Bhutan Journal of Animal Science (BJAS), Volume 10, Issue 1, Page No. 15-26, June 2026
https://doi.org/10.66961/sajb/v10i1.002

ASSESSING THE TRANSITION TOWARD REPRODUCTIVE TECHNOLOGIES: AWARENESS, ACCEPTANCE, AND CONSTRAINTS OF ARTIFICIAL INSEMINATION AMONG YAK HERDERS IN BUMTHANG, BHUTAN

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Abstract: *This quantitative cross-sectional survey investigated awareness, acceptance, and barriers to artificial insemination (AI) adoption among 36 yak herders from Chhoekhortoe and Dhur chiwogs under Chhoekhor Gewog, Bumthang Dzongkhag, Bhutan. Although AI has the potential to enhance genetic merit, productivity, and disease control in yak populations, its use in Bhutan's highland pastoral systems remains restricted and poorly understood. The purpose of this study was to evaluate the level of awareness, willingness to accept, and perceived obstacles to AI adoption among yak herders in Bumthang Dzongkhag. A structured questionnaire was used to administer a quantitative cross-sectional survey to 36 yak herders, and data were analyzed using descriptive statistics together with non-parametric tests, including the one-sample Wilcoxon signed-rank test, Fisher's exact test, and the Mann-Whitney U test, to assess location-specific differences and respondents' perceptions. The proportion of respondents who were aware of AI was 52.8%. Location had a significant influence on awareness (p = 0.005), with herders in Chhoekhortoe showing significantly higher awareness (72.7%, n=22) than those in Dhur (21.4%, n=14). Despite this variation, 91.7% of herders expressed willingness to adopt AI. The main perceived benefit was genetic improvement, followed by improved disease resistance, increased productivity, and reduced inbreeding. Despite the benefits of AI in yaks, three key challenges to adoption were identified, with transportation constraints emerging as the most significant barrier, followed by difficulties in the management of breeding bulls and persistent cultural preferences favoring natural mating practices. These findings indicate that AI adoption in yak farming is in an incipient but promising phase, with high acceptance despite heterogeneous awareness and logistical constraints. Enhancing adoption requires strengthening extension services, improving infrastructure for AI delivery in remote locations, and implementing targeted awareness campaigns, particularly in less-exposed communities. In Bhutan, promoting AI in yak production systems may contribute to improved productivity and enhanced genetic diversity.*

Keywords: Artificial Insemination; Awareness; Bhutan; Reproductive technologies; Yak Herders

1. INTRODUCTION

In Bhutan, yaks are an indispensable part of the socio-economic fabric and cultural heritage of high-altitude communities. Yaks provide critical resources, including milk, meat, wool, and transportation, supporting the livelihoods of over a thousand yak herding households (Wangdi et al. 2023). However, Bhutanese yak populations are facing significant challenges such as a narrow genetic base, inbreeding, low reproductive performance and seasonal breeding constraints (Wangdi and Wangchuk 2017). These interrelated factors collectively contribute to reduced productivity and compromise the long-term sustainability of yak production systems, which operate under inherent constraints associated with changing climatic conditions and limited pasture availability (Wangdi et al. 2023). In Bhutan, yak husbandry is practiced by approximately 1,100 households across 10

of the 20 Dzongkhags. However, since 2019, the sector has undergone a substantial decline, characterized by a 28% reduction in yak population and a 22% decrease in yak-rearing households. This contraction is driven by multiple interacting factors, including persistent forage scarcity, diseases (such as gid disease) wildlife predation, and the progressive decline in herding labor due to limited generational succession (Wangdi and Wangchuk 2017). Furthermore, the continued reliance on traditional and largely unstructured breeding system exacerbates inbreeding, leading to negative impacts on key productive and reproductive traits (Dorji et al. 2023).

In Bhutan natural mating remains the predominant breeding method practised, however, it is often associated with low reproductive efficiency. This is primarily due to silent estrus expression in yaks, which impairs accurate heat detection, alongside the challenges of coordinating controlled breeding and effective bull utilization across dispersed grazing systems. Although artificial insemination (AI) has been introduced with some success, its application remains limited due to technical constraints and inadequate infrastructure to support large-scale implementation (Dorji et al. 2023)

Given the critical role of yaks in Bhutan's highland economy and culture, there is an urgent need to enhance reproductive technologies such as AI to improve genetic diversity, reproductive rates, and boost overall yak productivity. Strengthening AI adoption through tailored protocols, capacity building for herders and AI technicians, and improved semen processing facilities will contribute significantly to the sustainable development of yak husbandry in Bhutan, thereby improving the livelihoods of marginalized mountain communities and reserving their unique cultural heritage (Dorji et al. 2023; Wangdi et al. 2023).

This study aims to comprehensively examine the traditional yak herding practices prevalent in the study area, which constitute a vital component of the socio-economic fabric of high-altitude communities in Bhutan. Additionally, the study seeks to evaluate the adoption rate of AI among yak herders, considering AI's potential to enhance reproductive efficiency and broaden the genetic base of Bhutanese yak populations.

2. MATERIALS AND METHODS

2.1 Study area

The present study was conducted in Chhoekhor Gewog, one of the largest gewogs in Bumthang Dzongkhag, specifically targeting yak herders in two chiwogs: Dhur Lusibe chiwog (referred to as Dhur Chiwog) and Nangsiphel Zangling and Zhabjethang chiwog (referred to as Chhoekhortoe Chiwog). These areas are representative of traditional yak pastoral systems in the country. The study area is characterized by rugged mountainous terrain with altitudes ranging from approximately 2,600 to over 5,800 meters above sea level, providing ideal ecological conditions for yak husbandry (Bumthang Dzongkhag Administration 2025). The gewog experiences long, harsh winters and short summers, which limit conventional agricultural practices but make it well-suited for pastoral livestock rearing.

National Statistics Bureau (2025) reported that Chhoekhor Gewog is home to about 40 yak-rearing households, collectively managing an estimated 3,500 yaks. Yak farming forms the primary livelihood source for these households, offering sustenance through dairy products, meat, hair, and dung, while also contributing significantly to

the local economy. The remoteness of grazing areas, seasonal migration to higher pastures, and traditional reliance on natural breeding methods present both challenges and opportunities for introducing reproductive technologies like Artificial Insemination.

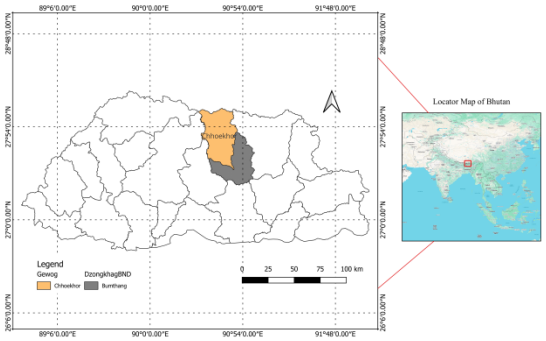

Figure 1: Map of the study site.

2.2 Study design and sampling

A quantitative cross-sectional survey design was employed to assess the awareness, perceptions, and willingness to adopt artificial insemination (AI) among yak herders. The study utilized a quantitative, semi-structured questionnaire to collect data on demographic characteristics, herd composition, awareness and perceptions of AI, perceived benefits and challenges, and attitudes toward adoption. A total of 36 yak herders (90% of yak herders in the study area) were selected from the target population using population sampling, comprising 14 herders from Dhur-Lusibe (referred to as Dhur Chiwog in the study) and 22 from Nangsiphel Zangling and Zhabjethang Chiwogs (collectively referred to as Chhoekhortoe Chiwog in the study), with both male (n=21) and female (n=15) participants reflecting the gender distribution of yak ownership in the study area.Population sampling was employed as the most appropriate approach for this study, capturing the entire accessible yak herding community in Chhoekhor Gewog, where only a limited number of households actively engage in yak husbandry. This method ensured comprehensive representation of experienced herders directly relevant to AI adoption, maximizing the applicability of findings for policy and extension interventions.

2.3 Data collection

This study employed a quantitative cross-sectional survey design to evaluate artificial insemination (AI) awareness, benefit perceptions, adoption willingness, and barriers among yak herders in Chhoekhor Gewog, Bumthang. The design facilitated snapshot assessment of current adoption determinants across spatial and demographic strata. Data were collected through face-to-face interviews conducted by trained enumerators fluent in the local language. The semi-structured questionnaire included both closed and open-ended questions. The study gathered demographic data, including age, gender, and location, to understand the herders' background. Yak herd characteristics such as herd size, body weight, milk production, and primary use of rearing yaks were recorded to profile the herds.

Respondents were asked about their awareness of AI as a breeding technique and rated the importance of its benefits, such as genetic improvement, increased productivity, disease resistance, and reduced inbreeding, using a five-point Likert scale. They also identified challenges to AI adoption, including transportation, breeding bull management, and cultural practices. Finally, the study measured herders' willingness to adopt AI, indicating their readiness to implement this technology in their herds.

2.4 Data analysis

Quantitative data were coded and entered into Microsoft Excel for analysis. Descriptive statistics (frequencies, percentages, and means) were used to summarize demographic characteristics, awareness levels, perceived benefits and challenges, and willingness to adopt AI. One-sample Wilcoxon signed-rank tests, Fisher's Exact Test, and Mann-Whitney U Test were conducted in R-studio (version 2023.06.1) to assess differences in awareness and adoption rates between the two chiwogs. The Mann-Whitney U test was chosen to compare ordinal data, specifically, the Likert-scale ratings of perceived benefits of yak AI between two independent groups (Dhur and Chhoekhortoe herders). Since the data are ordinal and may not follow a normal distribution, this non-parametric test provides a robust method to detect differences in perception without relying on parametric assumptions. For categorical variables with small sample sizes or low expected frequencies, such as the challenges faced by herders (e.g., transportation, cultural barriers) with yes/no responses, the Fisher's Exact test was used. This test is more reliable than the Chi-square test under these conditions, providing exact p-values and ensuring valid inference despite sparse data. The One-Sample Wilcoxon Signed-Rank Test was used to analyze the perceived benefits of Artificial Insemination (AI), which were measured using a Likert scale. Since Likert-scale data are ordinal and may not meet the assumption of normal distribution, a non-parametric test was considered appropriate. This test allowed for the comparison of the median perception score against a specified reference value, such as the neutral point on the scale. Finally, all findings were interpreted with caution due small sample size, and results apply primarily to Chhoekhor Gewog, not all yak-rearing areas of Bhutan.

3. RESULTS AND DISCUSSIONS

3.1 Demography

A total of 36 (14 from Dhur and 22 from Chhoekhortoe) nomadic herders were surveyed using quantitative questionnaires, out of which 21 (9 from Dhur and 12 from Chhoekhortoe) were males and 15 (5 from Dhur and 10 from Chhoekhortoe) were females. There were 2581 (1040 yaks in Dhur and 1541 yaks in Chhoekhortoe) yaks in total, including adult yaks and young calves from 36 surveyed herders. The average body weight of the *Zholay* (an adult male yak specifically used for breeding purposes to sire female yaks) was 267kg (285kg in Dhur and 256kg in Chhoekhortoe). On average, milking yaks weighed approximately 157 kg (182 kg in Dhur and 141 kg in Chhoekhortoe). The average milk production of the yaks in summer was 1.5 litres (1.2L in Dhur and 1.7L in Chhoekhortoe) and 0.43 litres (0.35L in Dhur and 0.49L in Chhoekhortoe) in winter. This is consistent with findings by Wangdi and Wangchuk (2017), who reported that average milk production of central Bhutan yaks were approximately 1.15 litres in summer and 0.30 litres in winter, highlighting pronounced seasonal variation in productivity driven by feed availability and climatic conditions (Wangdi and Wangchuk 2017). All the participants agreed that the yaks were reared for meat, milk and its product, fibre, and for transportation. These findings align with previous studies highlighting the multifunctional role of yaks in Bhutanese highland livelihoods The variation in body weight and milk yield between chiwogs may be attributed to differences in pasture quality, management practices, and climatic conditions (Dorji et al. 2020; Wangdi et al. 2024).

3.2 Perceived benefits

Figure 2 presents the perceptions of yak herders regarding the benefits of AI across four key domains: reduced inbreeding, disease resistance, increased productivity, and genetic improvement. The responses were measured on a reverse-coded five-point Likert scale (1=Very important; 5=Not important at all). and are displayed using a horizontal diverging stacked bar chart for Likert-scale data for visual clarity (Figure 2). Across all four benefit categories, a substantial majority of respondents expressed favorable perceptions of AI in yaks. The highest positive perception was recorded for genetic improvement, with over 80% of respondents rating it as either important or very important, and very few (less than 10%) indicating it as not important or not at all important. Similarly, disease resistance was also perceived as a critical advantage of AI, receiving one of the highest proportions of very important responses.

The benefit of increased productivity was also widely recognized, with the majority (over 70%) assigning it high importance. While reduced inbreeding had a slightly broader distribution across response categories, it still showed a dominant trend towards positive perception, with over two-thirds of respondents rating it as important or very important. The minimal proportions of responses falling under the "not important" and "not at all important" categories across all four domains indicate a strong overall recognition of the value of AI in yak breeding systems. This perception aligns with previous findings in livestock genetics research, which emphasize the role of AI in enhancing productivity, improving herd health, and accelerating genetic gains (Perry 2019).

One-sample Wilcoxon signed-rank tests substantiated that yak herders in Chhoekhor Gewog (n=38) perceived all four AI benefits as significantly exceeding neutral importance (test median=3.0) on a reverse-coded five-point Likert. Highly significant endorsement was observed across all perceived benefits (Table 1), with disease resistance and genetic improvement showing the strongest consensus. Low medians (1.5–2.0), small standard deviations (0.83–1.18), and significant p-values ($p \leq 0.008$) indicate strong overall approval of AI technologies among yak herders.

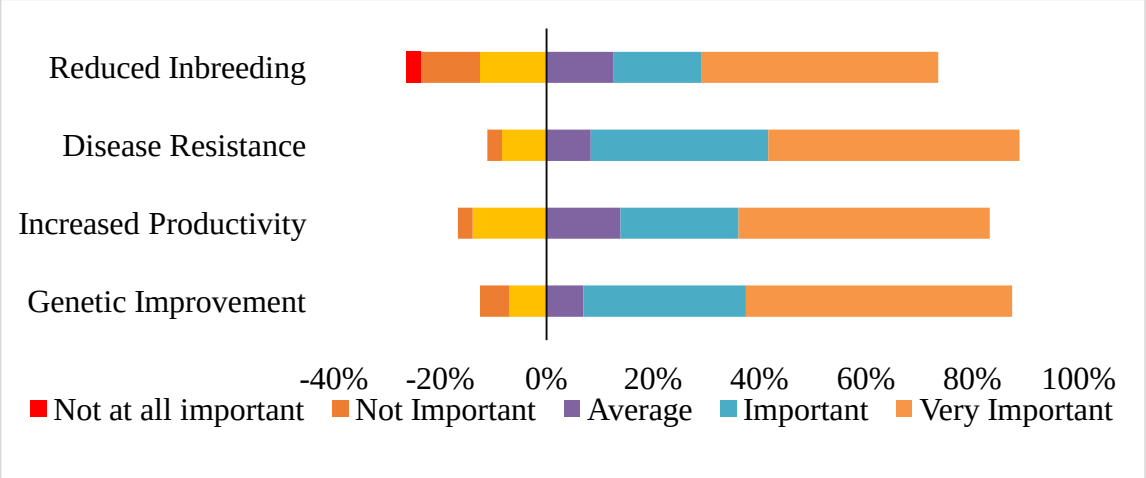

Figure 2: Perceived benefits of AI in Yaks.

Table 1: One-sample Wilcoxon signed-rank test.

Benefit	Mean	SD	Median	V-statistic	% Rating 1-2	p-value
Genetic Improvement	1.74	0.89	1.5	55	79%	<0.001
Disease Resistance	1.74	0.83	2	56	82%	<0.001
Increased Productivity	1.87	0.93	2	85	76%	<0.001
Reduced Inbreeding	2.11	1.18	2	154	71%	0.008

Overall, these findings align with livestock genetics studies reporting that AI enhances productivity, reduces disease risk, and improves genetic diversity (Rawat et al. 2025).

The Mann–Whitney U test revealed no statistically significant differences ($p > 0.05$) in the perceived importance of artificial insemination (AI) benefits between herders in Dhur and Chhoekhortoe across all evaluated parameters. Specifically, perceptions regarding improved genetics ($U = 174.5$, $p = 0.480$), increased productivity ($U = 200.0$, $p = 0.112$), disease-resistant calves ($U = 151.5$, $p = 0.944$), and reduced inbreeding ($U = 197.0$, $p = 0.144$) were statistically comparable between the two groups. This finding is consistent with observations by Meena et al. (2017), where it was reported that farmers operating under similar production environments and socio-economic conditions tend to exhibit comparable perceptions toward livestock technologies. The lack of significant variation in the present study may therefore reflect the relatively homogeneous nature of yak production systems in both chiwogs, including shared grazing practices, similar access to extension services, and comparable levels of exposure to information on AI.

3.3 Challenges

As presented in Figure 3, the adoption of AI in yaks has several challenges, out of which transportation, management of yak breeding bull, and culture and traditions were the three most important challenges in the Bhutanese context. All the herders agreed that transportation was one of the major challenges that restrict the adoption of AI in yaks. The transportation challenge echoes previous reports highlighting logistical constraints in delivering AI services in Bhutan's mountainous terrain (Wangchuk et al. 2022). Furthermore, the yak breeding bulls can exhibit aggressive behavior, especially during the breeding season. The majority of the herders (94.5%) consider this a challenge. Aggressive behavior in yak bulls, especially during the breeding season, is a significant challenge for effective planned breeding management. Yak bulls are naturally territorial and exhibit dominance behaviors, including charging, horn fighting, and threatening displays, which intensify during the rut (Buzzard et al. 2013). These behaviors pose risks to handlers and can interfere with controlled breeding programs such as AI in yaks. Additionally, the challenge of controlling the Yak bulls pre- and post-insemination (AI) is exacerbated by a lack of manpower, as the younger generation increasingly shows unwillingness to engage in yak rearing. This shortage of skilled herders reduces the capacity to effectively manage and monitor aggressive bulls during and after AI procedures (Dorji et al. 2023).

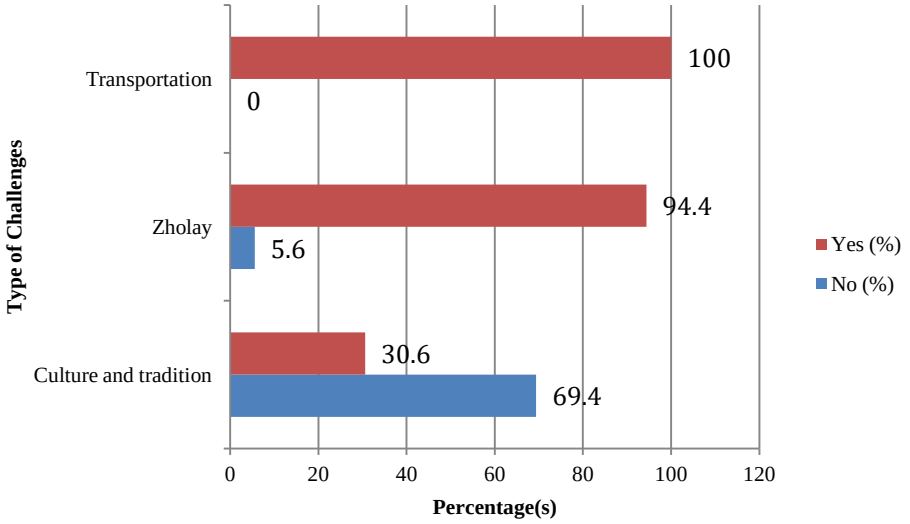

Figure 3: Barriers to AI adoption in Yaks.

Despite the majority of the herders recognizing this aggression as a significant challenge, some herders (5.5%) differed in perception. This variation could be explained by their experience and management practices. Herders who have been managing yaks for long periods may have developed techniques to control or mitigate aggressive behavior, thereby perceiving it as less of a challenge in practice. Such practices might include regular exercise, separation of bulls during non-breeding periods, or selection for calmer bulls over generations (Buzzard et al. 2013).

In contrast, cultural and traditional beliefs were perceived as a challenge by only 30.5% of respondents, while a greater proportion (69.5%) did not consider it a significant barrier. This suggests a positive shift in attitudes among yak herders, reflecting growing awareness and acceptance of AI despite deeply rooted cultural practices. The relatively low perception of cultural resistance may be attributed to increasing exposure to extension services and educational interventions in the region. Cultural factors, while less frequently cited, still pose barriers as some herders prefer traditional breeding practices, consistent with findings from pastoral communities in the region (Agutu et al. 2023). These findings are consistent with studies conducted in other mountainous regions, where logistical and management-related factors, rather than cultural barriers, were identified as primary constraints to AI adoption (Mekonnen and Gebremariam 2024).

The Fisher's Exact Test The lack of significant differences ($p > 0.05$) suggests that perceptions of AI-related challenges are consistent across chiwogs, indicating that these constraints are systemic rather than location-specific. Similar findings have been reported in smallholder livestock systems, where limitations in infrastructure, service

delivery, and technical capacity are broadly shared among farmers (Mathewos et al. 2023). In Bhutan's highland context, this likely reflects common challenges associated with remoteness and limited veterinary access. Therefore, AI interventions should be designed at a system level, focusing on strengthening service delivery, improving input supply chains, and enhancing farmer capacity. Such an approach is consistent with national livestock development priorities that emphasize coordinated extension services to improve productivity and genetic resources in remote areas.

3.4 Awareness

The present study revealed that among 36 yak herders surveyed, 19 (52.8%) reported awareness of artificial insemination (AI) as a breeding technique, whereas 17 (47.2%) were unaware of this technology. This finding (Table 2) indicates a moderate level of awareness of AI within the yak herding community, reflecting both the potential and challenges associated with the dissemination and adoption of reproductive technologies in remote pastoral systems. Geographical and socio-economic factors play a critical role in shaping awareness and utilization of AI technology. The rugged terrain and dispersed nature of yak herding communities hinder access to AI services and extension support, contributing to the nearly equal split in awareness observed in this study. These findings are consistent with broader livestock AI adoption literature, which identifies proximity to AI centers, cost considerations, and knowledge dissemination as key determinants influencing farmer uptake (Seth et al. 2025).

Governmental and institutional interventions have sought to enhance yak breeding through AI to improve genetic diversity and productivity. The establishment of yak herders' cooperatives and federations further supports knowledge exchange and capacity building, which are essential for increasing AI awareness and adoption. The application of AI and semen cryopreservation holds significant promise for genetic improvement in yaks by enabling the dissemination of superior germplasm across geographically isolated herds (Kalwar et al. 2022). Despite these advantages, the current level of awareness among herders in the study area suggests that further efforts are required to expand educational outreach, improve infrastructure, and reduce barriers to access.

Fisher's exact test confirmed a significant association between location and awareness ($p = 0.005$), indicating substantially higher odds of awareness among Chhoekhortoe herders compared to those in Dhur. Despite generally positive perceptions of AI benefits across both the groups, the high level of unawareness in Dhur (78.6%) represents a key bottleneck to adoption. Similar findings in livestock systems show that adoption is strongly influenced by information access, extension exposure, and farmer education, with awareness often acting as a primary determinant of uptake (Seth et al. 2025; Mathewos et al. 2023). Empirical studies further confirm that socio-demographic and institutional factors, particularly knowledge and extension contact, are more influential than attitude alone in determining adoption behavior in livestock technologies (Seth et al. 2025).

Table 2: Awareness of AI.

Location	Aware	Unaware
Dhur	3 (21.4%)	11 (78.6%)
Chhoekhortoe	16 (72.7%)	6 (27.3%)
Total	19 (52.8%)	17 (47.2%)

Therefore, the observed awareness gap suggests that strengthening information dissemination and extension outreach is critical for improving AI adoption in highland systems. Moreover, cultural and traditional beliefs can influence the acceptance and awareness of reproductive technologies.

Studies have shown that communities with strong traditional livestock breeding practices may be less receptive to AI, especially if the technology is perceived as complex or incompatible with local customs (Abebe and Mulu 2023). Therefore, the observed awareness gap suggests that targeted awareness campaigns considering local socio-cultural contexts and enhancing extension outreach are critical for improving AI adoption in highland systems.

3.5 Adoption rate

A semi-structured questionnaire was administered to 36 yak herders across two *chiwogs* to assess attitudes toward the adoption of artificial insemination (AI) in yaks. The results (Table 3) revealed a high overall willingness to adopt AI among the surveyed herders. Specifically, 33 out of 36 herders (91.66%) expressed agreement to adopt artificial insemination, while only 3 herders (8.34%) were reluctant.

Table 3: Willingness to adopt AI.

Gewog(s)	Yes	No
Dhur	13 (92.86%)	1 (7.14%)
Chhoekhortoe	20 (90.91%)	2 (9.09%)
Total	33 (91.67%)	3 (8.33%)

The findings indicate a highly favorable attitude toward the adoption of artificial insemination (AI) among yak herders in the study area, with agreement levels exceeding 90%. This reflects strong acceptance of reproductive technologies within Bhutan's high-altitude livestock systems and highlights considerable potential for scaling up AI in yak production where institutional and technical support systems are adequately established. Evidence from Bhutan and other Himalayan livestock systems shows that AI adoption is strongly constrained by structural and service-related factors, particularly limited accessibility of AI services, logistical challenges in remote mountainous areas, and the need for stronger veterinary and extension support systems (Wangdi and Wangchuk 2017). In Bhutan, although AI has been introduced in yak populations, its coverage remains limited and implementation is challenged by mobility of herds, remoteness, and difficulty in delivering reproductive inputs to high-altitude areas (Sharma et al. 2020). These studies consistently show that positive farmer perceptions alone are not sufficient; effective adoption depends on reliable service delivery, institutional capacity, and field-level technical support. Therefore, strengthening awareness programs, improving extension services, and ensuring consistent AI delivery systems will be critical for improving adoption rates and achieving genetic and productivity gains in Bhutan's yak production systems.

Chiwog-wise analysis showed variation in adoption responses, where 20 herders agreed to adopt artificial insemination (AI) and 2 were reluctant in Chhoekhortoe, compared to 13 willing adopters and one reluctant herder in Dhur. Although both chiwogs exhibited high willingness, the greater absolute number of adopters in Chhoekhortoe may reflect differences in herd size, exposure to extension services, or prior engagement with technological interventions. The small proportion of reluctant herders (8.34% overall) may be associated with limited awareness, perceived practicality concerns, or preference for

traditional breeding systems, which are commonly reported barriers in livestock technology adoption studies (Zander et al. 2013). Fisher's exact test indicated no significant association between location (Dhur vs. Chhoekhortoe) and willingness to adopt AI ($p > 0.05$), with high willingness observed in both Dhur (92.86%) and Chhoekhortoe (90.91%), yielding an overall readiness of 91.67%. This suggests that adoption behavior is relatively homogeneous across the study area and not strongly influenced by geographic location. Similar findings in livestock systems indicate that AI adoption is primarily driven by awareness, access to services, and institutional support rather than spatial differences between farming communities (Seth et al. 2025; Mathewos et al. 2023). These results highlight the potential for successful AI implementation in yak herds if supported by adequate training, extension services, and technical infrastructure, while also suggesting the need for targeted inquiry into the specific causes of reluctance among a small subset of herders.

4. CONCLUSION

This study demonstrates a favorable socio-behavioral environment for AI expansion in Bhutan's highland yak systems, characterized by strong perceived benefits and high willingness to adopt. However, infrastructural deficiencies particularly transportation and cold-chain limitations remain critical barriers. A moderate level of awareness of AI technology among yak herders was revealed, with 52.8% of respondents aware of the technology, while 47.2% remain unaware. Despite this, the overwhelming majority (91.7%) expressed willingness to adopt AI in yaks, indicating strong potential for integration of this reproductive technology within traditional yak husbandry systems. The findings underscore the recognition among herders of AI's key benefits, particularly genetic improvement, increased productivity, disease resistance, and reduction of inbreeding, which are critical for enhancing herd resilience and sustainability. However, several challenges constrain the widespread adoption of AI in the yak production system, notably transportation difficulties in rugged terrain, limited availability of frozen yak semen, and cultural preferences for natural mating. These barriers, coupled with infrastructural and extension service limitations, contribute to the uneven dissemination and practical application of AI technology in yak. Strategic investment in AI technicians' capacity building, yak AI infrastructures, and targeted awareness campaigns on the benefits of AI in yaks will be pivotal for the adoption of AI in yaks to reduce inbreeding, enhance genetic progress, enhance productivity, and strengthen livelihood resilience in fragile mountain ecosystems. Future research should focus on understanding the specific causes of reluctance among the minority hesitant to adopt AI and developing tailored strategies to overcome these barriers. Overall, the study highlights a favorable environment for scaling up AI adoption, provided that comprehensive support mechanisms are implemented to bridge knowledge and access gaps in these remote pastoral communities.

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