friesian. In contrast, The observation made by Qureshi *et al.* (2008) reported a 66.52% Conception rate in Holstein Friesian and 62.00% in Jersey breeds in Pakistan. The variations in conception rates between the two crossbreeds could be due to genotypes, heat detection accuracy, and farmers' production systems (Kenya Livestock Breeds Catalogue, 2019; Hamid. & Tadesse, 2021). In the current study, the Jersey crossbreed in terms of number was not closer to Holstein-Friesian crosses because Jersey breed is a new breed in the selected regions. The higher AI success rate of Jersey breed was probably due to its performances in terms of disease resistance, fertility, longevity, and its ability to adapt well in many types of climates, environments, and management practices (Opoola *et al.,* 2022). The difference might also be due to the high net energy for maintenance required by Holstein Friesian breeds to meet production and reproduction while Jersey breeds are characterized by their high feed conversion efficiency and relatively low feed requirements due to their small size (Kenya Livestock Breeds Catalogue, 2019)

In the present study, the conception rate of cows with ages less than 3 year was 57.7%, 44.4% in cows with age of 3 to 6 years, and 30.6% in cows with ages greater than 6 years. These findings are closer to the study conducted in Ethiopia by Hamid *et al*. (2021) who reported 57.9%, 64.1%, and 44.0% with age ≤3, >3–6; >6–9 years, respectively. Findings of the present study are higher than findings reported in Bangladesh by Alam and Sarder, (2010) in which the

conception rate based on age variation of animals were 33.33%, 38.5%, and 29.8% efficiency in dairy cows of <3 3–6, and >6 years of age, respectively. Similarly, the success rate of AI in Synchronized cows with 2.5 to 4 years of age was 65.8% and 41.4% after eight years of age (Belay *et al.,* 2016) in Dale district of Ethiopia. Earlier studies reported a marked increase of fertility in cows up to 4 years of age, and a decline in fertility in cows over 7 years of age (Spalding *et al* 1974). The reduction of fertility with age might be associated with embryonic mortalities in old cows (Kouamo *et al* 2012; Aurelius, 2019). The conception rate might also be affected by an increase of fetal mortalities as the age increases due to deterioration of quality of eggs ovulated, uterine failure due to hormonal imbalance, and reduced ovulation rate due to lack of gonadotropin release from hypophysis (Quintela *et al.,* 2004; Khan *et al.,* 2015 and Aurelius, 2019).

Timing of artificial insemination relative to the onset of heat was critical for successful conception rate in this study. Effect of timing on the conception was investigated in order to determine the optimum timing AI service after estrus onset (Table 1). The conception rate observed in cows inseminated within six hours of heat was 24.4%, seven to ten hours of heat was 60.0%; between eleven to fourteen hours of heat was 53.0%, and after fourteen hours of heat was 35.2%. The increased conception rate was reported in cows inseminated at 6 to 10 hours after the beginning of heat signs. The conception rate observed within six hours after showing estrous signs was lower than the 65% conception rate reported in Ethiopia by Befkadu *et al*. (2019); and Howlader *et al*.(2019). The current results are closer to the general information on Rwanda context AI practitioners where there is a rule of AM and PM. When a cow shows heat signs in the morning, the inseminator is advised to inseminate in the afternoon and inseminate the following day when the cow comes in heat in the evening which is in range of success in current results.

Heifers had a conception rate of 58.3%, whereas cows with one parity had a rate of 43.1%, 45.1% with two and three parities, and 29.0% with more than four parities. In this study, the conception rate of heifers was comparable to the data published in Ethiopia by Hamid et al., 2021, where the conception rate in primiparous cows was 61.7%. The conception rate in the present study in cows with 2 and 3 parities is consistent with 40.0% conception rate reported previously in Rwanda by Nishimwe *et al*.,2015 in cows with one to three parities, but distinct from the 59.1% reported in Ethiopia in multiparous cows (Hamid *et al*., 2021). The variations in conception rates amongst parities could be attributed to changes in management systems, calving difficulties, and environmental circumstances.

The conception rate was 38.6%, 45.6%, and 62.5% in <2.5, 2.6-3.0, and 3.1-3.5 body condition scores, respectively. Body condition score and weight did not significantly influence conception rate ($p < 0.05$). The conception rate of cows with a range of 3.1- 3.5 body condition scores is consistent with pregnancy rate (66.7%) of cows of 3.1 - 3.5 BCS (Alam, & Sarder, 2010). Earlier studies conducted in cattle and buffalo in Punjab demonstrated a lower conception rate of 30% in 2-3 body conditions score (Anzar *et al.*, 2003). Cows having body conditions score above three showed better conception rate. In this study, conception rate was not significantly ($p < 0.05$) affected by body weight. The conception rate of cows with 250-300kg, 301-350 kg, 351-400kg, 401-450kg, 451-500kg, and 501-550kg body weight categories was 48.3%, 41.7%, 57.3%, 39.4%, 33.5%, and 23.1%, respectively. The influence of body condition score and body weight on AI conception rate might be attributed to feeding practices. Appropriate feeding maintains a decent body condition score by eliminating the effects of negative energy balance on conception rate (Nordin et al., 2004).

Cows inseminated during natural estrus had higher conception rates compared to those inseminated through synchronization methods. The current study showed that cows inseminated with natural estrus had a conception rate of 72.90%, whereas cows inseminated after induced estrus had a conception rate of 24.50%. This result is in line with a prior study conducted in Benin by Boukari et al. (2018), who observed 28.52% and 79.22% for induced and natural estrus, respectively. In contrast, Alemneh et al. (2015) conducted a study in the north-west of Ethiopia and found that induction estrus had a conception rate of 26.88%, whereas natural estrus had a conception rate of 32.07%. The discrepancies, along with induced and natural estrus, may be attributed to cow management practices such as poor nutrition, suckling, and infection during calving, which may impair the normal functionality of hormones that intervene in the development of the corpus luteum (Alemneh et al. 2015).

The conception rate increases as the number of observed heat signs increases (Table 1). The higher conception rate of 73.9% resulted from cows presented three signs of heat. In cows presenting two signs of estrus, the conception rate was 68.8%, 59.0%, and 53.8% for clear mucus and restlessness, clear mucus and counting others, and restlessness and mounting others, respectively. In cows with a single sign of estrus, lower conception rates of 28.8%; 40%, and 36.4% were observed in cows with clear mucus, restlessness, and mounting respectively. The lowest conception rate of 11.5% was observed in cows inseminated with silent heat. The present study has similar findings to Anzar *et al.* (2003) in which the highest conception rate of 37.7% was observed

in cows showing mucus at estrus. Additionally, (Stevenson *et al.* (1983) reported that conception in AI was more frequent when there was clear mucus upon cervical manipulation during insemination. It is evident that the conception rate increases by increasing the number of estrus signs. This might be linked to the health status of the cow. The negative energy balance decreases production of GnRH, suppress LH concentration, and reduces the concentration of circulating estrogen and progesterone that reduces the duration and intensity of estrus (Reith & Hoy, 2018).

Conclusion

The study was conducted to determine factors affecting the success of bovine AI in smallholder dairy cattle production in Rwanda. This study indicates that the breed, age, number of estrus signs, type of estrus, and time for insemination are factors influencing the success rate of bovine AI. The conception rate resulting from bovine AI in the present study is low, thus improving existing bovine AI programs, decentralization of bovine AI centers, and improving cow management practices at farm level could enhance the success rate of bovine AI in Rwanda.

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