Physiological responses of the Holstein Friesian dairy cows raised under tropical conditions in Indonesia

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Abstract. This study aimed to evaluate the physiological responses of the Holstein Friesian (HF) dairy cows raised under tropical conditions in Indonesia. Twenty-one dry-pregnant cows, approximately 7–8 months of pregnancy, 1-3 of lactation, 500-600 kg of body weight and 3-5 of body condition score were used for that purpose. The cows were fed twice daily in the form of total mixed ration (TMR) and given add libitum amounts of drinking water. Ambient temperature, relative humidity and temperature humidity index (THI) were recorded. Physiological responses i.e. rectal temperature (RT), pulse rate (PR) and respiration rate (RR) and heat tolerance coefficient (HTC) were also recorded. Descriptive statistics such as mean and standard deviation were performed using SPSS software. The results showed that both ambient temperature and THI reached their maximum (26.5±1.5°C and 77.1±2.2, respectively) at 01:00 PM and minimum (22.6±0.5°C and 71.8±0.90, respectively) at 3:00 AM. Contrarily, the relative humidity was highest (88.9±1.56%) at 03:00 AM and lowest (78.8±2.49) at 01:00 AM. The physiological responses (RT, PR and RR) and HTC increased in line with the increasing ambient temperature and THI. In conclusion, all of the HF cows are exposed to mild stress due to increasing ambient temperature and relative humidity.

1. Introduction

Environmental conditions such as ambient temperature and humidity are determinants for the productivity of dairy cows. Exposure of the animals to heat stress can reduce the feed consumption and average daily weight gain. Heat stress is one of the major factors affecting the performance and productivity of dairy cows in the tropical areas, which is characterized by high temperature and humidity rates that often do not comply with the thermal comfort zones for dairy cows like Holstein Friesian [1].

Indonesia is a tropical country with the climate relatively even all year-round. The country’s weather is characterized by 2 tropical seasons, which vary according to the equatorial air circulation (the walker circulation) and the meridian air circulation (the hardley circulation). These circulation patterns cause high temperature and high humidity in the country that are less productive conditions for dairy cows [2]. Dairy cattle in Indonesia are mostly descendants of the \textit{Bos taurus} breed such as the Holstein Friesian (HF) cattle, which originally come from sub-tropical areas. Therefore, the Indonesian dairy cows often experience heat stress resulting in reduced feed intake and a negative energy balance (NEB).
Furthermore, heat stress has a direct impact on the productive and reproductive performance of dairy cows. Reduced performance is mainly due to the high utilization of energy for basic requirements and poor quality feedstuffs. A previous study shows that high ambient temperature combined with high humidity have negative impacts on productive and reproductive performance of dairy cows [3]. The determination of critical temperatures and effects on productivity have been widely studied in dairy cattle [4-6], but little in dairy cattle under tropical conditions in Indonesia [7]. Therefore, it is important to identify physiological responses of the Holstein Friesian dairy cows raised under tropical conditions. This present study aimed to determine the physiological responses of the HF dairy cows raised under tropical conditions in Indonesia.

2. Materials and methods
This experiment was conducted at BBPTU-HPT Baturaden, Banyumas, Central Java Province of Indonesia.

2.1. Animals and diets
Twenty-one dry-pregnant cows, approximately 7–8 months of pregnancy, 1-3 of lactation, 500-600 kg of body weight and 3-5 of body condition score were used in this study. They were housed in stanchion barn with cement floors, fed twice daily in the form of total mixed ration (TMR) and given ad libitum amounts of drinking water. Composition of the TMR offered to the dry-pregnant cows are shown in Table 1.

Table 1. Composition of the TMR offered to the dry-pregnant cows.

| Feed Ingredients          | Composition TMR (% DM) | Proportion F : C |
|---------------------------|------------------------|-----------------|
| Pennisetum purpureum      | 31                     | 62              |
| Rice straw                | 11                     |                 |
| Costus spicatus           | 20                     |                 |
| Complete feed             | 7                      | 38              |
| Concentrate F2 :          |                        |                 |
| Copra meal                | 1                      |                 |
| Soybean meal              | 6                      |                 |
| Pollard                   | 1                      |                 |
| Corn gluten feed          | 7                      |                 |
| Corn gluten meal          | 8                      |                 |
| Cassava waste             | 7                      |                 |
| Mineral mix               | 1                      |                 |
| Total                     | 100                    |                 |

2.2. Data collection
Ambient temperature (Tdb) and relative humidity (RH) were recorded at 3:00 AM, 6:00 AM, 9:00 AM, 11:00 AM, 1:00 PM, 3:00 PM, 4:00 PM and 9:00 PM for two consecutive weeks using hygrometer. The temperature humidity index (THI) was calculated as follows [8]:

\[ \text{THI} = (0.8 \times \text{Tdb}) + 
\left\{ \left( \frac{\text{RH}}{100} \right) \times (\text{Tdb} - 14.4) \right\} + 46.4. \]

2.3. Physiological responses and Heat Tolerance Coefficient (HTC)
Physiological responses i.e. rectal temperature, pulse rate and respiration rate and heat tolerance coefficient (HTC) were also recorded at the same time when recording the environmental data. Thermometer, counter and stopwatch were used to measure rectal temperature, pulse rate and respiration rate, respectively. The HTC was calculated by using the Benezza formula as follows:

\[ \text{HTC} = \left( \frac{\text{Tb}}{38.3} \right) + \left( \frac{\text{Fr}}{23} \right) \]
of which Tb is the average body temperature (ºC), Fr is the average respiration rate, 38.3 is the normal body temperature (ºC) and 23 is the normal respiratory rate.

2.4. Statistical analysis

The collected data were entered into Microsoft Excel 2013 and descriptive statistics such as mean and standard deviation were performed using SPSS software version 16.0.

3. Results and discussion

3.1. Environmental condition at the study site

Environmental conditions at the BBPTU-HPT Baturraden are presented in Table 2. The results showed that both ambient temperature and THI reached their maximum (26.5±1.52ºC and 77.1±2.21, respectively) at 01:00 PM and minimum (22.6±0.51ºC and 71.8±0.90, respectively) at 03:00 AM. The average ambient temperature was 24.4±1.01ºC, which was in accordance with the thermo neutral zone (TNZ: 16-25ºC) for dairy cows [9]. At 11:00 AM and 1:00 PM the cows experienced heat stress due to rising ambient temperatures above the TNZ. The humidity was highest (88.9±1.56%) at 03:00 AM and lowest (78.8±2.49) at 01:00 AM with an average humidity of 85.9±2.17%. This relatively high humidity in the study site might due to high rainfall intensity. In addition, the high humidity can lead to heat stress as depicted by elevated respiration rate.

| Observation Times | Temperature (ºC) | Humidity (%) | THI      |
|-------------------|------------------|--------------|----------|
| 03:00             | 22.6±0.51        | 88.9±1.56    | 71.8±0.90|
| 06:00             | 23.3±1.12        | 87.7±2.89    | 72.9±1.92|
| 09:00             | 25.6±1.16        | 85.4±2.90    | 76.4±1.65|
| 11:00             | 26.0±1.47        | 82.7±2.76    | 76.7±2.24|
| 13:00             | 26.5±1.52        | 78.8±2.49    | 77.1±2.21|
| 15:00             | 24.7±1.29        | 86.5±1.56    | 75.1±2.02|
| 18:00             | 23.5±0.43        | 88.2±1.37    | 73.3±0.73|
| 21:00             | 23.4±0.61        | 88.7±1.82    | 73.1±1.06|
| Average           | 24.4±1.01        | 85.9±2.17    | 74.5±1.59|

A previous study by [10] reported that the productivity of the HF cows reaches optimum when they are raised at approximately 18.3ºC of ambient temperature and 55% of relative humidity. The increase in ambient temperature can lead to the physiological and behavioral changes [10]. When heat gain is greater than the animal’s capacity for heat loss, cattle store the excess heat in the form of an increase in core body temperature. Cattle will dissipate heat through various evaporative processes such as sweating and panting [11].

Average daily temperature and relative humidity in Indonesia are relatively high ranging from 24 to 34ºC and from 60 to 90%, respectively. These conditions might affect the productivity of the HF dairy cows and induce heat stress. Heat stress has a negative impact on the productive and reproductive performances of dairy cows such as reduced reproduction efficiency by 40–50% and decreased milk production by 15–20% [12]. Furthermore, heat stress affects endocrine and follicle development as depicted by a short duration of estrus and low-quality oocyte, which may lead to the lower fertility in dairy cows [13]. As shown in Table 2, the THI started to increase (76.4±1.65) at 09:00 AM and reached its highest peak (77.1±2.21) at 01:00 PM. This indicated that at about 09:00 AM the animals started to experience mild stress (THI >72). Interestingly, the THI were constantly more than 72 until 01:00 PM (THI= 3.1±1.06). The lowest THI (71.8±0.90) was observed at 03:00 AM with an average THI of 74.5±1.59. The animals will experience a mild stress when the THI reaches 72–79 [10].

Raising Holstein Friesian dairy cows is a great challenge in tropical regions due to relatively high ambient temperature that exceeds the thermo-neutral zone (TNZ). Rumetor [14] reported that animals
experience heat stress when the ambient temperature exceeds the upper critical temperature of the cow’s
TNZ. Heat stress occurs when the heat gain of an animal exceeds the heat lost. Temperature humidity
index (THI) is a common measure of heat stress in dairy cattle [14]. When the THI exceeds the TNZ
animal experience heat stress, which leads to the reduced productivity.

When the air temperature increases the relative humidity decreases or vice versa. It has been observed
that the dairy cows raised at BBPTU-HPT Baturraden might experience heat stress due to relatively high
ambient temperature, which were higher than the temperature range of the animal’s TNZ. Armstrong
[15] classified the THI into five different classes i.e. no stress (THI >72), mild stress (72 ≤ THI ≤ 79),
moderate stress (80 ≤ THI ≤ 89), severe stress (90 ≤ THI ≤ 98) and dead cows (THI>99). Therefore,
proper design of a dairy shelter is important to ensure good productivity and reduce stress. As previous
study mentioned that heat stress leads to a decrease in feed intake of dairy cows, thereby leading to a
reduction in milk yield [16]. When the ambient temperature and relative humidity rise the animals
increase body heat loss, which results in reduced metabolic rate and decreased feed consumption [14].

3.2. Physiological responses
Physiological responses of the dairy cows raised under tropical conditions are presented in Table 3. The
rectal temperature of the cows were highest (38.2±0.33°C) at 01.00 AM and lowest (37.5±0.32°C) at
03.00 PM, with an average rectal temperature of 37.9±0.35°C. These were in accordance with a previous
study by Hansen [17] who reported 38–39.2°C for rectal temperature of healthy dairy cows under
tropical condition. The animal’s TNZ in tropical areas ranges between 25°C and 37°C [18]. Pulse rate
was highest (66.3±2.69 times/min) at 01.00 AM and lowest (56.3±1.98 times/min) at 06.00 AM, with
an average pulse rate of 61.1±2.54 times/min. According to Kadzere et al. [3], pulse rate of healthy HF
cows is about 60-70 times/min. The respiration rate was highest (37.5±2.28 times/min) at 01.00 PM and
lowest (31.7±2.98 times/min) at 03.00 AM, with an average respiration rate of 34.5±2.47 times/min.
These results are relatively higher than the normal range of 24–32 times/min. High respiration rate
indicated that the cows might experience mild stress as also depicted by THI values. Rumetor [14]
reported that increased respiration rate is an indicator of heat stress in dairy cattle.

Table 3. Physiological responses of the dairy cows raised under tropical conditions.

| Observation Times | Rectal Temperature (°C) | Pulse Frequency (times/min) | Respiration Frequency (times/min) |
|-------------------|-------------------------|-----------------------------|----------------------------------|
| 03:00             | 37.5±0.32               | 56.4±2.75                   | 31.7±2.98                        |
| 06:00             | 37.7±0.39               | 56.3±1.95                   | 33.9±2.61                        |
| 09:00             | 38.0±0.34               | 62.9±2.46                   | 34.9±1.80                        |
| 11:00             | 37.9±0.33               | 63.5±2.51                   | 35.0±2.18                        |
| 13:00             | 38.2±0.33               | 66.3±2.69                   | 37.5±2.28                        |
| 15:00             | 38.1±0.35               | 62.5±2.51                   | 34.9±2.45                        |
| 18:00             | 37.9±0.39               | 61.9±2.74                   | 34.8±2.81                        |
| 21:00             | 37.6±0.34               | 59.2±2.66                   | 33.0±2.67                        |
| Average           | 37.9±0.35               | 61.1±2.54                   | 34.5±2.47                        |

Physiological responses of the dairy cows raised at BBPTU-HPT Baturraden indicated that those
animals experienced mild stress. Sudrajad and Adiarto [19] also observed physiological status of the
dairy cows at the same location. They reported varying values of respiration rate, pulse rate and
rectal temperature ranging from 25.33 to 80.00 times/min (average RR= 50.71 times/min), from 46.00
to 84.00 times/min (average PR=62.84 times/min and from 35.63 to 39.13°C (average RT= 37.63°C),
respectively. These indicated that HF dairy cows raised at BBPTU-HPT Baturraden experienced mild
stress, but none have not been observed as a severe stress. Heat stressed cattle may try to reduce the
body heat through thermoregulatory mechanisms which in turn affect feed conversion efficiency and
lead to decreased milk production [1].
3.3. Heat tolerance coefficient

Table 4 represents the heat tolerance coefficient (HTC) values of the dairy cows. Heat tolerance is the ability of an animal to adapt to hot environmental conditions and can be predicted based on physiological traits i.e. respiration rate and rectal temperature [20]. The HTC values were highest (2.63±0.10) at 01.00 PM and lowest (2.36±0.13) at 03.00 AM, with an average HTC of 2.49±0.11. The HTC value was calculated according to the Benezra formula. Cows with HTC= 2 indicated a better heat tolerance, while those with HTC value >2 indicated a low heat tolerance [21]. All dairy cows observed in this study had the HTC >2 indicating a low heat tolerance. Cattle is a homoiotherm animal that can maintain body temperature under various ambient temperatures. Cattle’s responses to heat stress involve changes in physiological status such as increased respiration rate [22]. The respiration rate increases in line with the increasing relative humidity. When the humidity is high, it is more difficult for animals to lose heat through evaporation and therefore, the animals increase the respiration rate to further lose heat.

| Time   | Heat Tolerance Coefficient |
|--------|-----------------------------|
| 03:00  | 2.36±0.13                   |
| 06:00  | 2.46±0.12                   |
| 09:00  | 2.51±0.08                   |
| 11:00  | 2.51±0.10                   |
| 13:00  | 2.63±0.10                   |
| 15:00  | 2.51±0.11                   |
| 18:00  | 2.50±0.13                   |
| 21:00  | 2.42±0.12                   |
| Average| 2.49±0.11                   |

4. Conclusion

All of the HF cows are exposed to mild stress due to increasing ambient temperature and relative humidity. Generally, the cows show the ability to adapt heat stress by increasing their rectal temperature, pulse rate and respiration rate.

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