Research Article

Reproductive Performance of Indonesian Friesian Holstein Dairy Cattle Across Lactation Periods: A Case Study at TIU-LBF Batu, Indonesia

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Abstract | Reproductive efficiency is a critical determinant of sustainability and profitability in dairy farming. This study evaluates the reproductive performance of Indonesian Friesian Holstein (FH) dairy cattle across lactation periods at the Technical Implementation Unit for Livestock Breeding and Forage (TIU-LBF) Batu. Parameters assessed included Age at First Calving (AFC), Service per Conception (S/C), Days Open (DO), Conception Rate (CR), and Calving Interval (CI). The average AFC was 34.16 months (ideal: 24–26 months, with the highest S/C observed in first lactation cows (2.65; P<0.05 vs. second lactation). Both DO and CI exceeded 120 and 420 days, respectively, across all periods. Conception Rate (CR) was lowest in lactation I (22.92%). The use of sexed semen resulted in 63.16% male calves, higher than the expected 50% female bias. These findings underscore the limitations of current sexing technology in achieving the intended increase in female calf births, with implications for breeding strategies and herd replacement planning. Overall, the results reveal persistent inefficiencies in reproductive management due to suboptimal estrus detection, nutritional deficits, and low efficacy of sexed semen technology.

Keywords | Friesian holstein, Reproduction, Lactation, Sexed semen, The Technical implementation unit for livestock breeding and forage batu

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INTRODUCTION

Indonesian Friesian Holstein (FH) cattle are the backbone of national milk production in Indonesia. However, their reproductive performance is frequently hampered by delayed age at first calving (AFC), prolonged days open (DO), and extended calving intervals (CI), leading to reduced productivity and profitability for dairy farms (Armengol *et al*., 2023; Tadesse *et al*., 2022). These challenges are exacerbated by suboptimal management practices, inadequate feed quality, and the physiological limitations of FH cattle to Indonesia's tropical climate, resulting in lower conception rates and inefficiencies in herd replacement (Aryogi *et al*., 2024; Mandal *et al*., 2021).

The ideal reproductive benchmarks include an AFC ranges between 24–26 months to support optimal milk productivity (Pasaribu *et al*., 2023; Christi, 2023), S/C value is 1–2 artificial inseminations (AI) per pregnancy, DO should be less than 120 days (Adyatama *et al*., 2024), and CI is 365 days. However, prolonged CI and suboptimal CR (<60%) persist due to management gaps like poor estrus detection and nutritional deficits (Sudrajat *et al*., 2022; Nuryamin *et al*., 2024; Tadesse *et al*., 2022). Lactation periods also play an important role in the reproductive performance of FH cattle. During early lactation, energy deficits frequently occur due to high demands for milk production, resulting in delayed estrous cycles and reduced conception rates (Knegsel *et al*., 2022). Additionally, technology-based approaches such as AI using sexed semen offer potential to improve reproductive efficiency while increasing the female birth ratio. However, the effectiveness of this technology still requires further evaluation to ensure results align with expectations.

The Technical Implementation Unit for Livestock Breeding and Forage (TIU-LBF) Batu plays a strategic role in addressing these challenges by ensuring livestock breeding quality meets Indonesian National Standards (SNI). However, an in-depth evaluation of FH cattle reproductive performance at this unit remains limited. Therefore, this study aims to evaluate the reproductive performance of Indonesian FH cattle based on lactation periods TIU-LBF Batu and to assess the effectiveness of the implemented livestock breeding policies.

MATERIALS AND METHODS

Time and Location of Research

This research was conducted from December 2024 to February 2025 at the Technical Implementation Unit for Livestock Breeding and Forage (TIU-LBF) Batu located at Jalan Raya Tlekung, Beji Village, Junrejo District, Batu City, East Java Province, Indonesia.

Research Materials and Sampling Method

The study involved 62 female Friesian Holstein (FH) dairy cows kept at TIU-LBF Batu. All cows meeting the inclusion criteria were selected as samples (census), with reproductive data collected retrospectively from herd records for the period 2021–2024. Inclusion criteria consisted of FH dairy cows with complete records of birth date, calving, insemination, and pregnancy confirmation, and being in lactation periods I, II, or III during the study period. Cows with a history of abortion, those not originating from TIU-LBF Batu, or inseminations using semen from sources other than BBIB Lembang/Singosari or with incomplete calf sex data were excluded from the analysis.

Research Design

This study employed a case study design with a quantitative approach. Primary data were obtained through interviews with inseminators and barn staff, while secondary data were sourced from herd reproductive records.

Observed Variables

The study population comprised 62 Indonesian Friesian Holstein (FH) dairy cattle at UPT PT dan HMT Batu. Reproductive data were collected retrospectively from herd records (2020–2025), with parameters selected based on availability and alignment with international dairy cattle reproduction KPIs (Armengol et al., 2023). Data collection included:

Age at first calving (AFC): Defined as the cow's age (in days) at initial parturition. This parameter reflects heifer rearing efficiency and was analyzed against the optimal range of 22–25 months (Atashi *et al*., 2021).

Service per conception (S/C): The number of artificial inseminations (AI) required to achieve pregnancy. Values >2.0 indicate suboptimal fertility, as per benchmarks for tropical dairy systems (Mungube *et al*., 2019).

Days open (DO): Postpartum interval from calving to subsequent conception. Ideal targets ≤120 days were applied (Temesgen *et al*., 2022).

Conception rate (CR): Percentage of cows conceiving on first AI. Values <60% suggest issues in estrus detection or semen quality (Nuryamin *et al*., 2024).

Calving interval (CI): Duration between consecutive calvings, with 365–420 days considered optimal for annual calving (Setyorini *et al*., 2022).

AI outcomes: Calf sex ratios from sexed (Singosari) and non-sexed (Lembang/Singosari) semen were compared to evaluate sexing technology efficacy (Wiranto *et al*., 2020).

The reproductive traits examined in this study included:

Age at first calving (AFC): The age at which a female cow first calves.

Service per conception (S/C): The number of inseminations required to achieve pregnancy.

Days open (DO): The interval between calving and the next pregnancy.

Conception rate (CR): The percentage of cows that conceive on their first insemination.

Calving interval (CI): The time span between consecutive calvings.

Results of AI using sexed and non-sexed semen: The percentage of calves produced from sexed versus non-sexed semen.

Ethical Approval

All research procedures involving animals were approved by the Faculty of Animal Science, Universitas Brawijaya (Approval No.: 00045/UN10.F0501/B/PP/2025), in accordance with national animal welfare regulations (Peraturan Menteri Pertanian Republik Indonesia No. 14 Tahun 2020) and with permission from TIU-LBF Batu.

Data Analysis

Data were analyzed descriptively to obtain the mean and standard deviation of each reproductive parameter (Lušņičenko *et al*., 2024). One-way ANOVA was used to compare S/C among lactation periods, followed by Tukey's test if significant differences were found (Setyorini *et al*., 2022). The chi-square test was used to compare AI success rates between the use of sexed and non-sexed semen (Adyatama *et al*., 2024; Wiranto *et al*., 2020; Jaglan *et al*., 2023). All analyses were performed using Microsoft Excel and R Studio (Herdian *et al*., 2024).

Research Ethics Statement

This research received permission from TIU-LBF Batu and followed animal welfare guidelines in accordance with the Regulation of the Minister of Agriculture of the Republic of Indonesia Number 14 of 2020 concerning Animal Welfare in Livestock. All research procedures were conducted with minimal stress to animals and ensured optimal health conditions during data collection.

RESULTS AND DISCUSSION

Key Findings

To provide a clear overview of the study outcomes, we summarize the key findings of reproductive performance in Indonesian Friesian Holstein dairy cattle across lactation periods as follows:

Age at first calving (AFC): 34.16 months, exceeding the ideal range of 24–26 months.

Service per conception (S/C): Highest in lactation I (2.65; P<0.05 vs. II), indicating reduced fertility in early lactation.

Days open (DO): Exceeded 120 days in all periods.

Calving interval (CI): Exceeded 420 days in all periods.

Conception rate (CR): Lowest in lactation I (22.92%), improving in later lactations but remaining below the 60% benchmark.

Sexed semen outcome: Sexed semen produced 63.16% male calves, contrary to the expected 50% female bias.

Age at First Calving (AFC)

We observed that the AFC value was 1,024.71 ± 182.42 days (≈34.16 months), exceeding the ideal standard of 24–26 months. This value is relatively higher compared to the ideal standard according to Atashi *et al.* (2023) of 24 to 26 months (720-780 days), indicating a delay of approximately 8 to 10 months from the ideal standard. The relatively large standard deviation (182.42 days) indicates high variability in the population, reflecting inconsistency in heifer management. Cattle reached the fastest AFC at 1.88 years of age, while delayed first-calving cattle reached AFC at 3.96 years, almost 4 years. Delayed AFC (>3 years) results from breeding management factors such as suboptimal estrus detection, high S/C (more than once), malnutrition during the pre-weaning phase, and reproductive health disorders.

Service Per Conception (S/C)

The Service per Conception (S/C) values for lactation periods I, II, and III were 2.65 ± 1.52, 1.98 ± 0.92, and 2.13 ± 1.52, respectively. A significant difference (P<0.05) was observed between periods I and II, indicating improved reproductive efficiency during lactation period II. This improvement may be attributed to enhanced reproductive management, including more accurate estrus detection, better semen straw quality, and improvements in livestock maintenance and nutrition. The lower S/C value in period II reflects the positive impact of these management adjustments.

The increase in S/C during lactation period III (2.13) suggests fluctuations in reproductive efficiency. This resulted from cattle health issues following the 2022 Foot-and-Mouth Disease (FMD) outbreak, which can cause reduced fertility and productivity (Torres-Aburto *et al*., 2020; Temesgen *et al*., 2022). This aligns with findings by Sudrajat *et al.* (2022), who reported that S/C values >2.0 are associated with chronic energy deficits and suboptimal nutritional status in late-lactation cows. Nutritional imbalances, particularly energy deficiencies, can reduce reproductive efficiency by lowering Body Condition Score (BCS), disrupting reproductive hormones, prolonging anestrus periods, and decreasing pregnancy rates.

Generally, high S/C values can be addressed through improved reproductive management (e.g., estrus detection, semen quality, insemination timing), enhanced livestock maintenance, and optimized nutrition-specifically ensuring adequate energy and protein intake. Integrated efforts across management and nutritional aspects are critical to achieving ideal S/C values (1–2 inseminations per conception).

The standard deviation (SD) of S/C was quite high, particularly in periods I (1.52) and III (1.52), showing significant variation between individuals in the number of AIs required to achieve pregnancy. Factors such as reproductive health conditions, semen quality, and AI timing can influence this variation (Tariq *et al*., 2024). Period III had the widest S/C value range, from minimum 1 to maximum 9, indicating extreme variation in reproductive efficiency. Period II had the narrowest S/C value range (1-4), indicating more consistent reproductive management. Overall, despite fluctuations, there are indications of improved reproductive efficiency from period I to subsequent periods. However, consistent efforts are still needed to achieve and maintain ideal S/C values across all periods.

Days Open (DO)

DO in lactations I, II, and III were 254.62 ± 163.58, 195.48 ± 110.37, and 210.81 ± 104.54 days, respectively. These values exceed the optimal standard (<120 days) (Adyatama *et al*., 2024). Short DO indicates cows return to estrus and achieve subsequent pregnancy more rapidly after calving, contributing to improved reproductive efficiency (Temesgen *et al*., 2022). Conversely, long DO reflects delays in rebreeding, which may result from suboptimal estrus detection, health disorders, or nutritional deficits. This results from factors such as improved nutrition, optimal health management, and more efficient breeding programs. However, the increase in Period III indicates variations in reproductive performance caused by external factors such as environmental stress, health disturbances, changes in feed management, and delayed AI during FMD recovery. The DO period in this study is longer than the ideal value, ranging from 85-115 days, related to lactation energy deficit (NE-l) of -8.42 Mcal/head/day. This deficit indicates that cows do not receive sufficient energy to support optimal milk production and post-lactation recovery. This can cause reproductive disorders such as increased Days Open (DO) and decreased Body Condition Score (BCS), as reported by Wicaksono and Susilorini (2022) at the same location, TIU-LBF Batu, where most cows had BCS values in the "rather thin" (1.75–2.50) to "medium" (BCS 2.75–3.00) categories.

Conception Rate (CR)

CR in lactations I, II, and III were 22.92%, 40.00%, and 37.50%. CR values show a similar pattern, with the lowest value in lactation period I (22.92±6.07) and highest in lactation period II (40.00±6.93). The ideal CR is 60% (Nuryamin *et al*., 2024); low CR is caused by improper AI timing and as well as poor body condition of livestock. Body condition score below 3 will result in a high S/C value. Research by Lee *et al*. (2021) showed that insemination at optimal timing after estrus detection can significantly increase CR. Additionally, using protocols such as Ovsynch to manage reproductive cycles has also been proven to increase CR to 67.7% (Borş, 2021). Environmental conditions, particularly heat stress, also significantly impact CR. This is supported by Wicaksono and Susilorini's (2022) research that temperatures at TIU-LBF Kota Batu around 15-34ºC with unpredictable weather can cause decreased production performance due to heat stress. This aligns with Aryogi *et al*. (2024) who reported that heat stress also impairs reproductive quality, including oocyte maturation and early embryonic development, leading to lower conception rates and higher pregnancy failure. Furthermore, Khan *et al*. (2023) stated that heat stress can reduce CR by 20-27% during summer, and Simmental cattle were found to exhibit higher heat tolerance than Holstein cattle, as indicated by a lower increase in somatic cell count in milk during heat stress conditions.

Calving Interval (CI)

The decrease in calving interval (CI) from 553.45 days in the first lactation to 468.22 days in the third lactation indicates improved reproductive efficiency. However, despite this reduction, CI values remained over 120 days longer than the ideal target of 365 days. This persistent gap highlights ongoing management deficiencies that need to be addressed to achieve the recommended goal of one calving per year in dairy cows (Setyorini *et al*., 2022; Prabowo, 2021; Alwinda *et al*., 2023). The extended CI at UPT is caused by high DO and low CR.

The standard deviation also decreased from period I to period III, from 173.81 days to 91.66 days. This indicates that variation in CI decreases with increasing lactation experience, which can contribute to increased stability and predictability in reproductive management (Handcock *et al*., 2020). The ideal CI value should not exceed 14 months (420 days), and longer CI can result in decreased profitability for farmers (Setyorini *et al*., 2022; Ózsvári *et al*., 2020). Factors affecting CI value in this study are closely related to DO value; period I CI: 553.45 days, DO: 254.62 days; period II CI: 474.70 days (decreased 14.2%), DO: 195.48 days; period III CI: 468.22 days, DO: 210.81 days.

Research in tropical regions shows that intensive management systems can produce shorter CI compared to semi-intensive systems, with average CI of 17.53 months and 20.03 months, respectively (Alwinda *et al*., 2023). Overall, several factors affecting reproductive performance include livestock health conditions, including FMD cases in 2022 that impacted reproductive efficiency, suboptimal feed management, environmental stress, particularly heat stress with environmental temperatures around 15-34°C. Aryogi *et al*. (2024) also emphasize that local cattle demonstrate better adaptation and more stable performance across various altitudes, whereas crossbred dairy cattle are more susceptible to extreme tropical environmental changes, making the development of crossbred dairy cattle more advisable in highland regions. This highlights the importance of management practices in reproductive efficiency.

AI Success Using Sexed and Non-sexed Semen

A critical finding was sexed semen produced 63.16% male calves vs. expected 50% female bias (Figure 1). This outcome is highlighted here due to its significant implications for breeding strategies and herd replacement planning. This finding is consistent with Harshini *et al.* (2022), who reported reduced X-sperm viability after the sexing process.

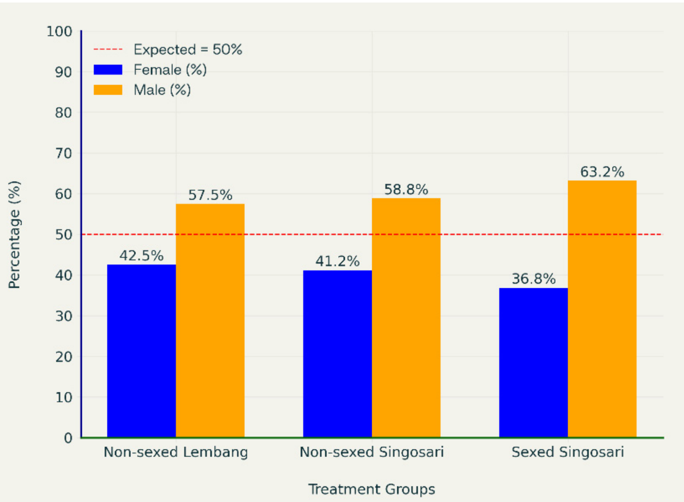

Figure 1: Sex distribution of offspring resulting from artificial insemination (AI) using sexed and non-sexed semen in three treatment groups: Lembang non-sexed, Singosari non-sexed, and Singosari sexed. **Note:** This graph shows the sex distribution of offspring resulting from artificial insemination (AI) using sexed and non-sexed semen from BBIB Lembang and Singosari. In the non-sexed semen groups (Lembang and Singosari), sex distribution approaches random expectation (50:50). However, in the Singosari sexed semen group, the proportion of male calves is higher (63.16%) compared to females (36.84%), ineffective sexing technology in increasing the female birth ratio.

The histogram in Figure 1 shows the sex distribution of offspring resulting from artificial insemination (AI) using non-sexed semen from BBIB Lembang. The histogram shows the proportion of female calf births is 42.50% (17 head), while male calves reach 57.50% (23 head) from a total of 40 samples. The red horizontal line marks the expected value of balanced sex distribution (50%). Test results show that sex distribution does not significantly differ from the expected 50%. This indicates that the non-sexed semen used produces a sex distribution approaching random. In contrast, Singosari sexed semen resulted in a male-biased ratio (63.16% male vs. 36.84% female), contradicting the intended purpose of sexing technology to increase female births. This discrepancy suggests technical limitations in the sperm-sorting process, such as suboptimal X/Y chromosome separation or reduced sperm viability post-sorting (Harshini *et al.*, 2022; Guo et al., 2020).

Overall, non-sexed semen from both BBIB Lembang and Singosari produces sex distributions approaching random without significant difference from the 50% expectation. This aligns with the characteristics of non-sexed semen that does not undergo X and Y chromosome separation. Research shows that non-sexed semen, which does not undergo chromosome separation, produces balanced sex proportions (50:50), similar to those found in natural populations (Harshini *et al.*, 2022). In this context, non-sexed semen serves as an important control to compare the effectiveness of sex-sorted semen that often shows different results in terms of reproductive success rates and birth ratios (Guo et al., 2020; Reese *et al.*, 2021). The chromosome separation process in sexed semen can reduce sexed sperm viability by 15–20% (Hamid *et al.*, 2021; Koca et al., 2023), potentially affecting insemination success rates (Ayoub and Mohamed, 2022). The results of using sexed semen in this study demonstrate ineffectiveness in increasing the likelihood of female calf births. Factors include: potentially suboptimal sexing process in separating X and Y spermatozoa, semen quality after the sexing process, AI timing precision relative to ovulation which is critical for successful AI with sexed semen, or the physiological condition of the cow that can affect sexing technique success. Thus, AI results from BBIB Lembang and Singosari semen support the understanding that non-sexed semen produces balanced sex distribution, which is a natural characteristic of semen that does not undergo chromosome separation process. This affirms the importance of considering separation methods and their impact on semen quality and reproductive outcomes in artificial insemination practices (Meles *et al.*, 2022; Wiranto *et al.*, 2020) although sexed semen can be used for sex selection purposes, we still need to consider overall reproductive success (Sawant *et al.*, 2022).

Managerial Factors and Recommendations

The herd experienced a NE-l deficit (−8.42 Mcal/head/day) exceeds critical thresholds. Deficits greater than −5 Mcal/head/day have been shown to significantly increase the risk of decreased Body Condition Score (BCS), prolonged postpartum anestrus, reduced conception rates, and extended days open and calving intervals (Nigussie, 2018; National Academies of Sciences, 2021). Estrus detection in the herd relied primarily on visual observation, a method susceptible to inaccuracies; thus, integrating activity monitoring systems or infrared thermography is recommended to enhance detection accuracy (Shokrollahi *et al.*, 2024). The use of a modified Ovsynch protocol (GnRH–PGF2α–GnRH–timed AI) is recommended, as it has been shown to increase conception rates in multiparous cows.

The Ovsynch protocol is a reproductive management technique that uses a timed sequence of hormone injections (GnRH and PGF2α) to synchronize ovulation, allowing for fixed-time artificial insemination without the need for estrus detection (Lee *et al.*, 2021; Borş, 2021). Nutritional management should be improved by adjusting the forage-to-concentrate ratio to 60:40 during early and mid-lactation and providing targeted mineral supplementation (Zn, Cu, Se) to correct energy and micronutrient deficits (National Academies of Sciences, 2021). Furthermore, it is essential to routinely evaluate the effectiveness of sexed semen before large-scale implementation to avoid skewed calf sex ratios and ensure optimal herd replacement.

CONCLUSIONS AND RECOMMENDATIONS

This study reveals that the reproductive performance of Indonesian Friesian Holstein dairy cattle at TIU-LBF Batu remains below optimal standards, as indicated by delayed age at first calving, high service per conception, prolonged days open, low conception rates, and extended calving intervals. These inefficiencies are primarily driven by inadequate energy intake, suboptimal estrus detection, and the limited effectiveness of sexed semen technology. Strategic interventions are required, including adjusting the forage-to-concentrate ratio to 60:40 during early and mid-lactation, providing targeted mineral supplementation (Zn, Cu, Se), adopting reproductive management protocols such as Ovsynch to synchronize ovulation and optimize insemination timing, and routinely evaluating the effectiveness of sexed semen before large-scale use. Addressing these issues is critical, as persistent reproductive inefficiencies increase production costs, reduce farm profitability, and hinder progress toward national breeding standards and sustainable dairy development in Indonesia.

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NOVELTY STATEMENTS

1. This study provides the first integrated analysis of key reproductive parameters (AFC, S/C, DO, CR, and CI) of Indonesian Friesian Holstein cattle across lactation periods at a government breeding unit (TIU-LBF Batu), highlighting persistent inefficiencies despite institutional interventions.
2. The field-based assessment of sexed semen technology, which unexpectedly resulted in a male-biased calf ratio (63.16% males), highlighting the current limitations of sexing technology in achieving targeted female calf production for herd replacement.
3. The identification of a negative net energy balance (–8.42 Mcal/head/day) as a major contributing factor to poor reproductive outcomes underscores the critical role of nutritional management in optimizing reproductive efficiency in institutional dairy herds.

AUTHOR'S CONTRIBUTIONS

The authors confirm contribution to the paper as follows: St. Theresia Sri Wulandari Setiawanti: Collected the data, Conceptualization, methodology, and manuscript drafting,Tri Eko Susilorini: Performed the statistical analysis and the preparation of tables, Sri Wahjuningsih: corrected the manuscript attending the reviewer's suggestions and language of the manuscript, Kuswati: Review of results and critical manuscript revision and Suyadi: Supervision, project administration, and corresponding author responsibilities.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this article.

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