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Physiological adaptability of pregnant doe Kacang goats in a dry-land-area of Indonesia

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Abstract The objective of the present study was to evaluate the physiological adaptability of pregnant doe Kacang goats in a dryland area of Indonesia. Thirty pregnant doe Kacang goats aged 2-3 years were observed. The rearing system was semi-intensive without giving concentrated feeds. Local grasses and legumes such as *Leucaena leucocephala* leaves, *Gliricidia sepium* leaves, *Sesbania grandiflora* leaves, and drinking water were offered *ad libitum*. Experimental data such as respiration rate, rectal temperature, adaptability coefficient, heart rate, and heat tolerance coefficient, were collected during 2-3 months of gestation. The mean and standard deviation were calculated using a descriptive analysis method. The average humidity in the morning and afternoon and the ambient temperature in the middle of the day were outside the normal range. The THI value indicates that the experimental animals are under medium heat stress. The average values of HTC, AC, RT, HR, and RR were still typical for goats. In conclusion, although the average ambient temperature at midday and humidity in the morning and afternoon were outside of the normal range, they did not cause any effects on feed and water intake, health, and fetus growth and development of pregnant doe Kacang goats. This happened because the Kacang goat is a local breed that can adapt well to extreme environments. Therefore, pregnant doe Kacang goats in Malaka District can be allowed to graze in the paddock throughout the day and housed at night.

Keywords: adaptability coefficient, heat tolerance coefficient, temperature-humidity index

1. Introduction

Kacang goat is a local breed that the Indonesian government has designated as a living genetic resource of local goats in Indonesia. In Indonesia, smallholder farmers generally keep Kacang goats for meat production (Depison et al 2020). In Malaka District, East Nusa Tenggara Province, households in the rural areas raised and kept Kacang goats as a source of income to pay children's school fees, source of food and nutrition, and use the male goat for cultural and religious ceremonies. Even though Kacang goats play a vital role in people's lives in Malaka District, studies about the negative impacts of high air temperature on pregnant doe Kacang goats' physiological adaptability remain limited. Based on the climate data from BPS-Statistics of Nusa Tenggara Timur Province (2021), Malaka District has a longer drought period (8–9 months) compared to the wet season, the average precipitation in a year is 141.9 mm, the annual average ambient temperature is 27–28 °C. The agricultural system in Malaka District is dominated by the dryland farming system, with 539,885.7 ha of dryland area and 20,994.8 ha of wetland area. Therefore, in the current study, it was hypothesized that extreme environmental conditions that occur throughout the year in Malaka District would decline the physiological adaptability of pregnant doe Kacang goats.

The animals' productivity, reproduction, and growth can be affected by sunlight intensity, humidity, and air temperature (Rathwa et al 2017; Seixas et al 2017; Sejian 2013). Extreme ambient temperature strongly affects reproduction, physiology, and metabolism, depending on age, breed, species, reproduction performance, air temperature change, and altitude (Abecia et al 2017; Macías-Cruz et al 2016).

The animal's ability to adapt and tolerate any change in the environmental temperature could be assessed using the physiological status of the animals. The physiological status can also be used as an indicator to monitor the health condition of animals (Goetsch et al 2011, Sejian et al 2021) and the quality of feed consumed by the animals (Kubkomawa et al 2015). Therefore, the farmers can use them to detect and overcome any physiological disorders or abnormalities of their livestock.

No research has been conducted to investigate the negative impact of air temperature and humidity changes on the adaptability of pregnant doe Kacang goats in West Malaka Sub-district, Malaka District, East Nusa Tenggara Province, Indonesia. The rearing system applied in this trial is semi-intensive without offering any concentrate feeds. This system followed the goat production system that the farmers have practiced for many years. It is expected that the output from this trial will be used to formulate a management strategy for raising goats, specifically health and housing

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management, that is suitable for household conditions. Knowledge about the physiological response of livestock to heat stress is important to select which animals are adaptable to a specific ecology, feed management, housing, and health (Decampos et al 2013). The present study aimed to evaluate the ability of the pregnant doe Kacang goats to adapt to daily humidity and air temperature changes in a dryland area of Indonesia.

2. Materials and Methods

2.1. Animals and experimental designs

The experiment was conducted in West Malaka Sub-district, Malaka District, East Nusa Tenggara Province, Indonesia, from February to March 2020. Thirty pregnant doe Kacang goats were used in this study. These pregnant animals were healthy and not physically disabled, 2-3 years of age, and the initial average live weight was 21.1±4.1 kg. During the experimental period, all the pregnant doe Kacang goats were allowed to graze freely in the paddock throughout the day and free entry into the pen for water whenever needed. They were housed in pens at night (a semi-intensive goat production system). The pen consisted of 6 plots and was covered (roof) with dry local grasses and coconut leaves. Each animal was randomly allocated into a 5x4m plot (5 animals per plot). Local grasses, legumes such as *Leucaena leucocephala* leaves, *Gliricidia sepium* leaves, *Sesbania grandiflora* leaves, and drinking water were provided in each plot offered *ad libitum*.

2.2. Data collection

Physiological status data were recorded during 2 to 3 months of gestation. Data from each variable was collected once a week (3 times per day: at 06.00 am, 12.00 pm, and 5.00 pm). RT was measured from the rectum using a digital thermometer, HR was measured by locating a stethoscope on the left side of the thorax near the heart in a standing goat position, and RT was recorded by palpating the nose of the animals and then calculating the rate using a hand counter (Astuti et al 2019). Humidity and air temperature were measured simultaneously as physiological status data collection, using a digital thermohygrometer (HTC2 with 1 °C of temperature and 5% humidity of accuracy).

2.3. Statistical analysis

Before data analysis, the mean and standard deviation of ambient temperature, humidity, RT, HR, and RR were calculated using SPSS version 25.0. The significance test was determined using a t-test (SPSS version 25.0). THI was calculated following the formula according to Habeeb et al (2018):

THI = (1.8 x AT + 32) - ((0.55 - 0.0055 x RH) x (1.8 x AT - 26))

where: THI = Temperature humidity index, AT = Air temperature (°C), RH = Relative Humidity (%).

Adaptability coefficient (AC) was calculated following the Benezra test according to (Araujo et al 2017):

AC = RT / 39.1 ± RR / 19 ± HR / 75

where: AC = adaptability coefficient of the Benezra test, RT = Rectal temperature (°C), RR = Respiratory rate (breaths/min), 19 = respiratory on goats, and 39.1 = normal rectal temperature on goats; 75 = normal heart rate on goats; HR = heart rate.

Heat Tolerance Coefficient (HTC) was calculated following the Rhoad or Ibéria test according to (Araujo et al 2017):

HTC = 100 - [18 x (RT - 38.60)]

where: HTC = heat tolerance coefficient, 100 = maximum efficiency in maintaining body temperature at 38.6 °C, 18 = constant value, 38.60 °C = normal average rectal temperature on goats in thermal comfort zone, RT = final rectal temperature.

3. Results

3.1. Environmental temperature, humidity, and THI

The data describing the environmental temperature, humidity, and THI are presented in Table 1. The average ambient temperature was low in the morning at 23.67±1.21 °C and high in the middle of the day at 28.23±1.82 °C. The average humidity was higher in the morning (88.50±3.83%) than the average humidity at midday (80.50±9.85%), and afternoon (81.17±9.99%), respectively. The average THI was higher at midday and afternoon (80.11±2.70 and 79.37±2.12, respectively) than in the morning (73.56±2.15).

The analysis of the t-test showed that there were differences ($P < 0.05$) in the average ambient temperature in the middle of the day, afternoon, and morning. The average THI was also different ($P < 0.05$) at midday and afternoon than in the morning. However, there was no difference in average humidity recorded throughout the day ($P > 0.05$).

Table 1 Average environmental conditions at multiple times of the day.

Climate factor	Time		
	Morning (06:00)	Midday (12:00)	Afternoon (17:00)
Ambient temperature (°C)	23.67±1.21^{a}	28.23±1.82^{b}	27.78±1.98^{c}
Humidity (%)	88.50±3.83^{a}	80.50±9.85^{a}	81.17±9.99^{a}
THI	73.56±2.15^{a}	80.11±2.70^{b}	79.37±2.12^{b}

The numbers followed by different lowercase letters on the same line show a significant difference at the 5% test level (t-test).

3.2. Physiological status

Data about the physiological status of experimental animals are presented in Figures 1-5. The average RT was higher at midday and afternoon (39.08±0.37 °C and 39.06±0.48 °C, respectively) than in the morning. The average of RT, HR, RR, and AC, were lower in the morning compared with the average at midday and afternoon (37.88±0.67 °C, 74.17±0.84 beats/minute, 15.43±0.51 breaths/min, and 2.77±0.04, respectively). Moreover, the average HTC was lower at midday (91.28±6.62) and afternoon (91.77±8.72) than in the morning (112.88±12.05). The analysis of the t-test appeared that there was a significant difference ($P < 0.05$) in the physiological status (RT, RR, HTC, and AC) of the animals between morning and midday, but no significant differences were found between midday and afternoon ($P > 0.05$). In contrast, HR was a significant difference in the morning, midday, and afternoon ($P < 0.05$).

4. Discussion

4.1. Temperature and humidity

The average air temperatures recorded in this study were 23.67±1.21 °C in the morning, 28.23±1.82 °C at midday, and 27.78±1.98 °C in the afternoon, respectively. The average humidity was 88.50±3.83% in the morning, 80.50±9.85% in the midday, and 81.17±9.99% in the afternoon. The average ambient temperature was still in the normal range of Indonesian environment temperature, which is from 24 to 34 °C (Yani and Purwanto 2006). The average ambient temperature at midday and the humidity in the morning were a bit higher than the temperature tolerance of goats which is about 6–27 °C, and the comfortable humidity, which is 60–80% (Sejian et al 2021), and still at the normal range of comfortable temperature for tropical goat, which is in between 20 and 30 °C (Borges and Rocha 2018).

4.2. Temperature humidity index

The combination values of humidity and air temperature can be used to assess heat stress and thermal comfort in livestock (Habeeb et al 2018; Bernabucci et al 2010; Sejian et al 2021). THI values in the present study were 73.56±2.15 in the morning, 80.11±2.70 in the midday, and 79.37±2.12 in the afternoon. These values were higher than the THI values obtained from a study on Dwarf goats in Southern Nigeria, where the THI in the morning, midday, and afternoon, were 68.72, 83.97, and 69.98, respectively (Okoruwa 2014). The THI values from both studies differed due to differences in air temperature and humidity between the regions. Temperature and relative humidity in different climatic zones will produce different THI (Brügemann et al 2012). In addition, the value of THI in this study ranged from 73 to 80, indicating that all the pregnant doe Kacang goats are under medium heat stress. A THI value that is greater than 77 could cause medium heat stress and more than 85 as extreme heat stress conditions for livestock such as goats (Battini et al 2013; Aleena et al 2018). The values of RT, HR and RR are still in the normal range for goats. This means that the ambient temperature and humidity in Malaka District did not cause any adverse impact on the physiological conditions of pregnant doe Kacang goats.

4.3. Rectal temperature

The core temperature and heat stress response in livestock can be evaluated using rectal temperature (Alhidary et al 2012). The average RT of pregnant doe Kacang goat recorded in this study was 37.88±0.67 °C in the morning, 39.08±0.37 °C in the midday, and 39.06±0.48 °C in the afternoon (Figure 1). The average of RT recorded in the morning (37.88±0.67 °C) was lower than the average of RT in the morning (38.8±0.09 °C) reported by (Hereng et al 2018). The average of RT in the afternoon was higher (39.06±0.48 °C) than the average of RT in the afternoon (38.9±0.20 °C) reported by Hereng et al (2018). This could happen due to differences in ambient temperature. The doe Kacang goats observed in the present study were all pregnant, and their feeding activities were increased, leading to high RT. The increase in nutritional requirements during the gestation period causes goats to spend more time for a feed and the rest of the time spent resting (Vas and Andersen 2015; Averós et al 2014). The RT values measured in this trial were still in between the normal RT values of goats which is about 37-41 °C (Okoruwa 2014).

The average RT at midday and afternoon is greater ($P < 0.05$) than the average rectal temperatures recorded in the morning because all the experimental goats are grazing in the paddock from 9 am to 5 pm, which is a high chance of receiving the most heat and exposure to sunlight. According to Raharja et al (2011) and Wojtas et al (2014), goats' body temperature could increase when exposed to sunlight. Changes in the environmental temperature and solar radiation could potentially affect the physiological status of livestock. This is because livestock integrates the environmental conditions and then responds adaptively through physiological changes that include changes in body temperature (Atrian et al 2012). Increased livestock activity, environmental temperature and humidity, feed intake, and sun intensity will increase the rectal temperature (Adedeji 2012; Kubkomawa et al 2015). Body heat comes from metabolic processes in the body and fermentation processes in the rumen (Adhianto et al 2017).

4.4. Heart rate

HR is a mechanism of the body to release or reduce heat received from outside of the body. In the present study, the average HR was 74.17±0.84 beats/minute in the morning, 90.89±0.72 beats/minute at midday, and 90.69±0.65 beats/minute in the afternoon, respectively (Figure 2). The average HR of the study animals was 85.25±0.74 beats/minute, higher than the average HR of the male Kacang goats kept under an intensive system which is about 81.00±8.48 beats/minute (Suwignyo et al 2018). The different HR values from both studies may be due to the different sunlight intensity received by the animals. In this study, all the pregnant animals were in the paddock from 9 am to 5 pm, spent more time grazing, and received high sunlight intensity. Therefore, their average HR is higher than those of animals that are continuously kept in pens. These higher HR values could be caused by the increase in blood circulation from the heart to the peripheries to balance the heat dissipation from the body due to radiation, conduction, and convection (Marai et al 2007).

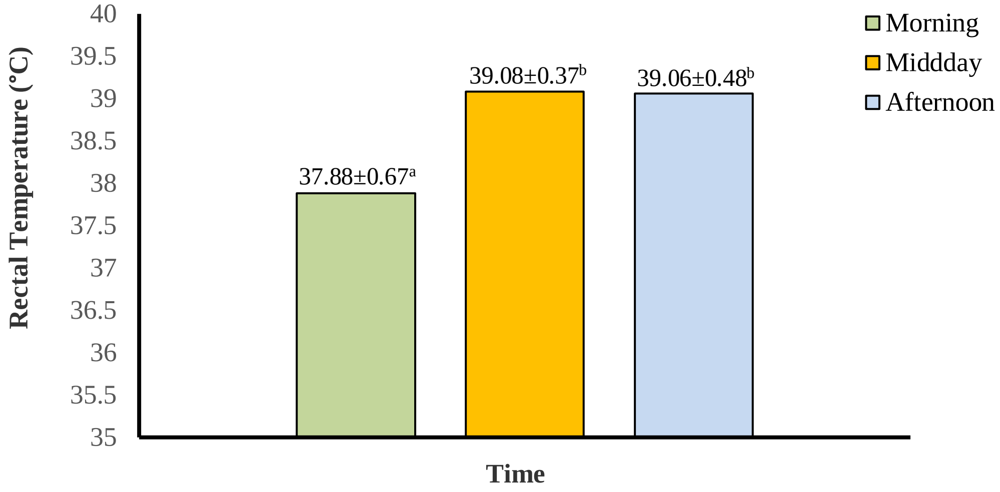

Figure 1 Average rectal temperature of pregnant doe Kacang Goats.
The means followed by different lowercase letters show a significant difference at the 5% test level (t-test).

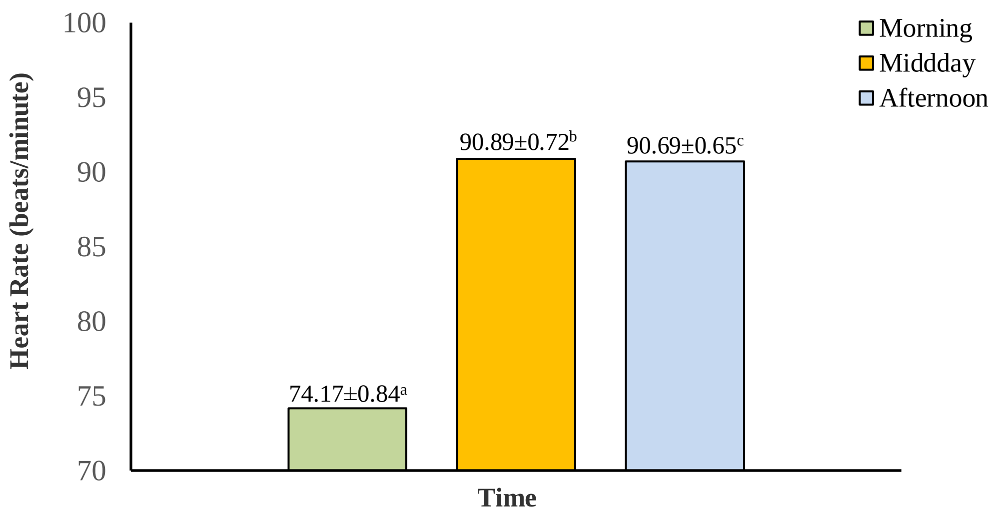

Figure 2 Average heart rate of pregnant doe Kacang Goats.
The means followed by different lowercase letters show a significant difference at the 5% test level (t-test).

The increase in HR is caused by a decrease in vascular resistance of the arterial and peripheral vascular veins and an increase in the activity of the muscles that control the respiratory rate and an increase in the respiratory rate (Gupta and Mondal 2021). Different environmental conditions will produce a variety of HR values (Araujo et al 2017). The average HR of the pregnant goats in this trial was still between the normal HR values of goats, which is about 90-95 beats/minute (Okoruwa 2014). The low HR happens in the morning, but it does not cause stress to the animals, because the Kacang goat is a local breed of Timor Island which is homoeothermic. The Kacang goat has a low growth rate but has excellent adaptability to hot and cold climates (Hifzan et al 2015).

The t-test results indicated that the average HR in the morning, midday, and afternoon was a significant difference ($P < 0.05$). HR values at midday and afternoon are increased because, during this time, the air temperature and grazing activities in the paddock are increased. Ruminant animals, including goats, are spent more time eating feeds throughout the day and used more time for rest at night (Nejad and Sung 2017).

4.5. Respiration Rate

Respiration is the process of removing carbon dioxide, and the entry of oxygen into the body under thermoneutral conditions causes loss of body moisture and evaporation through the respiratory tract to maintain the body's heat balance (Rashamol et al 2018).

The average RR of pregnant doe Kacang goats recorded in the present study was 23.54±0.55 breaths/minute (Figure 3), higher than the average RR of doe Kacang goats (16.85±0.48 breaths/minute) reported by Hereng et al (2018), but still in the normal range of goats, which is about 15-30 breaths/minute (Sarangi 2018). This difference in the average value of RR could happen because of the difference in the humidity and air temperature recorded in the two studies.

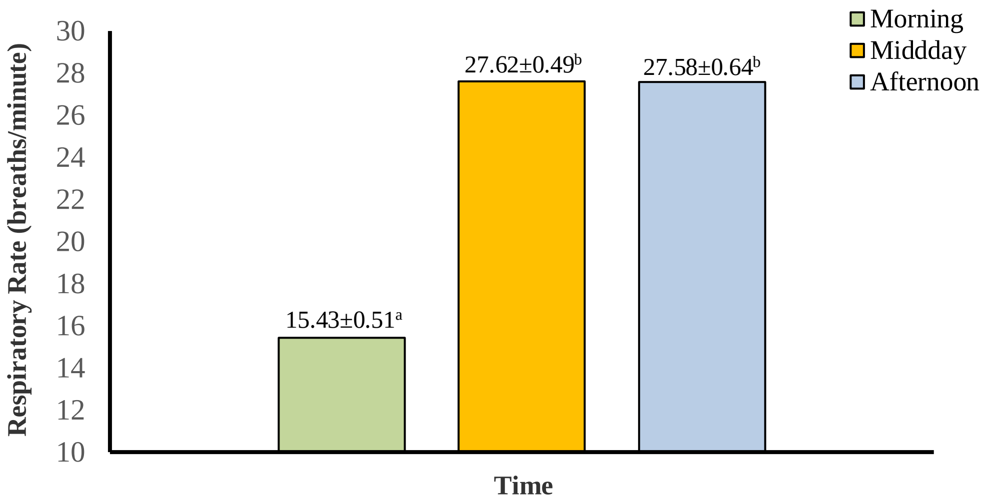

Figure 3 Average respiratory rate of pregnant doe Kacang Goats.
The means followed by different lowercase letters show a significant difference at the 5% test level (t-test).

The average RR in the present study was greater at midday and afternoon ($P < 0.05$) than in the morning. This is probably happened due to high grazing activity in the paddock and the high intensity of light from the sun at midday and afternoon increases the activity of the skin to receive environmental heat, which can increase blood circulation and redistribution to the surface (Attia 2016; Indu and Pareek 2015). When the environmental temperature increase, the animals will lower the temperature in the body by releasing heat via skin and respiration (Hernawan 2019). RR is the first thermoregulation mechanism for goats to control the body's temperature when they are stressed due to high air temperature (Berihulay et al 2019). Moreover, increasing the average THI can increase the average RT and RR (Sailo et al 2017).

4.6. Heat tolerance coefficient (HTC) and Adaptability coefficient (AC)

The adaptability of livestock to the air temperature change is influenced by species' genetic, physiological, and ecological diversity (Silanikove and Koluman 2015). An assessment of climate change's effect on livestock comfort is required to monitor the impact of heat stress on animal productivity (Serradilla et al 2018). HTC and AC can be used to identify the adaptability levels of an individual animal in response to various environmental conditions, and the normal values for HTC and AC in goats are 100 and 2 (Araujo et al 2017). The average HTC was high in the morning (112.88±12.05, Figure 4) when the air and rectal temperature were low. HTC values at midday and afternoon were close to the normal HTC values in goats. The t-test results indicated that the HTC values recorded in the morning, midday, and afternoon, were significantly different ($P < 0.05$), however, the HTC values between midday and afternoon were not different ($P > 0.05$).

The AC value in this study (Figure 5) was greater than the normal AC value in goats. An increase in the AC value of the pregnant doe Kacang goats at midday and afternoon occurred because the afternoon humidity and air temperature were high. The AC value obtained in this study was higher than the normal AC value of goats. This indicates that the pregnant animals observed in this study had better adaptability (Qisthon and Hartono 2019). Goats are very tolerant of water shortage and heat stress; they can also adapt to climatic change compared with cattle, buffalo, and sheep (Aziz 2010).

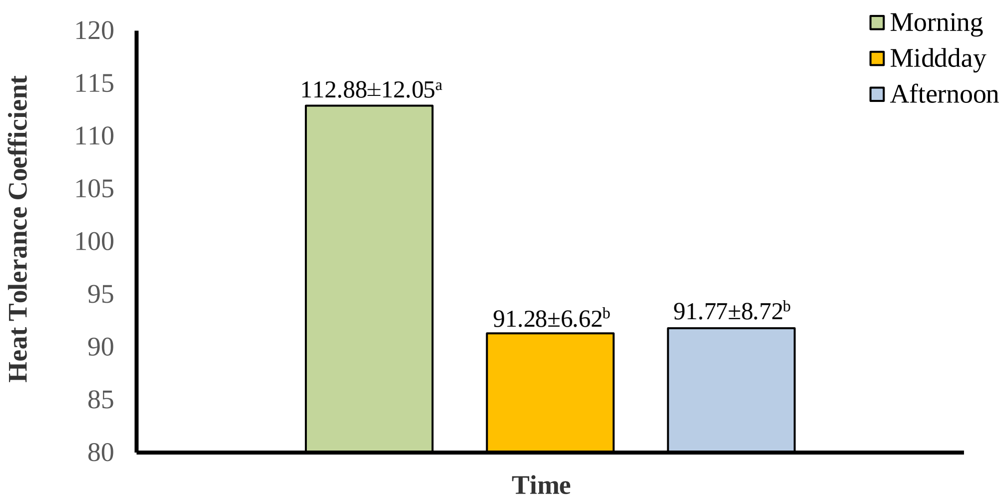

Figure 4 Average heat tolerance coefficient of pregnant doe Kacang Goats.
The means followed by different lowercase letters show a significant difference at the 5% test level (t-test).

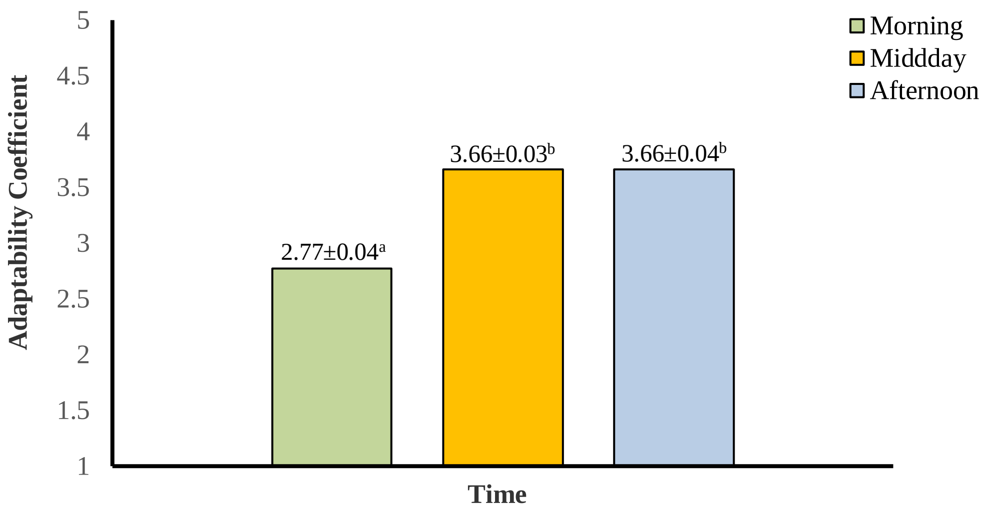

Figure 5 Average adaptability coefficient of pregnant doe Kacang Goats.
The means followed by different lowercase letters on the same line show a significant difference at the 5% test level (t-test).

5. Conclusions

The THI value in the present study indicated that the pregnant doe Kacang goats were in moderate heat stress but the ambient temperature and humidity had no effect on RT, HR, and RR values. This is supported by the values of HTC and AC, which show that the Kacang goats in this study had an excellent tolerance and adaptability to high air temperature and humidity. Therefore, it can be suggested that farmers in Malaka District can allow their pregnant doe Kacang goats in the paddock throughout the day for feeds and water, and housed at night.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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