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Physiological Response and Endurance of Madurese Cattle and Their Crosses at The Tropical Environment in Pamekasan Regency

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ABSTRACT. This study aimed to determine the physiological response of Madura cattle and Limura cattle (Limousin x Madura) to the tropical environment. The research was conducted in Galis District, Pamekasan Regency from July to August 2024. The sample consisted of 50 Madura and Limura cattle, selected by purposive sampling. The parameters observed included rectal temperature, respiratory frequency, heart rate frequency, Heat Tolerance Coefficient (HTC), as well as the microclimate of the pen, which included air temperature, relative humidity (RH), and Temperature Humidity Index (THI). The results showed that the average THI at the research site was 83.24. The average rectal temperature (°C) in the morning, afternoon, and evening for Madura and Limura cattle were as follows: 37.7±1.5, 38.7±0.4, 37.2±0.7 for Madura cattle, and 38.6±0.5, 38.9±0.3, 38.5±0.3 for Limura cattle, respectively. The mean respiratory frequency (times/minute) in the morning, afternoon, and evening for Madura and Limura cattle were: 23.5±3.4, 28.6±6.8, 23.3±5.2 for Madura cattle, and 25.6±2.0, 30.3±2.0, 26.7±3.1 for Limura cattle, respectively. The mean heart rate (times/minute) in the morning, afternoon, and evening for both groups were similar: 65.3±4.2, 69.5±9.8, 65.1±6.7 for Madura cattle, and 65.4±3.8, 69.8±11.8, 66.5±4.2 for Limura cattle, respectively. The mean Heat Tolerance Coefficient (HTC) for Madura and Limura cattle were 2.1±0.23 and 2.2±0.1, respectively. It was concluded that both Madura and Limura cattle exhibit similar responses in terms of heart rate and respiration rate. However, Madura cattle have lower rectal temperatures than Limura cattle. The Heat Tolerance Coefficient (HTC) was found to be higher in Limura cattle compared to Madura cattle.

Keywords: HTC, Limura cattle, Madura cattle, physiological, response

INTRODUCTION

Beef cattle are vital livestock commodities supporting the livestock sector in Indonesia, especially in the Madura region. Madura cattle are known for their excellent adaptability to harsh tropical environmental conditions (Kurniati et al., 2022). Additionally, Madura cattle have been crossbred with Limousin cattle to produce Limura cattle (Limousin × Madura), which are expected to inherit the superior traits of both breeds, improving both productivity and environmental adaptation. According to data from the East Java Livestock Service Office (2022), beef cattle production in Pamekasan Regency totaled 2,664,972 heads, with 60% (1,598,983 heads) being Madura cattle and 40% (1,065,672 heads) being Limura cattle.

The tropical environment of Pamekasan Regency, Madura, characterized by high temperatures, extreme humidity, and fluctuating feed availability throughout the year, presents challenges for livestock in maintaining health and productivity. As Asmarasari et al. (2023) noted, tropical conditions in Indonesia are environmental factors that influence livestock growth and physiological status. The condition of livestock reflects their biological capabilities, which include production activities. Growth rate is one of the key performance indicators used to assess the success of beef cattle farming.

To cope with these extreme environmental conditions, cattle must exhibit strong physiological responses, such as maintaining stable body temperature, efficient respiration rate, and balanced heart rate to sustain homeostasis. Furthermore, the physiological endurance of cattle under environmental stress can be assessed through the Heat Tolerance Coefficient (HTC), which reflects the ability of livestock to maintain optimal oxygen and blood circulation under stressful environmental conditions.

The aim of this study was to investigate the differences in physiological responses (rectal temperature, respiration rate, and heart rate) between Madura cattle and Limura cattle in Pamekasan Regency. This research is crucial as it provides scientific insights into the adaptation of these two cattle breeds to the Madura environment. Understanding the physiological differences in adaptation between local Madura cattle and crossbred Limura cattle will provide valuable information for the development of effective cattle breeding policies in tropical regions, as well as improving livestock management practices in Pamekasan Regency.

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MATERIALS AND METHODS

Location and Time

This research was conducted in Galis District, Pamekasan Regency, Madura from July 8 to September 2, 2024.

Research Material

The research material consisted of 50 Madura cows and 50 Limura cows (Limousin × Madura) from the first generation (F1), aged 1 to 2 years, all of which were female. The selection of females was based on the fact that female cows are more susceptible to heat stress than males (Sutedjo, 2016). Data were obtained from farmers across Galis District, Pamekasan Regency.

Equipment Used

The following equipment was used in the study: a stethoscope for measuring pulse, a stopwatch and hand counter to calculate respiratory rate, a clinical thermometer to measure rectal temperature, and a thermohygrometer to measure ambient temperature and relative humidity.

Method

This research employed a survey method with primary data collection. Primary data were gathered through direct measurements in the field, which included temperature and humidity at the research site, Temperature Humidity Index (THI), rectal temperature, respiratory rate, heart rate, and Heat Tolerance Coefficient (HTC). The sampling method was purposive sampling, which involved selecting healthy Madura and Limura cattle that were not pregnant.

Parameters Observed

Two main aspects were measured: abiotic environmental factors and the physiological aspects of the cattle. The abiotic environmental factors include temperature, relative humidity, and the Temperature Humidity Index (THI). The physiological parameters of the cattle include rectal temperature, respiratory rate, heart rate, and Heat Tolerance Coefficient (HTC). Measurements were taken three times a day: in the morning (05:00-09:00 WIB), afternoon (12:00-15:00 WIB), and evening (16:00- 8:00 WIB), over a period of 30 days. The climate variable was used to measure the Temperature Humidity Index (THI) using the formula based on Jeelani et al. (2019).

$$THI = (1.8 \times T + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T - 6)]$$

Description:
THI = Temperature Humidity Index (THI)
T = Air Temperature (°C)
RH = Relative Humidity (%)

The physiological parameters measured include rectal temperature, heart rate, respiration rate, and Heat Tolerance Coefficient (HTC). Rectal Temperature: Rectal temperature was measured using a rectal thermometer. One-third of the thermometer was inserted into the cow's rectum, and the measurement was taken for one minute. The result recorded was the cow's rectal temperature. This measurement was repeated twice (duplo) for accuracy. Heart Rate (Pulsus): Heart rate was measured by palpating the vena caudalis at the base of the cow's tail. The pulse was measured for one minute and repeated twice (duplo) to ensure consistency. Respiration Rate: Respiration rate was assessed by placing the back of the hand near the cow's nose to detect the exhalation. The measurement was taken for one minute and repeated twice (duplo) to confirm the result. Heat Tolerance Coefficient (HTC): Heat tolerance was evaluated using the Heat Tolerance Coefficient (HTC) based on the method of De Bie et al. (2019).

$$HTC = RR/23 + RT/38$$

Description:
HTC = Heat Tolerance Coefficient (HTC)
RR = Respiratory Rate (times/minute)
RT = Rectal Temperature (°C)

Data Analysis

The variables observed in this study included the physiological responses of livestock, which were measured as rectal temperature (°C), respiratory rate (times/minute), heart rate (times/minute), and Heat Tolerance Coefficient (HTC). Additionally, the microclimate of the enclosure was measured, including air temperature, Relative Humidity (RH), and Temperature Humidity Index (THI). The data obtained were analyzed using an unpaired comparison test (T-test), with Madura cattle and Limura cattle considered as separate treatment groups.

RESULTS AND DISCUSSION

Temperature Humidity Index (THI) at the Research Location

Galis District is located between 113º19'-113º58' East Longitude and 6º51'-7º31' South Latitude, with an elevation ranging from 1 to 16 meters above sea level. This district is a lowland area and is one of six districts in Pamekasan Regency that borders the sea (Pamekasan in Figures, 2024). The results of observations on the average air temperature, humidity, and Temperature Humidity Index (THI) are presented in Table 1.

Table 1. Average air temperature, humidity, and THI at the research location

Climate Element	Value
Temperature (ºC)	33.6±1.2
Humidity (%)	52±0.9
THI	83.24±2.1

Source: Primary data processed

Table 1 shows that the air temperature is considered high for livestock, especially cattle. Cattle are homeothermic animals with a limited ability to regulate their body temperature within the normal range (Toledo et al., 2020). When ambient temperatures exceed 30°C, cows begin to show symptoms of heat stress because their ability to dissipate heat becomes limited. An air humidity level of 52% still allows for evaporation through respiration and sweating in cows, although the efficiency of evaporation decreases at high temperatures. However, if humidity continues to rise, the cow's ability to cool its body through sweating will be reduced (Cooke et al., 2020).

The Temperature Humidity Index (THI) is a combined indicator of air temperature and humidity used to assess the potential for heat stress in livestock. A THI value of 83.24 indicates that the environmental conditions in Galis District, Pamekasan Regency, fall into the dangerous category for livestock. In general, a THI value exceeding 78 is considered a high risk for heat stress in cattle (Singh et al., 2019). Heat stress negatively impacts cattle physiology. Physiological effects include increased respiratory and heart rates, decreased feeding activity, and changes in milk or meat production patterns in beef cattle. Heat stress leads to reduced feed consumption as cattle prefer to rest rather than eat, which results in decreased productivity (Hussain et al., 2023).

Physiological Parameters

Rectal Temperature

The average rectal temperature of Madura and Limura cattle during the study is presented in Table 1. The results of the T-test analysis show a significant difference (P>0.05) between Madura and Limura cattle in terms of their rectal temperature responses. The body temperature values indicate that the livestock are in normal condition, as supported by the research of Polsky and von Keyserlingk (2017), which defines normal temperatures as 38-39.2°C. The highest average body temperature and standard deviation were recorded in Limura cattle at noon, with a value of 38.9±0.3°C. This indicates that the cattle are able to adapt to the surrounding environment and maintain their body temperature within normal limits.

The increase in body temperature during the day (Figures 1 and 2) is due to the rise in ambient temperature. The ambient temperature fluctuates over a 24-hour period, reaching its maximum when solar radiation intensity peaks, typically between 12:00 and 14:00 local time. Body temperature is considered an index of ambient temperature, despite temperature variations in different parts of the livestock's body at various times of the day (Aditia et al., 2017).

Respiratory Rate

Based on Table 1, it is evident that the average respiration frequency of Limura cattle is higher than that of Madura cattle. The results of the T-test analysis show a significant difference (P>0.05) between Madura and Limura cattle in terms of their physiological response to respiration. Livestock breathe to take in oxygen and release carbon dioxide. The respiration process also plays a role in heat dissipation during conditions of heat stress (Mishra, 2021). According to Islam et al. (2023), the normal respiration rate in cattle ranges from 18 to 34 times per minute. Both Madura and Limura cattle exhibit normal respiration rates, indicating that the cattle are not experiencing distress. During the day, Limura cattle have the highest respiration rate compared to Madura cattle, at 30.3±2.0 times per minute.

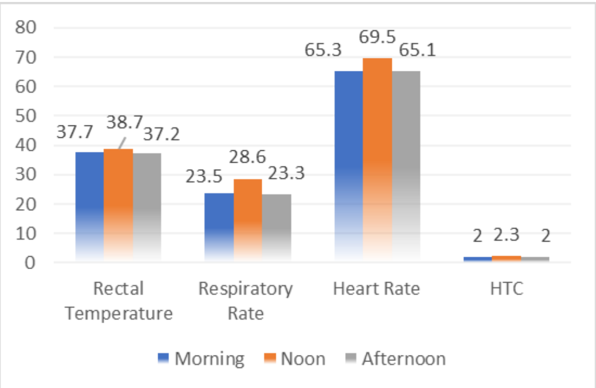

Figure 1. Physiological response of Madura cattle

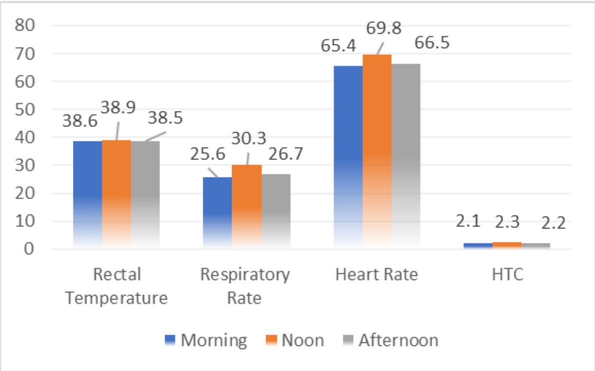

Figure 2. Physiological response of Limura cattle

The respiration rate increases from morning to noon and then decreases in the afternoon for both Madura and Limura cattle (as shown in Figures 1 and 2). The difference in respiratory rates between Madura and Limura cattle can be attributed to several factors, including genetics, environment, and body size. As Madura and Limura cattle are different breeds, genetic differences between the two may influence the function and characteristics of their respiratory systems. Genetic variation can impact lung size and capacity, sensitivity to environmental conditions, and respiratory regulation (Aritonang et al., 2017). Additionally, the difference in body size between Madura and Limura cattle may also affect respiratory rate. Madura cattle generally have a smaller body size compared to Limura cattle, which could influence lung capacity and oxygen requirements (Yan et al., 2019).

Table 2. Physiological parameters of madura cattle and limura cattle

Type	n (Head)	Physiological Status									HTC
		Rectal Temperature (°C)			Respiratory Rate (Times/minute)			Heart Rate (Times/minute)			
		Morning	Noon	Afternoon	Morning	Noon	Afternoon	Morning	Noon	Afternoon	
Madura	50	37.7±1.5^a	38.7±0.4^a	37.2±0.7^a	23.5±3.4^a	28.6±6.8^a	23.3±5.2^a	65.3±4.2^a	69.5±9.8^a	65.1±6.7^a	2.1±0.23^a
Limura	50	38.6±0.5^b	38.9±0.3^b	38.5± 0.3^b	25.6±2.0^b	30.3±2.0^b	26.7±3.1^b	65.4±3.8^a	69.8±11.8^a	66.5±4.2^a	2.2±0.1^b

Note: Different lowercase letters in the same column indicate a significant difference between treatments (P<0.05)

Heart Rate

The heartbeat is a mechanism used by the cow's body to dissipate or release heat absorbed from the environment. Analysis of the heart rate for both Madura and Limura cattle shows no significant difference (P<0.05). According to Yan et al. (2019), increased peripheral circulation is an effort to accelerate the release of body heat. Livestock under heat stress will experience an accelerated heart rate to increase blood circulation, allowing body heat to reach the surface of the animal and be released into the environment. Madura cattle exhibit a higher average heart rate, indicating that they can dissipate more heat into the surrounding environment by increasing blood flow to the surface of their bodies (Machado et al., 2016).

The average morning, noon, and evening heart rates for both Madura and Limura cattle, as shown in Table 2, remain within the normal range. According to Toledo et al. (2020), the normal heart rate for adult cattle in tropical climates is approximately 40-70 beats per minute. The highest heart rate was observed at midday (2:00 p.m. Western Indonesian Time). The high heart rate observed in the afternoon and evening indicates the high heat load in the body that must be distributed to the skin surface (Wangui et al., 2018). The heart rate and ambient air temperature values are directly proportional, as evidenced by the study results of Singh et al. (2019), which are supported by Velayudhan et al. (2023). These studies show that daily livestock activities, such as eating and standing for extended periods, increase during the day.

Heat Tolerance Coefficient (HTC)

The heat resistance of cattle in an environment is considered optimal when the HTC value is equal to 2.0. The higher the HTC value, the lower the heat resistance (Maylinda and Riskila, 2023). Based on Table 2, the HTC values for Madura cattle and Limura cattle are 2.1±0.23 and 2.2±0.1, respectively. It can be observed that the average HTC for both Madura and Limura cattle exceeds the optimal value. Both cattle types (Table 2) show HTC values above the standard body temperature (38.3°C) and respiratory rate (23 breaths/minute) at high ambient temperatures. Although the difference between the two is not substantial, it indicates that both Madura and Limura cattle demonstrate relatively good adaptability to hot environments. However, during the day when the air temperature rises, Limura cattle are observed panting and increasing their respiration rate. According to Nurhidayat et al. (2024), an HTC value exceeding 2 suggests that the cattle are experiencing heat stress, which may be influenced by feed factors and environmental discomfort.

CONCLUSION

This study concludes that Madura cattle and Limura cattle exhibit similar responses in several physiological parameters, including heart rate and respiration rate. However, the rectal temperature of Madura cattle is lower than that of Limura cattle. Additionally, the Heat Tolerance Coefficient (HTC) of Limura cattle is higher than that of Madura cattle.

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