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SEX-DEPENDENT HEAT TOLERANCE PROFILES OF BALI CATTLE EXPOSED TO TROPICAL HEAT STRESS

Profil Toleransi Panas Berdasarkan Jenis Kelamin pada Sapi Bali yang Terpapar Stres Panas Tropis

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ABSTRACT
Heat stress is one of the main challenges in livestock farming systems in tropical areas, directly affecting the physiological response and productivity of livestock. Bali cattle, as one of Indonesia's local germplasms, are known to have good adaptability to extreme environmental conditions. This study aims to evaluate the heat tolerance of male and female Bali cattle using the Iberian Heat Tolerance Coefficient (IHTC), Benezra's Coefficient of Adaptability (BCA), and Thermal Stress Resistance Index (TSRI). Data analysis used the independent samples t-test to compare between male and female sexes under heat stress conditions (THI = 84.8–87.2). The results showed significant differences ($P < 0.05$) in IHTC and BCA values between male and female Bali cattle, while TSRI did not show significant differences ($P > 0.05$). Male Bali cattle had lower IHTC values and higher BCA values compared to female cattle. This finding indicates that female Bali cattle have relatively better heat tolerance compared to male Bali cattle.

Keywords: *Bali cattle, Heat stress, Heat tolerance, Physiological adaptation, Tropical*

ABSTRAK
Cekaman panas merupakan salah satu tantangan utama dalam sistem pemeliharaan ternak di wilayah tropis yang berdampak langsung pada respons fisiologis dan produktivitas ternak. Sapi Bali sebagai salah satu plasma nutfah lokal Indonesia dikenal memiliki kemampuan adaptasi yang baik terhadap kondisi lingkungan ekstrem. Penelitian ini bertujuan untuk mengevaluasi daya tahan panas sapi Bali jantan dan betina dengan menggunakan *Iberia Heat Tolerance Coefficient* (IHTC), *Benezra's Coefficient of Adaptability* (BCA), dan *Thermal Stress Resistance Index* (TSRI). Analisis data yang digunakan adalah *independent samples t-test* untuk membandingkan antar jenis kelamin pada kondisi lingkungan stres (THI = 84.8–87.2). Hasil penelitian menunjukkan bahwa terdapat perbedaan yang signifikan ($P < 0,05$) pada nilai IHTC dan BCA antara sapi Bali jantan dan betina, sedangkan TSRI tidak menunjukkan perbedaan yang signifikan ($P > 0,05$). Sapi Bali jantan memiliki nilai IHTC yang lebih rendah dan BCA yang lebih tinggi dibandingkan sapi betina. Hal ini mengindikasikan bahwa sapi Bali betina memiliki daya tahan panas yang relatif lebih baik jika dibandingkan dengan sapi Bali jantan.

Kata Kunci: *Adaptasi Fisiologis, Cekaman Panas, Daya Tahan Panas, Sapi Bali, Tropis*

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INTRODUCTION

One of the main challenges in livestock maintenance systems in tropical regions is heat stress (Santoso et al., 2023). Heat stress occurs due to an imbalance between the body's heat production and its ability to dissipate heat, which can ultimately disrupt physiological functions and reduce productivity (Rinca et al., 2022). Under such circumstances, physiological adaptability becomes crucial in maintaining bodily functions and livestock production performance. The ability of livestock to adapt to heat stress is known as heat tolerance.

Physiological responses to thermal stress are typically characterized by increased body temperature, respiratory rate, and heart rate, which serve as mechanisms to accelerate heat dissipation from the body (Sukandi et al., 2023). This resistance to heat stress is complex because it is influenced by various factors, such as livestock breed, genetic traits, humidity, air circulation, sun exposure, coat condition, season, age, reproductive system, shading habits, and individual differences (Fayza et al., 2020; Qisthon et al., 2019). Therefore, heat tolerance measurements are necessary to determine how well livestock can survive in high-temperature environments.

The common method for assessing heat stress in livestock using environmental parameters is the Temperature-Humidity Index (THI). This index combines ambient temperature and relative humidity to estimate the level of thermal stress. High THI values have been shown to correlate positively with increased physiological stress in livestock (Chrást et al., 2023) and are widely used as an environmental indicator in studies of thermoregulation. In tropical regions like Indonesia, THI often exceeds the tolerance thresholds for livestock.

Kutai Kartanegara Regency has a tropical climate characterized by high temperatures and humidity throughout most of the year, which can create thermal conditions that are an environmental stress factor for livestock. In response to this challenge, Bali cattle are known as one of the local livestock breeds with proven adaptability to extreme environments (Racmadani et al., 2024; Baco et al., 2020). Bali cattle have also been designated as a national beef cattle breed through the establishment of SNI 7651-4:2020. This status emphasizes the strategic value of Bali cattle in supporting food security based on local livestock (Andhitia et al., 2022).

The effort to complete the missing data necessitates the application of an objective, standardized, and quantitatively measurable physiological measurement method. Several heat tolerance indexes that can be widely used to assess thermoregulation include the Iberia Heat Tolerance Coefficient (IHTC), Benezra's Coefficient of Adaptability (BCA), and Thermal Stress Resistance Index (TSRI). All three indexes use rectal temperature, respiratory rate, and heart rate as physiological indicators to measure adaptive responses to heat stress.

Based on this, this study aims to determine the level of heat tolerance in Bali cattle based on gender using the three heat tolerance index parameters.

MATERIALS AND METHODS

Study Location

This study was conducted on a farm situated in Manunggal Jaya Hamlet, Tani Bhakti Village, within the Loa Janan Subdistrict of Kutai Kartanegara Regency, East Kalimantan. The research was carried out in April 2025, and the farm is positioned at an altitude of 23 meters above sea level.

Study Animals

This study involved 20 Bali cattle, comprised of 10 males and 10 females, aged between 2 and 3 years. The cattle were purposefully selected based on their healthy physical condition and the absence of clinical signs of disease. They had a relatively uniform body weight, ranging from 250 to 280 kg.

Housing System

The cattle were housed intensively in open-sided pens, allowing direct exposure to microclimate conditions. Each animal was kept in an individual pen measuring 1 x 1.5 m. The roof material of the pen buildings is

made of galvanized iron. Prior to the start of the treatment, all cattle underwent a seven-day adaptation period to reduce stress caused by environmental changes and interaction with researchers or staff. Feeding occurred twice daily, offering forage and concentrate, tailored to the nutritional needs of each. Water was provided *ad libitum.* Handling and treatment of the cattle were carried out by experienced personnel in accordance with animal welfare principles to ensure comfort and minimize stress during the research period.

Physiological data collection as the basis for calculating the heat tolerance index was conducted when the livestock were under severe heat stress. During the study, THI values were recorded within the range of 84.8 - 87.2.

Study Parameters

1. Iberia Heat Tolerance

The Iberia Heat Tolerance Coefficient (IHTC) can be calculated using the formula from Rhoad (1944) as follows:

$$HTC = 100 – 10\ (RT\text{-}101)$$

Notes:
IHTC = The Iberia Heat Tolerance Coefficient
RT = Rectal Temperature (°F) measured at THI 84.8 - 87.2
101 = Perfect coefficient value at RT
10 = Constant

2. Benezra's Coefficient of Adaptability

Benezra's Coefficient of Adaptability (BCA) can be calculated using the following formula (Benezra, 1954):

Notes:

$$BCA = \frac{RT}{38.33} + \frac{RR}{23}$$

BCA = Benezra's Coefficient of Adaptability
RT = Respiratory Rate, measured at a THI of 84.8 - 87.2
RR = Respiratory Rate, measured at a THI of 84.8 - 87.2
38,33 = Normal body temperature
23 = Normal respiratory rate

3. Thermal Stress ResistanceIndex

The Thermal Stress Resistance Index (TSRI)) can be calculated using the following formula (Thomas et al., 1973):

$$TSRI = \frac{0.5RT_1}{RT} + \frac{0.3RR_1}{RR} + \frac{0.2HR_1}{HR}$$

Notes:
TSRI = Thermal Stress Resistance Index
RT_1 = Rectal Temperature (°C), measured at a THI of 84.8 - 87.2
RT = Rectal Temperature (°C) before exposure to heat stress
RR_1 = Respiratory Rate, measured at a THI of 84.8 - 87.2
RR = Respiratory Rate before exposure to heat stress
HR_1 = Heart Rate, measured at a THI of 84.8 - 87.2
HR = Heart Rate before exposure to heat stress

Statistical Analysis

The independent samples t-test was utilized to compare the heat tolerance index between male and female Bali cattle. Data analysis was conducted using IBM SPSS Statistics Version 29, and results were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Iberia Heat Tolerance Coefficient (IHTC)

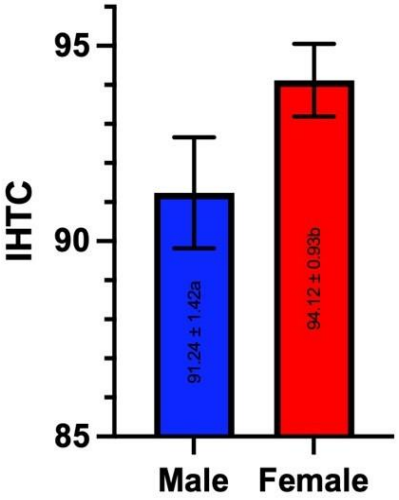

Figure 1. Mean IHTC Values for Male and Female Bali Cattle Under Severe Stress Conditions

In Figure 1, the IHTC values measured under severe environmental stress conditions were 91.24 ± 1.42 for male Bali cattle and 94.12 ± 0.93 for females, which statistically showed a significant difference ($P < 0.05$). IHTC is a measure developed to evaluate the extent to which livestock can adapt to heat stress, especially in tropical climates (Tej et al., 2020). The IHTC value reflects the ability of cattle to regulate their body temperature when facing heat stress, with higher values indicating better heat tolerance. This study shows that females have higher IHTC values than males, indicating that females have superior physiological adaptability to heat stress.

Adiputra et al. (2025) evaluated IHTC values in horned and polled Bali cattle and reported that although IHTC values in the morning were still within the tolerance range, there was a significant decrease during the day and after physical activity when the cattle were under heat stress. Other studies by Setiawan et al. (2021) and Kumari et al. (2018) showed that IHTC values tend to decrease under higher THI conditions. A similar finding was reported by Rai et al. (2022), who noted that heat tolerance adaptability in Murrah buffaloes decreased when THI conditions were in the range of 83–85 during summer compared to THI 77–80 during spring. Additionally, physical activity performed under heat stress conditions with high environmental THI can increase body heat accumulation in Bali cattle and indirectly negatively affect their physiological responses.

Heat stress can also have a negative impact on the reproductive system of livestock, for example, by disrupting the estrus cycle and the ovulation process and reducing the quality of somatic cells. Yosi et al. (2019), in their study on Madura cattle, showed that female Madura cattle had higher IHTC values than male Madura cattle. Female cattle with better heat tolerance, as indicated by higher IHTC values, have a greater chance of maintaining optimal reproductive function under tropical environmental temperature stress. Efficient adaptation to heat allows physiological and hormonal stability to be maintained, including key reproductive hormones such as LH and FSH. Therefore, female Bali cattle with better ther-

moregulatory capabilities not only demonstrate resilience to hot conditions but also have the potential to support reproductive efficiency, particularly in regions at risk of chronic heat stress (Wang et al., 2020; Giannone et al., 2023).

Kumar (2023) highlights in his research that low IHTC values are not only associated with physiological stress but also impact overall productivity, including growth, feed efficiency, and milk or meat production. Therefore, identifying individuals with high IHTC values is very important for determining adaptive management strategies, such as providing shade, scheduling feeding, or modifying livestock activity times to avoid exposure to extreme heat.

Benezra's Coefficient of Adaptability (BCA)

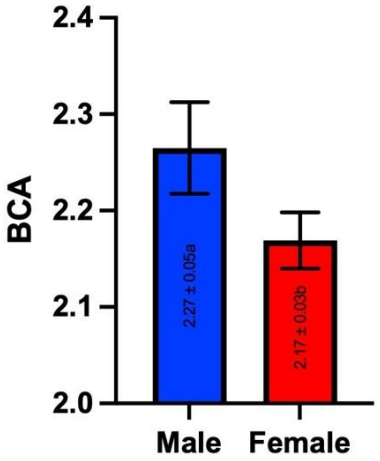

Figure 2. Mean Benezra's Coefficient of Adaptability Values for Male and Female Bali Cattle Under Severe Stress Conditions

The Benezra's coefficient of adaptability (BCA) is an index used to assess the efficiency of livestock physiological adaptation to hot environmental conditions. This index is calculated based on a combination of rectal temperature and respiratory rate. The ideal BCA value is 2, so the lower or closer to 2 the value is, the better the livestock's ability to maintain physiological balance under heat stress (Vaidya et al., 2025). In Figure 2, there is a significant difference between male and female Bali cattle ($P < 0.05$) in BCA values measured under severe environmental stress conditions. The BCA values for male and female Bali cattle were 2.27 ± 0.05 and 2.27 ± 0.05, respectively. This study aligns with the findings of Yosi et al. (2019), who reported that BCA values for female Madura cattle were lower than those for males. The lower BCA values in female cattle indicate that these animals have better adaptive capacity to high temperatures.

The significant difference between male and female Bali cattle suggests that females have better physiological adaptive capacity to heat stress. This is evident from the lower BCA values, which reflect body temperature stability and respiratory rate despite being in a high-temperature environment. In other words, female cattle can maintain more efficient thermoregulatory responses, thus avoiding excessive physiological changes such as extreme increases in rectal temperature or respiratory rate.

Utamy et al. (2024) explain that livestock with low BCA values exhibit a more stable and efficient body heat regulation system, characterized by physiological responses that remain within normal ranges despite exposure to heat stress. The study also confirms that stable body temperature and respiration in animals with low BCA values support metabolic function and maintain optimal reproductive activity. High BCA values indicate increasing intolerance of livestock to heat stress (Pribadi et al., 2021).

Thermal Stress Resistance Index (TSRI)

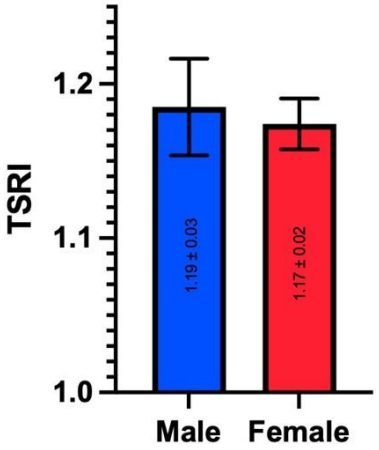

Figure 3. Mean Thermal Stress Resistance Index Values for Male and Female Bali Cattle Under Severe Stress Conditions

The Thermal Stress Resistance Index (TSRI) is a numerical indicator used to assess livestock's ability to adapt to heat stress based on key physiological responses, namely rectal temperature, respiratory rate, and heart rate. This index is calculated using a combined formula of these three parameters by comparing observed values to normal physiological values or values before exposure to heat stress. In thermoregulation research, TSRI is an important measurement tool because it can describe the overall heat resistance of livestock. An increase in TSRI values indicates a reduced ability to adapt to high ambient temperatures. Conversely, low TSRI values indicate the ability of an animal to maintain physiological stability in the face of heat stress (Thomas et al., 1973).

The TSRI values for male and female Bali cattle were 1.19 ± 0.03 and 1.17 ± 0.02, respectively, indicating no statistically significant difference ($P > 0.05$). Although the numerical TSRI value for male cattle is slightly higher, the difference is not large enough to indicate a difference in thermal adaptation between the sexes. This indicates that both groups of Bali cattle demonstrate good heat adaptation ability, with physiological responses still within normal limits based on reference physiological values for tropical livestock. Furthermore, Singaravadivelan et al. (2025) stated that TSRI values are considered to increase significantly when exceeding 2.0, reflecting high heat stress on the animals and reduced physiological adaptation capacity. Conversely, TSRI values approaching 1.0–1.2 indicate good thermal adaptation performance, as found in the Vechur cattle in that study.

It is important to note that TSRI values are not constant; they tend to fluctuate in response to changes in the microenvironment surrounding the animals, including temperature, humidity, and air circulation. Rai et al. (2022) reported that the TSRI values for Murrah buffaloes were lower in spring than in summer. Additionally, the TSRI values can be significantly influenced by the physiological condition of each individual animal, which may vary based on factors such as age, reproductive status, activity level, and overall health (Amir et al., 2025)

CONCLUSION

The results indicate that Bali cattle, both male and female, possess strong physiological adaptability to tropical environments, as evidenced by their heat tolerance index values. However, there are significant differences between the sexes regarding the Iberia Heat Tolerance Coefficient (IHTC) and Benezra's Coefficient of Adaptability (BCA). Female cattle display higher IHTC values and lower BCA values compared to their male counterparts, suggesting that female Bali cattle have better heat tolerance. Therefore, gender should be considered when managing Bali cattle in tropical climates.

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