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Innovative Barn Cattle for Microclimate Management through the Misting System

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ABSTRACT

Cattle is meat-producing livestock of the large ruminant. The environmental conditions must remain in the thermoneutral zone because this affects livestock productivity. An environmental modification related to microclimate management is required through a misting system using a water sprinkler. The study was conducted in one of the barns of the Sekolah Peternakan Rakyat (SPR) Maju Bersama livestock group in Drokilo Village, Kedungadem District, Bojonegoro Regency, East Java. The purpose of this study was to analyze the microclimate management of the barn through the misting system in order to improve the physiological response of cattle. The variables observed were the air temperature, air humidity, Temperature Humidity Index (THI), respiratory frequency, heart rate, rectal temperature, and body surface temperature. Body surface temperatures were measured on the face, back, and rump. The analytical method used in this was unpaired T-test five replications. The results showed that the average microclimate data for barn cattle were: air temperature 27.40±0.59°C, air humidity 83.92±1.55%, and Temperature Humidity Index (THI) 79.59±1.06. The results showed that the average physiological response data for cattle were: heart rate 47.02±2.29 beats per minute, respiration rate 16.94±1.26 beats per minute, and rectal temperature 38.65±0.27°C. The results showed that the average body surface temperature data for the face was 37.03±0.38°C, the back was 36.33±0.59°C, and the rump was 36.28±0.68°C. The results showed that the treatment before and after the morning measurement water misting was significantly different ($p<0.05$) in all the observed variables. Water misting has the effect on decreasing the air temperature, humidity, Temperature Humidity Index (THI), respiratory rate, heart rate, body temperature, and rectal temperature.

Keywords: Cattle, Innovative barn, Microclimate, Misting process

Introduction

The population of cattle in 2021 will reach 18,053,710 heads, and the province of East Java has a population of 4,938,874 heads (BPS, 2021). Ongole Crossbreed (PO) cattle are the result of crosses between Ongole cattle and local cattle, especially Java cattle, resulting in cattle that are similar to Ongole cattle Hamdani *et al*., 2019).

According to the BMKG (2022b), the air temperature in Indonesia ranges from 23 to 31°C, with air humidity ranging from 68 to 96%. The results of the calculation of the average THI ranged from 71.23 to 87.89. This shows that the THI value is in the normal category of severe stress for the livestock environment (Bulitta *et al.,* 2015). The temperature of the tropical climate is relatively high, so cattle make metabolic adjustments to adapt to the environment. This makes the formation of meat slow because of the energy needed in the metabolism of the cattle's body. Some cattle breeds in Indonesia come from a subtropical climate, so the cattle need a longer adaptation time. The tropical climate can cause long dry events, thus disrupting the provision of forage for livestock, especially cattle (Sudarmono and Sugeng, 2016).

Microclimate control aims to determine the comfort level of livestock, which is influenced by air temperature, humidity, solar radiation, and wind speed (Nuriyasa *et al.,* 2015). The core body temperature of livestock, especially cattle, is normally 38-39°C (Amiano *et al.,* 2018). According to Yetmaneli *et al.* (2020), the ideal air temperature for tropical cattle is around 22-30°C. The humidity that is suitable for the environment for cattle is 50-75% (Yani *et al.,* 2013).

Changes in air temperature can affect the comfort of cattle, so they experience heat stress (hyperthermia) or cold stress (hypothermia). Cattle will give an initial response in the form of changes in behavior and increased activity of the respiratory and cardiovascular systems. Follow-up responses, namely changes in the hormonal, enzymatic, and metabolic systems, will occur if the initial response has not reached a state of homeostasis. Livestock will experience various disease symptoms accompanied by low production and reproductive efficiency if the follow-up response has not yet reached a state of homeostasis (Yetmaneli *et al.,* 2020). The respiratory rate of adult cattle is in the range of 15-35 times per minute (Serang *et al.,* 2016). According to Aditia *et al.* (2017), the heart rate of cattle under normal conditions is between 40 and 65 beats per minute. The body temperature of cattle in the tropics is 33.5 - 37.1°C (Novianti *et al.,* 2013). Environmental control management techniques, such as modification techniques to control the heat temperature, need to be implemented. This aims to provide a level of comfort for livestock so that it can produce optimally (Adhianto *et al.,* 2015).

The barn is used as an important factor because it can protect livestock from outside disturbances such as sunburn, bad weather, rain, and strong winds so that it can determine the health of livestock (Sandi and Purnama, 2017). According to Suherman *et al.* (2017), several efforts have been made in modifying the microclimate environment, namely choosing low-conductivity roofing materials and increasing the size of the barn. One way to increase the size of the barn is to elevate the roof of the barn so that the volume of air and airflow that enters the barn becomes larger. Efforts to engineer the use of technology to reduce hot air temperatures and physiological effects due to heat stress can be carried out using sprinklers on livestock bodies (Adhianto *et al.,* 2015). This study aims to analyze the microclimate management of the barn through the misting system in improving the physiological response of cattle, especially those related to cattle thermoregulation such as body temperature, heart rate, and respiratory rate.

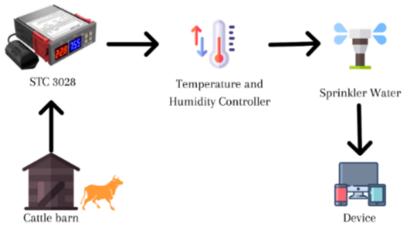
Materials and Methods

Research area

This research was conducted from November to December 2021. The study was conducted in one of the barns of the Sekolah Peternakan Rakyat (SPR) Maju Bersama livestock group in Drokilo Village, Kedungadem District, Bojonegoro Regency, East Java. The total area of Bojonegoro Regency is 2,307.06 km^2 with the total area owned by the Kedungadem District of about 145.15 km^2 long (BPS, 2013). The average air temperature and average humidity in Bojonegoro Regency, Kedungadem District, are 28°C and 70% in the morning (BMKG, 2022a). The average air temperature and average humidity during the research were 28.30-28.84°C and 81.72-83.96% in the morning.

Material and equipment

The materials used in this study were five two-year-old female Peranakan Ongole (PO) cattle, water (drinking water and water for misting), and feed. The equipment used to regulate the microclimate of the barn is a sprinkler water system. The STC 3028 thermohygrocontroller can show temperature and humidity data through the DHT11 sensor while running the pump so that misting occurs. Sprinkler water functions to control the air temperature of the cattle pens by marking the temperature of the barn at the desired temperature. The Flir C2 thermal camera is used to measure the temperature of the components of the pen, such as the roof, floor, and animal feeding area. The tools used to measure the physiological response of cattle are a respiration and heart rate measuring belt (heart rate and respiration sensor), and a digital thermometer to measure rectal temperature.



Sprinkler Water scheme

Data collection

Data collection was carried out by observing the pens, which were given two treatments: one in the morning without going through the misting system (P1) and one in the morning through the misting system (P2). The morning measurement was carried out around 08.00-09.00 AM. Data collection was carried out five times for each observed variable. This data collection was carried out for five days for each treatment.

Data collection before going through the misting system was carried out on November 8-12, 2021. The data was collected before the installation of the sprinkler water device. This is done to determine the original air temperature in the enclosure environment to be observed. Data retrieval after going through the misting system was carried out from November 29th, 2021 until December 3rd, 2021. The data was taken after the water sprinkler was turned off. This is done to prevent data collection in the form of water vapor temperature.

The variables observed were the temperature of the air temperature, air humidity, Temperature Humidity Index (THI), respiratory frequency, heart rate, rectal temperature, and body surface temperature. Body surface temperatures were measured on the face, back, and rump. The temperature and humidity of the barn air were measured using a thermohygrometer. Measurement of the temperature and humidity of the barn air is done by placing the Xiaomi Meija thermohygrometer in the middle of the barn environment. The results of recording data on the temperature and humidity of the air in the cattle pen are used to calculate the Temperature Humidity Index (THI). According to Bulitta *et al.* (2015), the mathematical model of the Temperature Humidity Index (THI), namely:

$$THI = 0.8Tab + RH (Tab – 14.4) + 46.4$$

Information:
THI = Temperature Humidity Index (THI);
Tab = Ambient air temperature (°C); and
RH = Humidity (%).

Heart rate data acquisition using a Polar heart rate belt and stethoscope. Measurements are made by attaching a heart rate monitor belt to the left chest, and the measurement results are viewed through the application Strava. Acquisition of heart rate is also done using a stethoscope. It aims to compare the measurement results using a heart rate measuring belt. Respiratory rate acquisition using a Vernier respiration belt. Measurements are made by attaching a tool to the chest. Measurement results are viewed through the application for one minute. Rectal temperature of cattle using a digital thermometer. Rectal temperature is measured by inserting a digital thermometer in the rectal area. Measuring body surface temperature using thermal camera flir C2.

Data analysis

The data obtained were analyzed using an unpaired T test. A T-test analysiz is used to determine the effect of the fogging system on the management of stable microclimates and the physiological responses of cattle. The formula for the T test (Walpole, 1995) is as follows:

$$T = \frac{(\bar{y}a - \bar{y}b)\ (\mu a - \mu b)}{sb\sqrt{\frac{1}{na} + \frac{1}{nb}}}$$

Information:
a. = controls;
b. = treatment;
ȳa = sample mean a;
ȳb = sample mean b;
µa = population mean a;
µb = population mean b;
sb = standard deviation of sample
na = number of samples a; And
nb = number of samples b.

Results and Discussion

Barn characteristic and microclimate

The barn used during the study had a spandex roof type with lightweight steel roofing material. The barn area is 168 m^2 (12 m wide and 14 m long) and the barn capacity is 48 birds. The barn used during the study had a height of 4 m. The direction of the barn during the study was facing north. The materials that make up the barn include hebel walls, cement floors, plastic feed containers, and concrete barn frames.

Table 1. Category Temperature Humidity Index (THI)

THI value	Category heat stress
74	Normal
75–78	Mild
79–83	Moderate stress
84	Severe stress

Source: Bulitta *et al.,* 2015.

The microclimate can be evaluated through the state of the cattle pen, namely the comfort of the barn and the physiological response of the livestock. Measurement of the evaluation of the microclimate environment is needed to know the effect of the environment on livestock productivity (Suherman *et al*., 2017). Temperature and humidity data are used to measure the Temperature Humidity Index (THI), which aims to study the impact of heat stress on livestock (Dzivenu *et al*., 2020). From the BMKG microclimate data above, it can be said that the average relative temperature and humidity are the same as the microclimate data before misting (Table 2).

Table 2. Air temperature and humidity before and after misting

Day to	Temperature (°C)		Humidity (%)	
	Before	After	Before	After
1	28.40	28.20	85.0	84
2	29.10	27.20	78.0	84
3	27.40	28.90	86.0	79
4	28.00	28.60	82.0	76
5	27.50	28.40	80.0	87
Mean	28.26	28.08	82.2	82

Source: BMKG (2021).

Based on the Table 3, the average air temperature of the barn before and after misting is 28.15°C and 27.40°C, respectively. Yetmaneli *et al.* (2020) found that the ideal air temperature for tropical cattle is around 22°C - 30°C. The average ambient air temperature in the morning before and after misting is still within normal limits. The results of the statistical analysis of the ambient air temperature of the barn before misting were significantly higher than after misting ($p<0.05$). This means that the use of sprinkler water improves the microclimate of the livestock pen.

Based on Table 3, the average air humidity before and after misting is 84.34% and 83.92%, respectively. The humidity that is suitable for the cattle environment is 50% - 75% (Yani *et al.,* 2013). The average humidity of the ambient air exceeds the normal limits both before and after misting. The results of the statistical analysis of the humidity of the barn environment before misting showed that it was significantly higher than after misting ($p<0.05$). This means that the use of sprinkler water has improved the humidity of the livestock pen.

According to Prakoso (2018) if the air temperature of an environment is high, it causes low air humidity, and vice versa, if the air temperature is low, then the air humidity is high. This research shows low air temperature and low humidity. This statement describes the state of air temperature and humidity that is not Prakoso's opinion (2018). This happens because the misting of the water droplets is released as steam or gas. The form of the water has a lighter mass, so when

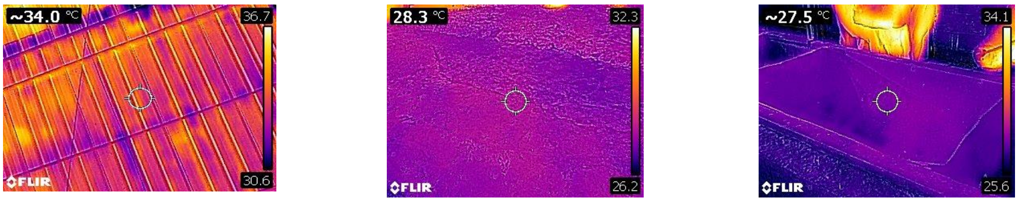


Figure 1. Temperature of barn using a thermal camera.

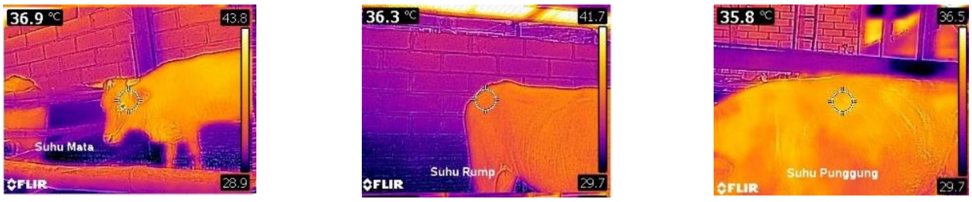


Figure 2. Body surface temperature using a thermal camera.

Table 3. Microclimate of the barn before and after misting

Day	Mean air temperature		Mean humidity		THI value	
	Before	After	Before	After	Before	After
1	28.48±0.36	27.32±0.60	84.56±0.36	81.76±1.48	80.25±0.87	79.63±1.24
2	28.00±0.44	27.59±0.6	84.40±0.50	84.12±1.05	80.18±0.80	79.71±0.66
3	28.46±0.23	27.61±0.55	84.60±0.76	83.76±0.97	80.66±0.75	79.95±1.03
4	27.90±0.33	27.06±0.48	84.28±1.06	85.28±0.46	79.84±0.85	79.09±1.02
5	27.90±0.31	27.44±0.58	83.88±0.73	84.68±0.75	79.91±0.84	79.56±0.89
Mean	28.15±0.43^{a}	27.40±0.59^{b}	84.34±0.81^{a}	83.92±1.55^{b}	80.17±0.86^{a}	79.59±1.06^{b}

^{a,b} Numbers with different superscripts in the same row indicate significant differences (p<0.05).

the water comes out, the water is absorbed by the heat from the barn, making the air temperature decrease. The humidity does not decrease because the water vapor, when it comes out, can be immediately lost to the wind in the barn, which makes the humidity value not increase.

Based on the Table 3, the average value of the Temperature Humidity Index (THI) before and after misting is 80.17 and 79.59, respectively. According to Bullita *et al.* (2015), the categories of THI values are THI 74 under normal conditions, THI 75 - 78 under mild stress conditions, THI 79 - 83 under moderate stress conditions, and THI 84 under severe stress conditions. The average environmental THI in this study causes livestock to be in a state of moderate stress.

According to Efendy (2018), the higher the level of heat stress experienced by livestock, the lower the weight gain in livestock. The results of the analysis of the average THI of the barn environment before going through the morning misting system were significantly higher (p<0.05). This means that the use of sprinkler water through the misting system improves the microclimate of the livestock pen.

Physiological response of cattle

The physiological response is like describing what the cattles are feeling and in order to make sure that they feel comfortable enough for them to be able to reproduce optimally. These factors are influenced by the internal environment and stress obtained from the external environment (Hermawansyah *et al.,* 2020). According to Brandl (2018), the physiological responses of cattle that can be measured include respiratory frequency, heart rate, body temperature, and a blood profile. The physiological response of cattle can also be measured by measuring the core body temperature of cattle, commonly called rectal temperature (Sahu *et al.*, 2018). According to Suherman *et al.* (2017), the physiological response of cattle increases based on increasing environmental temperature. The following is Table 4 about physiological response of the barn before and after misting.

As shown in Table 4, the average heart rate decreased from 55.94 times per minute before misting to 47.02 times per minute after fog. According to Aditia *et al.* (2017), the heart rate of cattle under normal conditions is between 40 and 65 beats per minute. The average heart rate before and after misting is still within normal limits. The results of the analysis of heart rate before going through the misting system were significantly higher (p<0.05). This means that the use of sprinkler water improves the physiological response of cattle.

Based on Table 4, the average respiratory frequency of cattle before water misting is 18.10 times per minute, but after water misting it becomes 16.94 times per minute. According to Serang *et al.* (2016), the respiratory rate of normal cattle is in the range of 15-35 times per minute. The average respiratory rate before and after water misting is still within normal limits. The result of respiratory frequency analysis before going through the misting system was significantly higher (p<0.05). This means that the water misting effects improve the physiological response of cattle.

Based on the Table 4, the average rectal temperature before misting was 38.85°C, and after misting it was 38.65°C. The core body temperature

Table 4. Physiological response of the barn before and after misting

Animal	Heart rate (per min)		Respiratory rate (per min)		Rectal temperature (°C)	
	Before	After	Before	After	Before	After
Cattle 1	56.64±2.66	48.52±2.12	18.64±1.35	16.96±1.37	39.01±0.19	38.81±0.22
Cattle 2	57.64±2.43	47.64±2.36	18.04±1.71	16.88±1.18	38.92±0.16	38.75±0.18
Cattle 3	54.24±2.33	45.84±2.21	17.76±1.36	16.92±1.06	38.79±0.25	38.62±0.25
Cattle 4	55.60±2.94	46.76±2.15	18.40±1.39	16.68±1.16	38.78±0.25	38.51±0.27
Cattle 5	55.60±2.84	46.32±1.65	17.68±1.67	17.24±1.42	38.74±0.30	38.56±0.29
Mean	55.94±2.85[a]	47.02±2.29[b]	18.10±1.55[a]	16.94±1.26[b]	38.85±0.25[a]	38.65±0.27[b]

[a,b] Numbers with different superscripts in the same row showed significant differences ($p<0.05$).

of livestock, especially cattle, is normally 38°C - 39°C (Amiano *et al.,* 2018). The measurement results show that the average rectal temperature of cattle before and after misting is still within normal limits. The result of the analysis of rectal temperature before going through the misting system was significantly higher ($p<0.05$). This means that the misting system improves the physiological response of cattle.

Body temperature

The body surface temperature will be higher if the barn temperature is high (Novianti *et al.,* 2013). Measurements using a thermal camera are used to reduce stress in in cattle due to direct physical contact. The following is Table 5 about face temperature before and after water misting.

Changes in the temperature of the cattle's faces before and after water misting during the day showed significantly different results. The temperature of the face is in the range of 37.21-37.7°C. According to Novianti *et al*. (2013), the ideal body surface temperature is 33.5°C - 37.1°C, so in this study cattle experienced heat stress before water misting. The high temperature of the barn causes the cattle's faces to become hot, causing them to experience heat stress, especially during the day. The high temperature of the barn environment will be directly proportional to the body surface temperature. The decrease in the temperature of the face after water misting indicates that the temperature and humidity of the barn have decreased, approaching the thermoneutral zone of the cattle, so that they feel comfortable. High body surface temperature indicates that the cattle are exposed to heat stress, which is indicated by the protruding tongue, which causes the cattle not to eat so that the cattle's productivity will decrease, and if it occurs for a long time, it will cause the livestock to die (Sihombing, 1999).

The daytime back temperature had a significant effect on cattle 1, 2, and 4, while cattle 3 and 5 were not significantly different. Based on Novianti *et al.* (2013), the ideal body surface temperature in cattle is 33.5°C - 37.1°C. Cattles that experience heat stress due to back temperature exceeding the normal limit before water misting are two cattles. The difference in yield of dorsal temperature may be due to the different thermoregulatory abilities of cattle (Brandl and Jones, 2011). The temperature of the barn is directly proportional to the surface temperature of the cattle's body, if the environmental temperature is high, the cattle's thermoregulation system will regulate the temperature in the body, which makes the body's surface temperature increase due to the release of heat. The following is Table 7 about rump section temperature before and after water misting.

The temperature of the rump during the day has a significant effect on cattle 1, 2 and 4, while in cattle 3 and 5, there is no significant difference. This is influenced by environmental factors such as the high temperature and humidity of the barn. Body surface temperature after water misting decreased because the temperature and humidity of the barn approached the cattle's thermoneutral zone. High body surface temperature can be interpreted as a thermoregulatory mechanism in the cattle's body. Thermoregulatory mechanisms can increase body temperature, heart rate and respiratory rate. This can be judged to cause changes in eating and drinking behavior in livestock. According to Curtis (1983), cattle that experience heat stress will experience changes in physiology, anatomy and behavior in an effort to

Table 5. Face temperature before and after water misting

Animal	Before misting (°C)	After misting (°C)
Cattle 1	37.77±0.61[a]	37.08±0.38[b]
Cattle 2	37.70±0.41[a]	37.30±0.29[b]
Cattle 3	37.33±0.36[a]	36.85±0.46[b]
Cattle 4	37.46±0.22[a]	37.03±0.37[b]
Cattle 5	37.21±0.42[a]	36.91±0.38[b]

[a,b] Numbers with different superscripts in the same row indicate significant differences ($p<0.05$).

Table 6. Back temperature before and after misting

Animal	Before misting (°C)	After misting (°C)
Cattle 1	36.66±0.76[a]	36.12±0.24[b]
Cattle 2	37.34± 0.58[a]	36.12±1.43[b]
Cattle 3	37.07±0.75[a]	36.98±0.41[a]
Cattle 4	36.57±0.42[a]	35.96±0.36[b]
Cattle 5	36.54±0.36[a]	36.48±0.50[a]

[a,b] Numbers with different superscripts in the same row indicate significant differences ($p<0.05$).

Table 7. Rump section temperature before and after water misting

Animals	Before misting (°C)	After misting (°C)
Cattle 1	37.12±0.81[a]	36.51±0.31[b]
Cattle 2	37.42±1.04[a]	36.32±1.26[b]
Cattle 3	37.12±0.93[a]	36.87±0.32[a]
Cattle 4	36.71±0.47[a]	35.28±0.88[b]
Cattle 5	36.57±0.43[a]	36.40±0.66[a]

[a,b] Numbers with different superscripts in the same row indicate significant differences (p<0.05).

Table 8. Comparison of body surface temperature with rectal temperature

Animal	Rectal (°C)	Temperature back (°C)	Temperature *rump* (°C)	Temperature face (°C)
Cattle 1	39.01±0.24[a]	36.12±0.24[b]	36.51±0.31[c]	37.08±0.38[d]
Cattle 2	39.00±0.24[a]	36.12±1.43[b]	36.32±1.26[c]	37.30±0.29[c]
Cattle 3	39.02±0.27[a]	36.98±0.41[b]	36.87±0.32[b]	36.85±0.46[b]
Cattle 4	38.96±0.31[a]	36.57±0.36[b]	35.28±0.88[c]	37.03±0.37[d]
Cattle 5	39.18±0.28[a]	36.48±0.50[b]	36.40±0.66[c]	36.91±0.38[c]

[a,b,c,d] Numbers with different superscripts in the same row indicate significant differences (p<0.05).

maintain heat balance. According to Sutedjo (2016), livestock exposed to high temperatures will increase efforts to release body heat by increasing water consumption and reducing feed consumption.

Body temperature in Table 8 shows significantly different results, but there are parts that are not significantly different. The increase in body temperature is caused by vasodilation or vasoconstriction of blood vessels (Knizkova and Kune, 2007). According to Kolibu and South (2019), an increase in body surface temperature can occur due to livestock being in high barn temperatures for 10 minutes. The temperature of the face has a significantly different result from the rectal temperature, which is in accordance with the research of Aditia *et al*. (2017). Facial temperature has a value that is almost similar to rectal temperature, it can be used as an indicator of stress in livestock. The eye area has a large number of capillaries, which makes it possible to be an indicator of stress (Martello *et al*., 2015). According to Santoso *et al*. (2019), the different parts of the body surface temperature are caused by differences in the energy radiation emitted by the cattle's body.

Body temperature in table shows significantly different results in all cattle. The results of the calculation of the cattle's body temperature before and after water misting decreased. The value of the body temperature of cattle before misting ranged from 38.92°C to 39.08°C, while the value of body temperature after misting ranged from 38.63°C to 38.72°C. According to Schutz *et al*. (2008), the body temperature of cattle kept in a comfortable microclimate was 38.3°C - 38.6°C. The five cattle were subjected to heat stress before misting, but the cattle did not experience stress after misting. Heat stress can cause a decrease in feed consumption, which, if left unchecked, will decrease daily body weight gain so that productivity is not optimal (Suherman *et al*., 2013).

Conclusions

The results showed that the use of an air sprinkler for the fogging system was able to improve the microclimate of the cage by reducing the temperature of the cage by 1-2°C. Based on the THI value, cattle are still experiencing mild to severe stress. In addition, these devices can reduce physiological responses, including heart rate, respiratory rate, and rectal temperature.

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