Physiological Responses of Saanen Does: A Comparative Study of Traditional Wooden and Aluminium Galvanized Iron Housing System in a Tropical Climate

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ABSTRAK

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Respon fisiologi merupakan indikator kunci untuk menilai kesejahteraan hewan ternak dan berfungi sebagai referensi penting dalam mendeteksi kondisi abnormal yang disebabkan oleh faktor lingkungan yang tidak sesuai. Penelitian ini bertujuan untuk mengevalusi respon fisiologi kambing Saanen betina berusia 9 sehingga 12 bulan dengan berat badan 23.54±1.15 kg, ditempatkan secara acak pada kandang kayu traditional (T_0) dan kandang aluminium besi galvanis (T_1). Setelah masa adaptasi selama 14 hari, variabel termoregulator seperti suhu rektal (RT), detak jantung (HR) dan laju pernapasan (RR) diukur setiap minggu selama 90 hari. Kadar kortisol serum juga diukur pada minggu ke-0, ke-4, ke-8 dan ke-12. Selain itu, parameter iklim micro seperti suhu lingkungan (AT) dan kelembapan relatif (RH) dicatat setiap minggu di setiap sistem kandang untuk menghitung indeks suhu-kelembapan (THI). Jenis kandang tidak berpengaruh signifikan (P>0.05) terhadap parameter iklim, namum variasi diamati sepanjang hari. AT dan THI dicatat tinggi pada sore hari, sedangkan Rh dicatat tinggi pada pagi hari pada kedua jenis rumah. Khususnya, RR dan HR secara signifikan (P<0.05) dipengaruhi oleh sistem kandang tetapi RT tetap tidak terpengaruh. Namun, kadar kortisol serum tidak terpengaruh oleh jenis kandang. Temuan ini menunjukkan bahwa kedua sistem kandang mungkin menyebabkan stres pada hewan, namun T_1 memberikan kondisi pembuangan panas yang lebih baik dan memiliki biaya pemeliharaan yang lebih rendah. Dengan demikian, T_1 menjadi alternatif yang lebih sesuai daripada T_0 di iklim tropis, yang berpotensi meningkatkan kesejahteraan dan kenyamana kambing Saanen.

Kata Kunci: Aluminium, Detak Jantung, Respons Fisiologis, Suhu, Kayu

ABSTRACT

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Physiological responses are key indicators that serve as valuable references for detecting abnormal conditions caused by unsuitable environmental factors. This study aimed to evaluate the physiological responses of Saanen in two different housing systems. Twelve female Saanen does, ages 9 to 12 months with an average weight of 23.54±1.15 kg, were randomly assigned to either a traditional wooden house (T0) or an aluminum galvanized iron house (T1). After 14 14-day adaptation period, thermoregulator variables, including rectal temperature (RT), heart rate (HR), and respiratory rate (RR), were measured every week over 90 days. Serum cortisol levels were also measured at weeks 0, 4, 8, and 12. Additionally, microclimate parameters, ambient temperature (AT), and relative humidity (RH) were recorded in each housing system weekly to calculate the temperature-humidity index (THI). Housing types did not significantly (P>0.05) affect the environmental parameters, but variations were observed throughout the day. High AT and THI were recorded in the afternoon, while RH was higher in both houses in the morning. Notably, RR and HR were significantly (P<0.05) affected by the housing system. However, RT remained unaffected. Serum cortisol levels, however, were unaffected by housing type. These findings suggest that both housing systems may induce animal stress, but T1 provided better heat dissipation and lower maintenance costs. Thus, T1 presents a more suitable alternative to T0 in tropical climates, potentially improving the welfare and comfort of Saanen does.

Key Words: Aluminum, Heart Rate, Physiological Responses, Temperature, Wood

INTRODUCTION

Saanen goats are widely recognized as one of the leading dairy goat breeds, prized for their high milk production and adaptability to diverse environmental conditions (Gökdai et al. 2020). However, maintaining optimal physiological health and welfare in tropical climates is challenging due to environmental stressors such as high temperature and humidity. Housing design is critical in mitigating these stressors influencing the livestock's physiological responses, behaviors, and overall well-being (Nunes et al. 2014). Inadequate housing can lead to numerous issues in dairy goats. For instance, Simões and Gutiérrez (2017) highlight that inadequate nutrient intake and environmental conditions can lead to metabolic diseases affecting overall health and production in dairy goats. Additionally, under heat stress, goats exhibit increased respiratory rates and altered metabolic processes, which can hinder hormone production essential for lactation, such as prolactin (Fonseca et al. 2016; Henn et al. 2021)

In Malaysia, smallholder farmers have traditionally relied on wooden housing systems due to their availability, low initial cost, and ease of construction. However, wood structures are prone to moisture absorption, insect infestation, and rapid decomposition in tropical environments, which can compromise the health and welfare of animals (Awang et al. 2020). Over time, these issues can lead to higher maintenance costs and reduced durability, raising concerns about the long-term sustainability of this housing option.

In contrast, aluminum galvanized iron houses are emerging as a modern alternative with numerous advantages, including outstanding durability, insect resistance, and lower maintenance requirements (Awang et al. 2020). These systems also have the potential to provide better ventilation and heat dissipation, which are crucial in hot, humid climates (Awang et al. 2020). Despite these benefits, the feasibility of this housing system on the physiological parameters of livestock, particularly in tropical climates, remains largely unexplored. The knowledge gap is particularly significant given the importance of physiological responses as animal welfare indicators.

The physiological responses can be one of the simple indicators of access to animal welfare in livestock. According to the International Physiology Journal (2023), physiological responses are the measurements of living organisms' characteristics that describe the functions and processes occurring within the body. These include heart rate, blood pressure, body temperature, respiratory rate, oxygen saturation, muscle strength, metabolic rate, and hormonal levels. Febretrisiana et al. (2022) stated that physiological responses can be used as references to assess abnormal livestock conditions caused by unsuitable livestock environments. Monitoring these physiological parameters is essential in assessing the effectiveness of housing designs in providing a comfortable and stress-free environment for livestock. By ensuring these physiological responses remain within normal ranges, the farmer can safeguard the well-being of their animals, ultimately leading to better health outcomes and higher productivity.

Heat stress is one of the most significant challenges in livestock management, particularly in tropical climates. This condition occurs when environmental factors such as high temperature, humidity, solar radiation, and wind speed exceed an animal's ability to regulate its body temperature (Sejian et al. 2018). Heat stress can elevate body temperature, respiratory rate, and heart rate, reducing feed intake and overall performance. These effects depend on various factors, including the animal's age, breed, reproductive status, and environmental conditions, such as air temperature fluctuations and altitude (Macías-Cruz et al. 2016; Abecia et al. 2017). Consequently, proper housing and environmental management are vital in mitigating heat stress and supporting optimal physiological function in livestock.

Given the importance of housing systems in moderating these physiological responses, this study aims to fill the gap in knowledge regarding the impact of traditional wooden versus aluminum galvanized iron housing on the physiological well-being of Saanen in a tropical climate. By systematically evaluating the physiological responses of Saanen does under both housing conditions, this research seeks to provide critical insights into the suitability of these housing systems in tropical livestock farming. The findings from this study have the potential to inform better housing designs that improve animal welfare, promote sustainable farming practices, and offer cost-effective solutions for smallholder farmers.

MATERIALS AND METHODS

Ethics approval

The research protocol for this study was approved by the UniSZA Animal and Plant Research Ethics Committee (UAPREC) under approval number UAPREC/008/003. Ethical considerations were made to ensure that the animals were handled with care and that all procedures adhered to the animal welfare guidelines.

Study design

The experiment was conducted over 90 days (12 weeks) at Ladang Universiti Sultan Zainal Abidin (UniSZA), Pasir Akar. The farm is situated at 102.471009 longitude and 5.643865 latitude. The average annual ambient temperature ranged from 25.7°C to 30.2°C, with an average humidity of 80.0%. This area received 181.4 mm of annual rainfall. The primary objective of this study is to evaluate the physiological responses of Saanen houses in two housing systems: traditional wooden and aluminum galvanized iron houses. The first housing system, T1, was a traditional wooden structure with slatted wooden flooring and wooden walls with an asbestos roof, utilizing the existing facilities at the farm. The second housing system, T2, was a modern design composed of aluminum and galvanized iron, featuring an aluminum mesh floor and walls made of aluminum galvanized iron with a zinc roof. Each pen's dimensions adhered to the standard space allowance of 0.75–1.0 square meters per goat, as recommended for goats aged 9 to 12 months (Acharya et al. 2017). Each pen was equipped with water drinkers and feed troughs to provide the animals with a consistent food and water supply.

Experimental animals

Twelve healthy, non-lactating, young adult Saanen goats, aged 9 to 12 months and averaging 23.54±1.15 kg, were randomly selected from the UniSZA farm flock. The goats were divided into two groups of six, one housed in traditional wooden pens (T_0) and the other in aluminum galvanized iron pens (T_1). Each goat was tagged for individual identification. All goats had a daily diet consisting of 40% commercial concentrate in the morning and 60% *Brachiaria humidicola* in the morning and afternoon. Table 1 shows the proximate analysis of feed used during the experiment. Water was provided ad libitum to both groups. Prior to data collection, the goats underwent a two-week acclimation period in their assigned housing to allow for adjustment to the new environmental conditions.

Microclimate variables

The microclimatic conditions within the two housing systems were asses by measuring the ambient temperature (AT) and relative humidity (RH) were measured using a digital thermohydrometer (SNDWAY SW572, China) with a measurement range of -20°C to 60°C (±0.3°C) for temperature and 0% to 100% (±3%) for relative humidity. Measurements were taken at three-time points daily: 8:30 a.m., 1:00 p.m., and 4:30 p.m., on the same days when physiological data were collected. The recorded AT and RH values were used to calculate the temperature-humidity index (THI), a commonly used indicator of heat stress, to provide a more comprehensive assessment of thermal comfort in each housing system. THI was calculated using the equation provided by Habeeb et al. (2018):

$$THI = (1.8 \times AT + 32) - ((0.55 - 0.0055 \times RH) \times (1.8 \times AT - 26))$$

This index provided a more comprehensive understanding of the environmental comfort levels within the wooden and aluminum galvanized iron housing systems.

Thermoregulatory variables

After the two-week adaptation period, thermoregulatory variables, including respiratory rate (RR), heart rate (HR), and rectal temperature (RT), were recorded at the same three-time points daily (8:30 a.m., 1:00 p.m., and 4:30 p.m.). The goats were restrained using a low-stress technique, positioned in the corner of the pen with their chin gently held to prevent movement. This procedure took approximately 1 to 3 minutes per goat.

Rectal temperature (RT) was measured by inserting a flexible-tip digital thermometer into the goat's rectum for 30 seconds. Heart rate (HR) was measured using a stethoscope placed on the left thoracic region over the aortic arch. Heartbeats were counted for 15 seconds and multiplied by four to obtain beats per minute (de Oliveira et al. 2018; Ferreira et al. 2020) . Respiratory rate (RR) was measured by counting the number of abdominal movements (breaths) for 15 seconds and multiplying by four to get breaths per minute. These measurements provided valuable insights into the goats' thermoregulatory responses to the varying environmental conditions within each housing system.

Blood sampling and analysis

Blood samples were collected from all goats via jugular venipuncture using a 21G needle at four-time points: week 0, week 4, week 8, and week 12. Blood was drawn into plain tubes immediately before morning feeding at 8.30 a.m. and then allowed to sit at room

Table 1. Proximate analysis of feeds used during the experiment

Parameters (% Dry Matter basis)	*Brachiaria humidicola*	Concentrate feed
Dry matter	50.4	87.0
Crude protein	3.4	14.0
Crude fat	<0.1	4.0
Crude fibre	15.2	20.0

temperature for 4 hours. The blood was centrifuged at 600xg for 5 minutes at room temperature using a tabletop centrifuge, after which the serum was separated and stored at -20°C for later analysis. Serum cortisol concentrations were determined using a commercial ELISA kit (Elabscience Biotechnology, China). The standard diluents were prepared and diluted according to the manufacturer's instructions before being added to the standard wells. In the test sample wells, 50 µL of serum sample was added, followed by 50 µL of biotinylated detection antibody working solution. The plate was sealed and incubated for 45 minutes at 37°C. After incubation, the liquid was discarded, and each well was filled with washing buffer, mixed gently, and shaken for 1–2 minutes before discarding the liquid. This washing step was repeated three times, and the wells were tapped onto absorbent paper to remove excess liquid. Following this, 100 µL of HRP conjugate working solution was added to each well, and the plate was sealed and incubated for 15 minutes at 37°C. The washing procedure was repeated five times, as described earlier. Next, 50 µL of substrate reagent was added to each well, and the plate was sealed and incubated for 10 minutes at 37°C, protected from light to prevent degradation of the chromogens. After incubation, 50 µL of stop solution was added to each well. Finally, the optical density (OD) values were measured at 450 nm using a microplate reader, and cortisol concentrations were determined by plotting a standard curve based on the standard concentrations and their corresponding OD values.

Statistical analysis

Statistical analysis was performed using SPSS version 27. Descriptive statistics, including means and standard deviations, were calculated for all microclimatic (AT, RH, and THI) and physiological responses (RT, HR RR) variables. A T-test was used to compare the microclimate variable and thermoregulatory responses between two housing systems within each of the times of day (morning, afternoon, and evening). A one-way ANOVA was conducted to evaluate differences in microclimatic and physiological response variables across three daily time points (morning, afternoon, and evening) within each housing system. Significant was set at $P < 0.05$. The correlation between THI with RT, RR, and HR was analyzed.

RESULTS AND DISCUSSION

Microclimate variables

Table 2 presents the microclimate variable observation across different housing systems at various times of the day in Saanen. The microclimate analysis showed that RH in the morning was significantly higher in aluminum galvanized iron housing (78.3 ± 1.41%) compared to traditional wooden housing (72.1±2.00%) with P value = 0.02. This difference could be attributed to the material properties of aluminum galvanized iron, which retains less moisture

Table 2. The microclimate variable across different housing systems at different times of day in Saanen does

Microclimate parameters	Times of day (N=3)	Housing system (N=2) Traditional wooden	Aluminium galvanized iron	Pooled mean	P value
RH (%)	Morning	72.1±2.00^{a}	78.3±1.41^{a}	75.2±1.32^{a}	0.02*
	Afternoon	58.7±2.00^{b}	60.0±1.56^{b}	59.3±1.24^{b}	0.6
	Evening	72.3±4.61^{a}	72.1±4.72^{a}	72.3±3.22^{a}	0.95
	Overall	67.8±2.08	70.1±2.14	69.0±1.49	0.44
AT (°C)	Morning	30.6±0.71^{a}	28.9±0.55^{a}	28.9±0.55^{a}	0.06
	Afternoon	35.2±0.48^{b}	34.2±0.27^{b}	34.1±0.29^{b}	0.06
	Evening	31.6±1.12^{a}	31.5±1.17^{c}	31.6±0.79^{a}	0.98
	Overall	32.5±3.32	31.5±3.29	32.0±0.41	0.24
THI	Morning	82.5±0.77^{a}	80.8±0.6^{a}	81.7±0.53^{a}	0.11
	Afternoon	86.9±0.41^{b}	85.7±0.66^{b}	86.3±0.26^{b}	0.02*
	Evening	83.7±0.95^{a}	83.5±1.04^{b}	83.6±0.69^{c}	0.91
	Overall	84.4±3.05	83.3±3.09	83.8±0.38	0.18

Means with different superscripts in the column differed significantly (P<0.05) than traditional wooden housing, leading to increased indoor humidity due to reduced ventilation or air exchange (Salonvaara et al. 2004). However, the lack of significant differences during the afternoon and evening indicates that both housing systems maintain similar humidity levels.

Regarding AT, there were no significant differences (P>0.05) between the housing systems on any day. However, traditional wooden housing consistently recorded slightly higher temperatures with mean AT in traditional wooden housing (32.5±3.32°C) and aluminum galvanized iron housing (31.5±3.29°C), but these differences were minimal; this suggests that both houses provided similar environments throughout this experiment.

While THI was significantly lower in aluminum galvanized iron housing during the afternoon (85.7±0.66) compared to traditional wooden housing (86.9±0.41) with a P value= 0.02, this reduction in THI during the afternoon could be attributed to aluminum's reflective and conductive properties, which reduce heat (Pradhan et al. 2021). No significant differences in THI were noted during the morning and evening in both housing types (P>0.05), suggesting that overall, both housing systems maintained similar THI levels.

The current result suggests stressful conditions were present in both housing systems in Saanen. However, aluminum galvanized iron provides more suitable conditions, allowing Saanen to experience sensible and latent heat loss. According to Sejian et al. (2021), the optimal AT range for goats is between 6°C to 27°C with RH 60% to 80%. In a recent study, the average AT in both housing systems exceeded this range (28.9±0.55°C to 35.2±0.48°C), while RH was within the normal range except in traditional wooden housing during the afternoon (58.7±2.00%). It was also observed that in both houses, the highest AT and lowest RH recorded during this study were in the afternoon. These findings align with Borges and Rocha (2018) and Singh et al. (2017), who also reported peak AT and reduced RH in the afternoon.

The combined values of RH and AT are critical for assessing heat stress and thermal comfort in livestock (Habeeb et al. 2018; Sejian et al. 2021). According to Aleena et al. (2018), THI values of 70 or less are considered comfortable for goats, values above 75 indicate heat stress, and those exceeding 85 suggest severe heat stress. This study's THI values ranged from 80.8±0.6 to 86.9±0.41, indicating that the goats experienced low to severe heat stress. However, Silanikove & Koluman (2015) and Srivastava et al. (2021) proposed that THI values above 90 represent severe to extreme heat stress. The discrepancy between these thresholds could be attributed to differences in the study locations, climate, or goat breeds.

Notably, goats in both housing systems experienced severe heat stress during the afternoon due to high AT and low RH. Such stressful conditions can prompt goats to alter their behaviors and physiological responses as adaptive mechanisms to cope with the environment. Due to their morphological and physiological characteristics, goats are generally more resilient to heat stress than cattle and sheep (Sejian et al. 2021).

Thermoregulatory variables

The objective of the current study was to determine the physiological responses of the Saanen in different types of housing: traditional wooden and aluminum galvanized iron houses. Table 3 shows the variation of the RT, RR, and HR in traditional wooden and aluminum galvanized iron houses at various times of the day. RT of Saanen does in both housing systems showed no significant differences (P > 0.05) at any time of the day. The overall RT was similar between the traditional wooden (39.4±0.02°C) and aluminum galvanized iron housing (39.5±0.02°C). In contrast, significant differences were observed between housing systems (P<0.05). Does in the wooden system exhibited higher (61.9±1.68 breaths/min) than those in the aluminum galvanized iron system (53.9±1.54 breaths/min). In both housing systems, RR peaked during the afternoon compared to morning and evening values. HR also differed significantly (P<0.05) between housing systems, with higher HR observed in the aluminum galvanized iron housing (101.1±1.30 beats/min) compared to the traditional wooden housing (94.8±1.38 beats/min). However, no significant differences were observed in HR at specific times of the day (P>0.05). These patterns are consistent with previous studies by Borges and Rocha (2018), Beyleto et al. (2022), and Singh et al. (2023), which reported an afternoon peak in RR compared to other times.

Rectal temperature is a critical indicator of livestock's core body temperature and heat stress (Rejeb et al. 2016). The lack of significant differences in RT between the two housing systems suggests that both environments provided similar thermal regulation for Saanen. The lower morning temperature suggests that both housings effectively maintained a stable thermal environment during more incredible hours, keeping the goats in a thermoneutral state where their body temperature was well-regulated and within a healthy range. However, the significant rise in body temperature during the afternoon in both houses can be attributed to the elevated THI. By evening, as THI decreased, the goat's body temperature also lowered, yet it remained within the 37°C–41°C range, as Okoruwa (2014) reported.

RR and HR are vital indicators of both the environmental conditions and the animal’s health status. Under normal, unstressed conditions, goats' respiratory and heart rates typically range between 12 breaths/min to 20 breaths/min (Gupta & Mondal, 2021) and 16 beats/min to 34 beats/min (Samimi et al. 2018), respectively. However, this rate can increase significantly due to various factors such as heat stress, physical activity, and illness. In the present study, RR was significantly influenced by both housing systems at different times of the day. It reflects the goats' effect on maintaining thermal balance in varying environmental conditions. For instance, studies by Ribeiro et al. (2016) and (Silanikove 2000a) reported that goats typically increase their RR in response to high AT to dissipate excess body heat. The observed respiratory rates in the current study align with these physiological responses, particularly during the afternoon when environmental temperature peaks and heat stress are most pronounced, consistent with Borges & Rocha (2018) and Santos et al. (2021).

According to (Silanikove 2000a; Silanikove, 2000b), the severity of heat stress can be qualified according to respiratory rate (breaths/min) (low: 40–60, medium: 60–80, high: 80–120, and severe: >200). The recent study indicates that the goats in the traditional wooden house experienced medium heat stress while aluminum galvanized iron experienced low heat stress; this could be due to the house's material, which caused the high RR in a traditional wooden house. While wood offers some insulation, it also retains heat and limits air circulation (Michaud et al. 2020), creating a warmer environment for the goats. As a result, goats in traditional wooden houses showed higher RR as they tried to cool down. In contrast, aluminium galvanized iron house reflects heat better and promotes airflow. Increased air movement help lower the effective temperature experience by goats (Jacobson 2013). This environment allows them to maintain a lower respiratory rate, reducing heat stress. Thus, an elevated RR in goats is a clear indicator of thermal discomfort due to heat stress.

According to Heath & Olusanya (1985), HR is the normal beat rate of the arteries as blood is pushed through them to heart. HR can be altered due to animals' biological activities or an external factor such as temperature. Interestingly, HR increases during heat stress to dissipate heat to its surroundings by enhancing blood flow to the body's surface (Shilja et al. 2016). The goat's physiological adaptation HR was 106.7±15.27 beats/min (de Souza et al. 2014). In a recent study, the HR was still below the range of physiological adaptation. Interestingly, the HR rate remains consistent in the morning and afternoon but increases slightly in the evening. This result is inconsistent with previous study by Singh et al. (2017) and Borges & Rocha (2018), where the HR peaks in the afternoon in their study. This evening's HR increase in this study, despite the cooling external temperatures, could be due to the cumulative effect of the day's heat stress, indicating the goats were still recovering from the afternoon's high temperatures, leading to a sustained elevation in HR as their bodies continue to cool down.

Table 3. Thermoregulatory variables of Saanen does (N=12) in different housing system at various times of day

Thermoregulatory variables	Times of day (N=3)	Housing system (N=2)		Pooled mean	P value
		Traditional wooden	Aluminium galvanized iron		
RT (°C)	Morning	39.3±0.03[a]	39.4±0.04[a]	39.4±0.03[a]	0.384
	Afternoon	39.5±0.03[ab]	39.5±0.03[ab]	39.5±0.02[ab]	0.41
	Evening	39.4±0.03[b]	39.5±0.04[b]	39.5±0.03[b]	0.19
	Overall	39.4±0.02	39.5±0.02	39.4±0.02	0.09
RR (Breath/min)	Morning	49.7±2.23[a]	43.6±1.82[a]	46.6±1.46[a]	0.04
	Afternoon	72.7±2.66[b]	63.6±2.97[b]	59.5±2.04[b]	0.02
	Evening	64.3±3.02[b]	55.2±2.67[c]	31.6±2.04[c]	0.03
	Overall	61.9±1.68	53.9±1.54	57.7±1.16	<0.001
HR (Beats/min)	Morning	96.5±2.55[a]	100.3±2.42[a]	98.5±1.76[a]	0.28
	Afternoon	94.5±2.34[a]	100.1±1.98[a]	97.4±1.54[a]	0.07
	Evening	93.2±2.29[a]	102.9±2.28[a]	98.3±1.67[a]	0.003
	Overall	94.8±1.38	101.1±1.30	98.1±0.96	<0.001

Means with different superscripts in the column differed significantly (P<0.05)

Table 4. Relationship between temperature humidity index and rectal temperature, respiratory rate, and Saanen's heart rate in both houses

Correlated parameter	Type of houses	
	Traditional wooden	Aluminium galvanized iron
Temperature humidity index and mean rectal temperature	0.483**	0.386**
Temperature humidity index and mean respiratory rate	0.489**	0.438**
Temperature humidity index and male heart rate	-0.007	0.172*

**Correlation significant at the level P<0.01, *Correlation significant at level P<0.05

Table 5. Cortisol concentration of Saanen is in different types of houses.

	Type of houses	Weeks				Overall mean	P-value
		0	4	8	12		
Cortisol (ng/ml)	Traditional wooden	87.82±1.70	90.17±0.16	90.32±0.47	89.18±0.60	89.37±0.49	0.375
	Aluminium galvanized iron	89.49±0.82	87.80±0.82	87.35±0.91	89.02±0.61	88.42±0.47	

Table 4 shows the relationship between THI and RT, RR, and HR of Saanen in both types of houses. The results show that both housing systems exhibit a medium correlation with RT and RR; this suggesting as THI increases, the RR and RT also increase, indicating a thermoregulatory response to heat stress. Similar findings have been reported by Srivastava et al. (2021), who demonstrate that THI directly influences the RT and RR in small ruminants. Polsky and von Keyserlingk (2017) stated that elevated RR could be a significant stress indicator in evaluating thermally stressed animals as it represents a key mechanism for dissipating excess body heat through evaporating cooling (Shilja et al. 2016) While for the HR, in the aluminum galvanized iron house, have small positive correlation with THI indicating the HR increases slightly with heat stress, possibly as a compensatory mechanism to maintain thermoregulatory and blood flow, as describe by (Gupta et al. 2013). In contrast, in traditional wooden houses, HR did not show a correlation with THI, which may suggest a less pronounced effect of thermal load in this environment. Interestingly, this finding contradicts Srivastava et al. (2021), who observed a highly positive correlation between HR and THI in their study.

Cortisol concentration

Cortisol is the primary stress-related hormone used to measure goat stress (Silanikove, 2000a). When the goats are exposed to stress, their hypothalamic-pituitary-adrenal (HPA) axis is activated, which causes an increase in blood cortisol concentration. Cortisol secretion induces physiological adaptations that equip animals to abolish stress-induced effects (Adenkola & Ayo, 2010).

Table 5 shows the concentration of Saanen's cortisol in different types. The mean concentration observed in Saanen was higher than reported (30 to 46 ng/ml) by Singh et al. (2023). This elevated concentration may reflect the additional thermal load associated with Malaysia's tropical climate, characterized by high ambient temperatures and relative humidity. Similarly, Idris et al. (2024) reported that exposure to higher THI levels led to increased fecal cortisol concentrations in beef cattle, emphasizing the impact of thermal stress.

Interestingly, the type of houses did not influence the serum concentration of cortisol between the two types of houses where the Saanen experienced the same level of stress. However, as Hydbring-Sandberg et al. (2022) noted, cortisol alone may not provide a comprehensive measure of stress. Evaluating stress responses requires complementary indicators, such as thermoregulatory variables or additional hormonal markers, to ensure a holistic understanding. Further studies are needed to examine the interactions between housing systems, environmental conditions, and stress physiology. This approach could provide insights into optimizing goat welfare and productivity in hot climates while minimizing stress-related effects.

CONCLUSION

In conclusion, this study suggests that both housing types present stressful conditions for the goats, particularly in the afternoon. However, the aluminum galvanized iron house provided more suitable and comfortable conditions, aiding both sensible and latent heat loss. Goats housed in this system showed improved thermal comfort and welfare, suggesting its potential to enhance productivity and growth performance in tropical climates like Malaysia. This housing system is a viable alternative to traditional wooden housing. Future research should focus on the long-term feasibility and performance of aluminum galvanized housing to further validate its effectiveness over time.

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