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Research Article

Effect of Body Condition Score on the Success of Artificial Insemination in Sumba Ongole Cattle under Smallholder Farms

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Abstract | Sumba Ongole (SO) cattle are a local breed found exclusively on Sumba Island, East Nusa Tenggara Province, Indonesia. Artificial insemination (AI) failure in SO cattle is often not caused by the technology itself, but by one frequently overlooked factor: Body condition score (BCS). This research aimed to determine the effect of BCS on the success rate of AI in SO cattle at smallholder farms in East Sumba Regency. The study employed a randomized block design with three BCS category groups: low (≤2.50), moderate (2.75-3.00), and high (≥3.25), with each group containing 30 experimental units. The results showed that BCS had a significant effect ($p<0.05$) on AI success. The BCS group of 2.75–3.00 demonstrated the best AI success rate, with values for Non-Return Rate-1 (NRR-1): 63.33%, NRR-2: 50.00%, Conception Rate (CR): 50.00%, and Services per Conception (S/C): 1.27. This was followed by the BCS ≥3.25 group with NRR-1 (46.67%), NRR-2 (33.33%), CR (33.33%), and S/C (1.40). The BCS ≤2.50 group showed the lowest AI success, with NRR-1 (23.33%), NRR-2 (16.67%), CR (13.33%), and S/C (2.33). BCS significantly affected the success of AI in SO cattle, with the ideal range of 2.75–3.00 serving as a practical benchmark for AI implementation. These findings provide practical implications for livestock extension officers and farmers, emphasizing that proper BCS monitoring and good feed management should be implemented in AI programs to improve the reproductive efficiency of SO cattle.

Keywords | Body condition score, Non return rate, Conception rate, Service per conception, Artificial insemination, Sumba Ongole cattle

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INTRODUCTION

Global livestock production has advanced over the last two decades (Morotti *et al.*, 2025), to support food security and provide highly nutritious products (Davis and White, 2020). Indonesia, as the country with the second-greatest biodiversity in the world, possesses a diversity of local native cattle breeds (Widyas *et al.*, 2022). One local cattle breed of strategic importance is the Sumba Ongole (SO) cattle, which has long been developed in the East Nusa Tenggara region, with its distribution confined solely to Sumba Island (Kaka *et al.*, 2025a). SO cattle, as a local breed, serve as a source of animal protein, a driver of the local economy, and a part of the cultural identity of the Sumba people (Ina and Kaka, 2020; Lodu *et al.*, 2021; Mila *et al.*, 2022; Kaka and Ina, 2021; Awa *et al.*, 2022). Furthermore, as a native breed, it possesses a high adaptive ability to its environment (Tariku *et al.*, 2024; Kaka *et al.*, 2025b).

On one hand, the commercialization and dominance of imported cattle continue to increase annually, making the preservation and utilization of local cattle such as SO an urgency from both a scientific and a sustainable local livestock perspective. On the other hand, small-scale farmers play a crucial role in the beef cattle industry, as more than 90% of Indonesia's cattle population comes from smallholder farming systems (Hilmiati *et al*., 2024). However, traditional management practices in these farms often hinder the maintenance of optimal body condition in cattle (Rifa'i *et al*., 2024). Therefore, the development of technology-based reproduction programs, such as Artificial insemination (AI), is a primary strategy for enhancing the population and genetic quality of local cattle (Fitriana *et al*., 2025; Zuidema *et al*., 2021). One of the challenges in implementing AI in SO cattle under dryland ecosystem and smallholder farming systems is the wide variation in body condition score (BCS), which largely depends on the availability of nutritional intake according to the season and management practices. The assessment of the dam's nutritional status in AI programs, particularly in the field and smallholder farms, can be carried out visually through BCS using a 1–5 scale (Vall *et al*., 2025). Meanwhile, according to Pryce *et al*. (2001), BCS can be used as a management and selection tool to improve reproductive performance.

Variation in BCS can affect reproduction, leading to conditions such as anovulation, silent heat, and decreased oocyte quality (Crowe *et al*., 2018). The body condition of cattle influences various physiological aspects, and animals with good body condition have a more optimal metabolic capacity to support reproductive function (Surjowardojo *et al*., 2023). Meanwhile, cows with an ideal BCS have more regular and easily detectable estrous cycles, better hormonal responses, and optimal oocyte quality and uterine environment for fertilization. Although the effects of BCS have been widely studied in *Bos taurus* cattle (Luz *et al*., 2018; Manríquez *et al*., 2021; Poczynek *et al*., 2023), scientific data on *Bos indicus*-type indigenous cattle such as SO remain very limited.

To date, no published studies have specifically examined the relationship between body condition score and AI success in SO cattle reared under smallholder dryland conditions. This research gap is important to address, as BCS is a simple, low-cost, and practical parameter that can guide reproductive management and improve AI success under limited-resource settings. In physiological terms, the relationship between BCS and reproductive performance is mediated through the energy balance endocrine axis (Chaves *et al*., 2024). An imbalance in energy metabolism can disrupt the function of the hypothalamic, pituitary, gonadal axis, leading to decreased gonadotropin secretion and impaired follicular development, ultimately delaying ovulation (Herdis *et al*., 2025). Thus, maintaining cows within an optimal BCS range ensures a balanced metabolic and hormonal state that supports reproductive success in AI programs. Therefore, this research aims to analyze the effect of BCS on the success of AI in SO cattle using NRR, CR, and S/C as indicators. The results of this study are expected not only to provide scientific contributions but also to strengthen the genetic conservation of Indonesia's unique and dryland-adaptive indigenous cattle.

MATERIALS AND METHODS

Study period and location

This research was conducted in the operational area of the Department of Livestock in East Sumba Regency, East Nusa Tenggara Province, specifically focusing on smallholder farms that regularly implement AI programs. The location was selected based on the high population of SO cattle, intensive management practices, and active farmer participation in AI programs. Data collection was carried out over six months, from September 2024 to February 2025, to comprehensively cover reproductive cycles and enable observation of pregnancy parameters.

Experimental design

This study employed a randomized block design (RBD) with three categories of BCS: low (≤2.50), moderate (2.75–3.00), and high (≥3.25), each consisting of 30 cows. A total of 90 female cows were evaluated simultaneously before AI through visual observation and palpation of the back, ribs, and tail head based on a 1–5 scoring scale. The cows were then classified into BCS categories, and randomization was conducted using a random number table to assign animals to each treatment group.

Potential confounding factors included differences in management and feeding among farms, variations in age and parity, environmental conditions, subjectivity in BCS assessment, and technical factors related to insemination. To minimize these effects, farms of origin were treated as blocks, and cows with relatively uniform age and parity were selected. BCS assessments were performed by a single trained evaluator, and inseminations were carried out by the same technician using semen from the same bull with high motility. All cows were examined to ensure reproductive health, and the experiment was conducted during a relatively stable environmental period.

Population, sample and acceptor criteria

The research population consisted of all adult female SO cattle in the region meeting the selection criteria: having calved at least once, being clinically healthy, non-pregnant at the start of observation, and possessing a normal reproductive history. From this population, a sample of 90 cattle was selected via purposive sampling. Nevertheless, the relatively small sample size was due to the limited livestock ownership and suboptimal environmental conditions in smallholder farming systems. For cows subjected to AI, evaluation of NRR-1 and NRR-2 was conducted, coded as 0 for cows returning to estrus and 1 for confirmed pregnancy (no return to estrus post-AI) on days 21 and 42, respectively. Rectal palpation was performed on days 35–40 post-AI to confirm pregnancy. BCS was assessed using a standard 1–5 scale with 0.25 intervals, where a score of 1 indicated severe emaciation and a score 5 indicated obesity, following the valuation standard of Vall *et al.* (2025).

Recipient cows were selected and administered a synchronization treatment using Syncromate hormone. Estrus signs were observed from day 1 to day 7, with criteria including reddening of the vulvar labia minora, vulvar swelling, warmth, and the presence of mucus. The interval between $PGF_2\alpha$ injection and AI was on average day 4, although it could vary depending on each cow's hormonal response. AI was performed twice daily (morning and evening) as a standard procedure to ensure the correct ovulation period post-estrus.

Cows were required to be over two years old or have a parity of 1–4 (Yekti *et al.*, 2023). Artificial insemination was performed by four certified AI technicians with over one year of experience. Liquid semen was sourced from SO bulls selected according to the Indonesian National Standard (SNI) No. RSNI4 7651.8:2016, then diluted and stored at 3–5°C with an average motility of 50% used for insemination and evaluated for quality, including motility (%), viability (%), abnormalities (%), total motile sperm, intact plasma membrane (%), and intact acrosome cap (%), following prior research recommendations (Kaka *et al.*, 2025a).

Liquid semen production

Liquid semen was produced using a nanoparticle-based lontar fruit water-egg yolk extender (Kaka *et al.*, 2025) at the Integrated Laboratory of Kristen Wira Wacana Sumba University. Semen quality evaluation was conducted using a trinocular microscope (multimedia features: 48MP image pixel resolution with HDMI and USB ports, 2K 24fps/1080P video recording). Other equipment included an artificial vagina, AI gun, 0.25 mL straws, refrigerator, cooler box, scissors, plastic forceps, plastic gloves, lubricating jelly, pH meter, and thermometer

Estrus synchronization and artificial insemination

Estrus synchronization was performed using syncromate hormone (Bremer Pharma GmbH, Warburg, Germany) containing 0.250 mg cloprostenol (a synthetic analog of prostaglandin F2α, PGF2α), administered via intramuscular injection at a dose of 2 mL/head according to the manufacturer's specified concentration (registered with the Indonesian Ministry of Agriculture No. I. 17025239 PKC). Estrus detection was conducted for 7 days post-administration. Farmers received training sessions to enhance estrus identification skills, and the research team collaborated with farmers to ensure proper AI implementation. Cows exhibiting estrus were evaluated based on vulvar temperature, vulvar color, and cervical mucus pH. Artificial insemination was performed twice (morning and evening) using treatment-specific semen deposited beyond the fourth cervical ring.

Pregnancy evaluation and data coding

Insemination success was assessed through a two-stage evaluation: (1) Non-return rate-1: Cows not exhibiting return to estrus between days 19–21 post-AI were considered non-returned and potentially pregnant; (2) Non-return rate-2: A follow-up evaluation on days 39–42 to confirm the absence of estrus return. Conception rate and service per conception were confirmed via rectal palpation by an experienced veterinarian days 90 post-AI. Cows diagnosed as pregnant were coded '1', while non-pregnant cows were coded '0'.

Data collection

The reproductive success parameters observed in this study included: (1) Non-Return Rate 1 (NRR-1) and Non-Return Rate 2 (NRR-2): The percentage of cows that did not return to estrus after AI on days 19–21 and 39–42, respectively, used as early indicators of AI success (Susilawati *et al.*, 2023); (2) conception rate (CR): The percentage of cows that became pregnant following the first insemination (Yekti *et al.*, 2023); (3) Service per conception (S/C): The number of inseminations required for a cow to conceive. A lower S/C value indicates higher AI efficiency (Setiawan, 2018).

Data analysis

Data on the effect of BCS on NRR-1, NRR-2, CR, and S/C were analyzed using a randomized block design. If significant differences were observed between treatments, the analysis was continued with Duncan's test. Meanwhile, the relationship between BCS and NRR-1, NRR-2, and CR was analyzed using the Chi-square test. All data were processed using the Statistical Package for the Social Sciences (SPSS) software, version 29 for Windows.

RESULTS

The success of AI programs in livestock is determined not only by the technology employed but is also significantly influenced by the physiological condition of the dam, as reflected through BCS. BCS serves as an indicator of nutritional status and plays a crucial role in determining reproductive efficiency, particularly in local cattle such as SO. In this study, SO cows were categorized into three BCS groups (Figure 1). Subsequent observations included monitoring estrus signs, measuring vaginal temperature, and assessing cervical mucus pH (Figure 2).

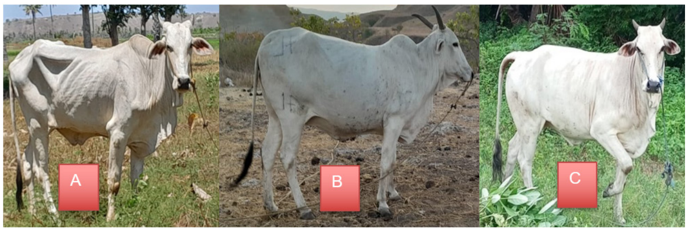

Figure 1: (A) Body condition score ≤ 2.50; (B) Body condition score 2.75–3.00; (C) Body condition score ≥ 3.25).

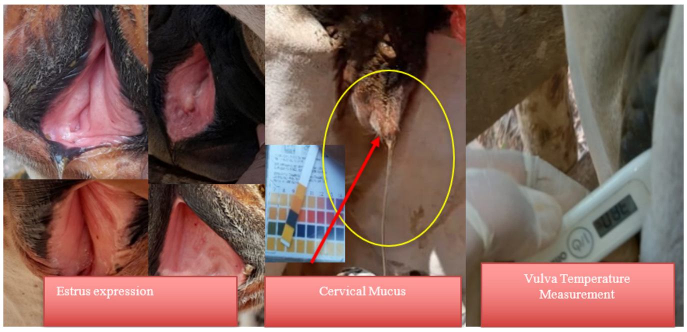

Figure 2: Evaluation of Estrus Quality in Sumba Ongole Cattle

Statistical analysis results indicated that BCS had a significant effect ($p<0.05$) on AI success (NRR, CR, and S/C). Based on the results, SO cattle with low BCS showed the lowest AI success rates, with many animals returning to estrus or failing to conceive, resulting in a higher number of S/C. In contrast, cows with medium BCS exhibited the best reproductive performance, emphasizing that optimal body condition strongly supports reproductive efficiency. Meanwhile, cattle with high BCS showed intermediate outcomes, with moderate AI success rates and a corresponding number of services per conception (Table 1 and Figure 3 compare NRR-1, NRR-2, and CR):

Duncan's test was conducted to identify differences among BCS groups. The test revealed that the cattle group with medium BCS yielded significantly better ($p<0.05$) NRR, CR, and S/C values compared to the low BCS group. However, no significant difference ($p>0.05$) was found between the medium BCS and high BCS groups regarding NRR, CR, and S/C values. Numerically, cattle with low BCS exhibited the lowest reproductive performance. This indicates that thin/emaciated body condition can adversely affect AI success. Conversely, the best performance was demonstrated by the medium BCS group, confirming that optimal body condition supports AI success. Meanwhile, the high BCS group numerically showed a declining performance reproduction, compared to the BCS medium group. This decline is presumably due to the negative impact of excess body fat on metabolism and hormonal function.

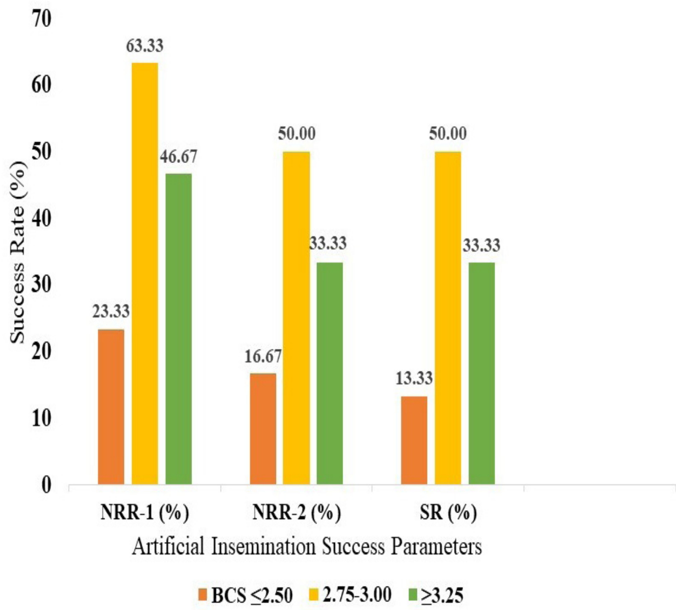

Figure 3: Comparison of artificial insemination success.

Figure 3, depicting the percentage distribution of success rates across BCS groups, reinforces the finding that SO cattle with medium BCS consistently demonstrated the highest success rates compared to the other two groups. This pattern illustrates that physiologically optimal BCS can support endocrine activity, follicular development, ovulation, and embryo implantation. Meanwhile, the high BCS group also exhibited a declining trend in NRR-2 values. This is likely attributed to excessive body fat accumulation, which may disrupt hormonal

Table 1: Effect of BCS on the success of artificial insemination.

No	Number of cows (head)	Mean BCS (Scale 1-5)	Mean±standard deviation			
			NRR-1 (%)	NRR-2 (%)	CR (%)	S/C
1.	30	≤2.50	23.33 ± 0.43^{b}	16.67 ± 0.38^{b}	13.33 ± 0.35^{b}	2.33 ± 0.80^{b}
2.	30	2.75-3.00	63.33 ± 0.49^{a}	50.00 ± 0.51^{a}	50.00 ± 0.51^{a}	1.27 ± 0.68^{a}
3.	30	≥3.25	46.67 ± 0.5^{ab}	33.33 ± 0.48^{ab}	33.33 ± 0.48^{ab}	1.40 ± 0.85^{a}

[a,b] Different superscripts in the same column showed significant differences ($p < 0.05$).

balance, impair ovarian function, and reduce sensitivity to insemination stimuli. Conversely, cattle with low BCS showed a significant decline in all AI success parameters. Only 16.67% achieved CR, with the majority returning to estrus, indicating that inadequate energy reserves may adversely affect ovulation quality and uterine readiness to support implantation.

Statistical analysis using the Chi-Square (χ^2) test was conducted to determine the relationship between BCS as the independent variable and several AI success indicators as dependent variables, namely NRR-1, NRR-2 and CR. The statistical test results revealed a statistically significant association between BCS categories and all three AI success parameters. This is indicated by p-values smaller than the significance level $\alpha = 0.05$ for all variables (Table 2).

Table 2: Association between body condition score and the success of artificial insemination.

Variable	Chi-Square (χ^2)	df	p-value
BCS*NRR-1	8.153	2	0.017
BCS*NRR-2	6.944	2	0.031
BCS*CR	7.479	2	0.024

Collectively, these results reinforce that BCS is a critical factor in supporting the success of AI, particularly in recipient selection. Therefore, maintaining BCS within the ideal range is essential for enhancing reproductive efficiency and improving the success rate of AI programs at both field and smallholder farm levels.

DISCUSSION

Sumba Ongole cattle with a low BCS exhibited a very low AI success rate. According to Pryce *et al.* (2001), BCS is closely associated with energy balance changes. The energy deficit occurring in thin body conditions impairs hormonal balance, particularly through increased cortisol levels that suppress the release of gonadotropin-releasing hormone (GnRH). Consequently, this disruption can lead to impaired estrous cycles, reduced ovulation quality, and ultimately pregnancy failure (Hassanein *et al.*, 2024). Meanwhile, the decline in GnRH directly reduces luteinizing hormone (LH) secretion, thereby disrupting follicular development and ovulation (Randall *et al.*, 2015; Mugwabana *et al.*, 2018).

The research found that the group of cattle with a low BCS experienced undetected estrus and anovulatory estrus. This resulted in low NRR and CR scores, as reflected in the research results where the low BCS group achieved only a 13.33% CR and the highest S/C value of 2.33. Therefore, low BCS serves as a primary indicator of metabolic and hormonal disruptions that impair reproductive efficiency. The high BCS group also demonstrated reduced AI success compared to the optimal BCS group. Excessive body fat accumulation may increase estrogen production from adipose tissue, which disrupts hormonal feedback mechanisms, particularly for GnRH and LH (Nasution *et al.*, 2021). Consequently, cattle with high BCS tend to experience ovulatory disorders, impaired luteinization, and even insulin resistance that negatively impacts ovarian function.

Females with either excessive or insufficient fat and muscle reserves show disrupted estrous cycles, weaker estrus signs, lower ovulation rates, increased risk of embryonic loss, prolonged postpartum anestrus, and overall reduced fertility due to decreased conception and survival rates, ultimately affecting productivity (Cox *et al.*, 2019). This is evidenced in the present study's results, where the high BCS group achieved only a 33.33% CR and 1.40 S/C. Thus, excess body fat can cause ovarian dysfunction and reduce reproductive sensitivity to hormonal stimuli in AI.

Sumba Ongole cattle with a medium BCS exhibited ideal conditions supporting AI success. Body conditions within this BCS range demonstrate a balance between energy reserves and reproductive metabolism. According to Luridiana *et al.* (2015a, 2025b), good BCS indicates enhanced reproductive performance compared to cattle with lower BCS values. Estrous cycles are more regular, oocyte quality is improved, and response to insemination is optimal. This aligns with reports that hormonal balance involving GnRH, LH, FSH, and progesterone remains within physiological ranges supporting ovulation and implantation (Pereira *et al.*, 2018; Kgari *et al.*, 2021). In this study, the medium BCS group achieved the highest CR: 50% and lowest S/C: 1.27), reflecting peak reproductive efficiency. Therefore, maintaining BCS within this ideal range represents a critical target for reproductive management of local SO cattle.

Fluctuations in BCS in Sumba's dry climate, driven by seasonal changes and feed availability, underscore the need for focused nutritional management to keep cattle in optimal condition and support successful reproduction. These results confirm that cattle with suboptimal body conditions whether underweight or overweight are at higher risk of reproductive disorders and metabolic diseases (González-Maldonado *et al.*, 2021; Nasution *et al.*, 2021). Even without hormonal analysis, the relationship between BCS and reproductive success in SO cattle can be physiologically explained. BCS reflects energy status, which influences the balance of reproductive hormones such as GnRH, LH, and progesterone, all critical for estrous cyclicity, ovulation, and implantation. Cattle with optimal BCS possess a hormonal milieu and oocyte quality conducive to pregnancy success. Thus, these findings remain relevant and are supported by a robust reproductive physiological basis.

Moreover, these findings provide a practical basis for extension programs, highlighting the importance of monitoring BCS to guide targeted nutritional interventions, enhance fertility, and implement strategies for conserving the genetics of SO cattle to ensure both reproductive performance and long-term population sustainability. This aligns with previous research indicating that an ideal BCS range optimally supports reproductive processes such as ovulation and embryo implantation (Armelia *et al*., 2019; Bo *et al*., 2025). Further reinforcing these findings, nutritional management utilizing BCS as a benchmark can reduce fertility issues, strengthening the link between energy balance and reproductive performance (Lemes *et al*., 2017). Meanwhile, cattle with low BCS that fail to conceive after the first AI require nutritional intervention to improve CR in subsequent inseminations (Setiaji *et al*., 2023).

Several other factors also influence the success of AI, including fertility, inseminator skill, accuracy of estrus detection, timing of insemination, sperm number and dose, as well as semen ejaculate quality (Musriati *et al*., 2024). In addition, age, parity, changes in BCS after AI, estrus expression, sire, and calving month also play a role (Da Silva *et al*., 2024). Meanwhile, according to Hess *et al*. (2005), reproductive performance is strongly influenced by the dam's nutritional status.

CONCLUSIONS

Body condition score is a key factor determining the success of AI in SO cattle. The BCS range of 2.75–3.00 has been proven to be the ideal condition, thus serving as an important benchmark in reproductive management to enhance AI success in Indonesian local cattle, particularly SO cattle. Maintaining BCS within this optimal range not only improves conception rates but also enhances the cost-efficiency of AI programs and reduces the need for repeat inseminations, thereby increasing overall herd productivity. Further studies are recommended to involve larger sample sizes and explore hormonal, nutritional, and husbandry management aspects to deepen the understanding of the relationship between BCS and AI success in SO cattle.

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NOVELTY STATEMENT

This study provides the first empirical evidence on the influence of BCS on artificial insemination outcomes in Sumba Ongole cattle maintained under dryland environments and smallholder production systems. The identification of an optimal BCS range of 2.75–3.00 for maximizing NRR, CR, and service efficiency introduces a new, evidence-based benchmark for recipient selection and reproductive management in this indigenous Bos indicus breed. These findings offer a novel contribution to the improvement of AI programs and the sustainable genetic conservation of Indonesia's local cattle populations.

AUTHOR'S CONTRIBUTION

AK: Conducted the research, performed animal selection, analyzed data, and prepared the original draft of the manuscript, APAY: Responsible for research administration, SM and SR: Contributed to reviewing and editing the manuscript. TS: Contributed to the conceptualization and supervision of the research.

Ethical approval

This research was conducted in accordance with the Animal Care and Use Committee, Universitas Brawijaya, Malang, East Java, Indonesia, with ethical clearance number 090-KEP-UB-2024.

Generative AI and AI-assisted technology statement

The authors declare that generative AI and AI-assisted technologies (such as Grammarly and ChatGPT) were used only for language editing and improving the clarity of English expressions. No AI tools were used to generate, analyze, or interpret data, nor to create any scientific content. The authors take full responsibility for the integrity, accuracy, and originality of all scientific aspects of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Armelia V, Saleh DM, Setianto NA (2019). Identification of factors contributed to beef cattle reproductive disorders in Ogan Komering Ulu Timur Regency (OKU Timur) of South Sumatra Province in UPSUS SIWAB program 2018. Anim. Prod., 20(3): 199. https://doi.org/10.20884/1.jap.2018.20.3.743

Awa SRLA, Kaka A, Denisius UP (2022). Population structure of Sumba Ongole cattle in Lambanapu Village, Kambera District, East Sumba Regency. Proc. Natl. Semin. Agric. Dev. Vocat. Educ., 3(1): 472–482. https://doi.org/10.47687/snppvp.v3i1.333

Bo D, Wang Y, Bai Y, Li J, Shen J, Wei J, Bai Y (2025). Global whole-genome resequencing of beef cattle reveals characteristic traits related genes in Pinan cattle. Animals, 15(11): 1626. https://doi.org/10.3390/ani15111626

Chaves AS, Silva F, Valentim R, Quintas H (2024). Body condition in small ruminants. Effects of nutrition on the hypothalamic–pituitary–gonad axis and ovarian activity that controls reproduction. Physiologia, 4(2): 213–225. https://doi.org/10.3390/physiologia4020012

Cox JF, Navarrete F, Carrasco A, Dorado J, Saravia F (2019). Effect of BST administration on plasma concentrations of IGF-I and follicular dynamics and ovulation during the interovulatory cycle of sheep and goats. Theriogenology, 123: 159–166. https://doi.org/10.1016/j.theriogenology.2018.10.003

Crowe MA, Hostens M, Opsomer G (2018). Reproductive management in dairy cows. The future. Irish Vet. J., 71(1): 1. https://doi.org/10.1186/s13620-017-0112-y

Da Silva LG, Da Silva LG, Ferreira LCL, Mascarello J, Moraes JGN, Lucy MC, Nogueira É (2024). Factors influencing pregnancy per artificial insemination (AI) and embryonic mortality in Nelore females subjected to timed-AI in Brazil. Anim. Reprod. Sci., 265: 107475. https://doi.org/10.1016/j.anireprosci.2024.107475

Davis TC, White RR (2020). Breeding animals to feed people: The many roles of animal reproduction in ensuring global food security. Theriogenology, 150: 27–33. https://doi.org/10.1016/j.theriogenology.2020.01.041

Fitriana SB, Maghfiroh NA, Baity AN, Diatmono DFF, Prihantoko KD, Bintara S, Widayati DT (2025). Effect of different thawing methods on frozen semen characteristics and DNA damage of Indonesian Simmental bull. Pak. J. Agric. Res., 38(1). https://doi.org/10.17582/journal.pjar/2025/38.1.8.18

González-Maldonado J, Pérez Hernández P, Salazar Ortiz J, Cortez Romero C, Gallegos-Sánchez J, García-Winder MJ (2021). Reproductive activity of dairy cattle in the postpartum anestrus period. Agro Productividad. https://doi.org/10.32854/agrop.v14i8.2103

Hassanein EM, Szelényi Z, Szenci O (2024). Gonadotropin-releasing hormone (GNRH) and its agonists in bovine reproduction: Structure, biosynthesis, physiological effects, and its role in estrous synchronization. Animals, 14(10): 1473. https://doi.org/10.3390/ani14101473

Herdis H, Inounu I, Santoso S, Anwar RI, Hayanti SY, Hudaya MF, Mahari DA, Lupitasari FBI, Hafid A, da Costa MA, Adianto N, Sitaresmi PI (2025). Reproductive integration of leptin and kisspeptin in small ruminants: Mechanisms, biomarker potential, and prospects for precision breeding. Vet. World, pp. 1614–1633. https://doi.org/10.14202/vetworld.2025.1614-1633

Hess BW, Lake SL, Scholljegerdes EJ, Weston TR, Nayigihugu V, Molle JDC, Moss GE (2005). Nutritional controls of beef cow reproduction. J. Anim. Sci., 83(suppl_13): E90–E106. https://doi.org/10.2527/2005.8313_supplE90x

Hilmiati N, Ilham N, Nulik J, Rohaeni ES, deRosari B, Basuki T, Hau DK, Ngongo Y, Lase JA, Fitriawaty F, Surya S, Qomariyah N, Hadiatry MC, Ahmad SN, Qomariah R, Suyatno S, Munir IM, Hayanti SY, Panjaitan T, Yusriani Y (2024). Smallholder cattle development in Indonesia: Learning from the past for an outcome-oriented development model. Int. J. Design Nat. Ecodyn., 19(1): 169–184. https://doi.org/10.18280/ijdne.190119

Ina AT, Kaka A (2020). Preservation of spermatozoa Sumba Ongole bulls using citrate yolk diluent with the addition of palmyra palm juice. J. Ternak, 11(2): 86–90. https://doi.org/10.30736/jt.v11i2.83

Kaka A, Ina AT (2021). Quality of Sumba Ongole spermatozoa in egg yolk tris diluent with different levels of palmyra palm juice *(Borassus flabelifer* L*)*. Indonesian J. Anim. Sci., 23(3): 255–261. https://doi.org/10.25077/jpi.23.3.255-261.2021

Kaka A, Yekti APA, Maylinda S, Rahayu S, Susilawati T (2025a). Effectiveness of nanoparticle-based young palmyra fruit water–egg yolk in liquid semen diluent of Sumba Ongole bulls. Int. J. Vet. Sci., 14(1): 16–24. https://doi.org/10.47278/journal.ijvs/2024.205

Kaka A, Yekti A, Syah H, Utami P, Maylinda S, Rahayu S, Susilawati T (2025b). Asian palmyra palm (*Borassus flabellifer* L.) and egg yolk as natural extenders for liquid semen of Sumba Ongole cattle. Open Vet. J., 15(10): 5192. https://doi.org/10.5455/OVJ.2025.v15.i10.36

Kgari RD, Muller CJC, Dzama K, Makgahlela ML (2021). Evaluation of female fertility in dairy cattle enterprises. A review. S. Afr. J. Anim. Sci., 50(6). https://doi.org/10.4314/sajas.v50i6.8

Lemes JS, Pimentel MA, Vaz RZ, Farias LB, Brauner CC (2017). Performance efficiency of pasture-raised primiparous beef cows of three different biotypes and two milk production levels. Acta Sci. Vet., 45(1): 8. https://doi.org/10.22456/1679-9216.80210

Lodu AUJ, Kaka A, Sirappa IP (2021). Characteristics and quality of Sumba Ongole cattle semen in BTS extender modified with soy milk. J. Anim. Sci. Technol, 2(2): 64–73. https://doi.org/10.31605/jstp.v2i2.1037

Luridiana S, Mura MC, Daga C, Farci F, Di Stefano MV, Zidda F, Carcangiu V (2015a). Melatonin treatment in spring and reproductive recovery in sheep with different body condition score and age. Anim. Reprod. Sci., 160: 68–73. https://doi.org/10.1016/j.anireprosci.2015.07.004

Luridiana S, Ouadday M, Cosso G, Carcangiu V, Mura MC (2025b). Influence of body condition score on reproductive recovery in spring and on some hematochemical parameters in Sarda breed sheep. Animals, 15(3): 372. https://doi.org/10.3390/ani15030372

Luz GB, Maffi AS, Farias LB, Xavier EG, Lima ME, Corrêa MN, Brauner CC (2018). Effects of the bull on conception rate of dairy cows in different seasons and according to AI type. Acta Sci. Vet., 46(1): 6. https://doi.org/10.22456/1679-9216.82554

Manríquez D, Thatcher WW, Santos JEP, Chebel RC, Galvão KN, Schuenemann GM, Bicalho RC, Gilbert RO, Rodriguez-Zas S, Seabury CM, Rosa GJM, Pinedo P (2021). Effect of body condition change and health status during early lactation on performance and survival of Holstein cows. J. Dairy Sci., 104(12): 12785–12799. https://doi.org/10.3168/jds.2020-20091

Mila FNH, Kaka A, Ina YT (2022). Characteristics and quality of

Sumba Ongole cattle semen in Tris extender supplemented with skim milk at 3–5 ºC. J. Anim. Sci. Technol., 3(1): 12–18. https://doi.org/10.31605/jstp.v3i1.1201

Morotti F, Dos Santos GMG, Silva-Santos KC, Dias JHA, Seneda MM (2025). Strategic use of estrus intensity to combine timed artificial insemination and embryo transfer in large-scale cattle reproduction programs. Theriogenology, 235: 162–167. https://doi.org/10.1016/j.theriogenology.2025.01.009

Mugwabana TJ, Nephawe KA, Muchenje V, Nedambale TL, Nengovhela NB (2018). The effect of assisted reproductive technologies on cow productivity under communal and emerging farming systems of South Africa. J. Appl. Anim. Res., 46(1): 1090–1096. https://doi.org/10.1080/09712119.2018.1466709

Musriati, Setiadi A, Samsudewa D (2024). Analysis of factors affecting the success of beef cattle artificial insemination (AI) in Jepon District, Blora Regency. IOP Conf. Ser.: Earth Environ. Sci., 1364(1): 012038. https://doi.org/10.1088/1755-1315/1364/1/012038

Nasution M, Siregar TN, Sayuti A, Hafizuddin H, Rosmaidar R, Adam M (2021). Identification of factors causing reproductive disorders of the cow found in North Labuhanbatu Regency, North Sumatera Province. Livest. Anim. Res., 19(1): 80. https://doi.org/10.20961/lar.v19i1.41766

Pereira L, Ferreira A, Vale W, Serique L, Neves K, Morini A, Monteiro B, Minervino A (2018). Effect of body condition score and reuse of progesterone-releasing intravaginal devices on conception rate following timed artificial insemination in Nelore cows. Reprod. Domest. Anim., 53(3): 624–628. https://doi.org/10.1111/rda.13150

Poczynek M, Nogueira LDS, Carrari IF, Carneiro JH, Almeida RD (2023). Associations of body condition score at calving, parity, and calving season on the performance of dairy cows and their offspring. Animals, 13(4): 596. https://doi.org/10.3390/ani13040596

Pryce JE, Coffey MP, Simm G (2001). The relationship between body condition score and reproductive performance. J. Dairy Sci., 84(6): 1508–1515. https://doi.org/10.3168/jds.S0022-0302(01)70184-1

Randall LV, Green MJ, Chagunda MGG, Mason C, Archer SC, Green LE, Huxley JN (2015). Low body condition predisposes cattle to lameness: An 8-year study of one dairy herd. J. Dairy Sci., 98(6): 3766–3777. https://doi.org/10.3168/jds.2014-8863

Rifa'i, Radiati LE, Hawa LC, Surjowardojo P (2024). Prevalence of subclinical mastitis in Holstein-Friesian cow dairy among small-scale farms in Batu, Indonesia. Int. J. Vet. Sci., 13(5): 592–595. https://doi.org/10.47278/journal.ijvs/2024.144

Setiaji A, Oikawa T, Arakaki D (2023). Relation between body condition score and conception rate of Japanese Black cows. Anim. Biosci., 36(8): 1151–1155. https://doi.org/10.5713/ab.22.0329

Setiawan D (2018). Artificial insemination of beef cattle UPSUS SIWAB program based on the calculation of non-return rate, service per conception and calving rate in the North Kayong Regency. Int. J. Trop. Vet. Biomed. Res., 3(1): 7–11. https://doi.org/10.21157/ijtvbr.v3i1.11339

Surjowardojo P, Nugraha P, Rifa'i, Muarifah H, Wardhana AC (2023). Relationship between steaming up with colostrum production at different milking times in Holstein-Friesian cows. Online J. Anim. Feed Res., 13(5): 391–395. https://doi.org/10.51227/ojafr.2023.55

Susilawati T, Yekti APA, Firdaus A, Damayanti DA, Prafitri R, Febrianto N, Kuswati K, Rachmawati A, Wahjuningsih S, Isnaini N (2023). The study of artificial insemination with double doses at different times in Friesian Holstein crossbred. Adv. Anim. Vet. Sci., 11(7). https://doi.org/10.17582/journal.aavs/2023/11.7.1159.1164

Tariku W, Betsha S, Melesse A (2024). Genetic improvement approaches of indigenous cattle breeds for adaptation, conservation and sustainable utilization to changing climate in Ethiopia. Vet. Integr. Sci., 22(1): 231–250. https://doi.org/10.12982/VIS.2024.018

Vall E, Blanchard M, Sib O, Cormary B, González-García E (2025). Standardized body condition scoring system for tropical farm animals (large ruminants, small ruminants, and equines). Trop. Anim. Health Prod., 57(2). https://doi.org/10.1007/s11250-025-04410-x

Widyas N, Widi TSM, Prastowo S, Sumantri I, Hayes BJ, Burrow HM (2022). Promoting sustainable utilization and genetic improvement of Indonesian local beef cattle breeds: A review. Agriculture, 12(10): 1566. https://doi.org/10.3390/agriculture12101566

Yekti APA, Bayuardhi M, Wahjuningsih S, Susilawati T (2023). Artificial insemination using double-dose frozen semen in Friesian Holstein crossbred dairy cattle, J. Trop. Anim. Prod., 24(2): 143–150. https://doi.org/10.21776/ub.jtapro.2023.024.02.9

Yekti APA, Setiawan RER, Rachmawati A, Susilawati T (2023). Quality of post thawing frozen semen on Limousin bull using cold water with different durations. J. Agripet, 23(1): 25–32. https://doi.org/10.17969/agripet.v23i1.23331

Zuidema D, Kerns K, Sutovsky P (2021). An exploration of current and perspective semen analysis and sperm selection for livestock artificial insemination. Animals, 11(12): 3563. https://doi.org/10.3390/ani11123563