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Thermoregulatory Responses of Swamp Buffalo Heifers to different Microclimatic Conditions and Feed Consumption

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ABSTRACT

Buffaloes are more susceptible to heat stress because they have poor thermoregulation due to fewer sweat glands. Like other livestock, buffaloes receive body heat from internal metabolic processes and the environment. This study investigates the relationship between buffalo thermoregulatory responses to microclimate and feed consumption in 12 Swamp buffalo heifers. This research was carried out in three sub-districts in West Sumatra, Indonesia, which were classified as low-land (Nan Sebaris District, Padang Pariaman Regency), moderate-land (Guguk District, 50 Kota Regency), and high-land (Batipuh District, Tanah Datar Regency). The Latin Square Design was used as the research design in three locations (4 heads per location) with varying microclimate conditions (altitude) and feed energy contents (TDN). F0 (buffaloes fasted for 24 hours), F1 (TDN = 58–60%), F2 (TDN = 63–65%), and F3 (TDN = 68–70%) were the feed treatments. The microclimate (ambient temperature-Ta and Temperature Humidity Index-THI), feed consumption (dry matter-DM and Total Digestible Nutrient-TDN), and thermoregulatory responses (rectal temperature-Tr, mean skin surface temperature-mTs, body temperature-Tb, heart rate-HR, and respiratory rate-RR) were all recorded. On days 11, 14, 17, and 20, environmental parameters and physiological responses were measured every 3 hours. The findings confirm that microclimate and feed consumption impact thermoregulatory responses. When the energy content of the feed increased, all thermoregulatory responses increased significantly ($P<0.05$). In conclusion, the buffalo thermoregulatory response was sensitive to changes in feed intake and microclimate variation. This study could help guide buffalo-raising management in various microclimate areas to achieve optimal productivity.

Key words: Altitude, Heat stress, TDN intake, Temperature humidity index.

INTRODUCTION

Swamp buffaloes are a type of large ruminants that potential meat and milk sources (Afriani et al. 2020; Roza et al. 2022). However, these animals are prone to heat stress due to the hot environmental conditions expected in the tropics, including Indonesia. Some triggering factors for such phenomena include their dark skin color, which absorbs more heat, and inadequate thermoregulation due to their thick epidermis (Khongdee et al. 2013; Yasothai 2014). Furthermore, this animal has fewer sweat glands than other livestock, such as goats, horses and cattle (Raghav et al. 2021), undermining their productivity. To control heat stress, buffalo management in the tropics must be closely monitored.

Buffaloes are found throughout Indonesia in low, moderate, and high-land areas with varying agroclimatic conditions. The physiological systems of animals are affected by environmental factors such as ambient temperature, relative humidity, solar radiation, atmospheric pressure, and wind speed (Purohit et al. 2020). Buffaloes accept varying amounts of heat from their surroundings depending on the microclimate. Heat stress occurs in animals when exposed to high temperatures,

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which activates physiological mechanisms to maintain body temperature and thermal body balance (Lendrawati et al. 2020; Purohit et al. 2020). Different microclimatic conditions caused different rectal temperatures, surface temperatures, respiration rates, and pulse rates in buffalo, according to Khongdee et al. (2013), Wankar et al. (2014), Li et al. (2020) and Yetmaneli et al. (2023).

Furthermore, feed availability and quality may vary in low-land, moderate-land, and high-land areas. As a result, feed and energy consumption may differ across the three regions. According to Ahmad et al. (2017) and Omran et al. (2019), different environmental conditions influence buffalo feed intake. According to Savsani et al. (2015), increasing environmental temperatures decreased the quantity of dry matter consumption, which dropped 9-13 percent in high temperatures, as also reported by Habeeb et al. (2023). Susanty (2018) discovered that as energy feed intake increases, so do physiological responses. This result demonstrates that buffalo thermoregulation is affected by environmental conditions and feed energy intake.

In India (Vaidya et al. 2011; Wankar et al. 2014), Pakistan (Younas et al. 2020), Brazil (Silva et al. 2015), and other countries the effects of the environment on riverine buffalo physiology have been extensively studied. Thailand has also conducted several studies on the physiological responses of Swamp buffalo (Khongdee et al. 2013). However, few studies have examined the combined effect of environment and feed intake on swamp buffalo physiological response. Our research investigates swamp buffalo thermoregulation, feed intake under various agroclimatic conditions, and the effects of microclimate and varying feed intakes on buffalo physiology. The findings can be used to improve buffalo-raising techniques and optimizing productivity across different microclimates.

MATERIALS AND METHODS

Ethical approval

The Animal Ethics Committee, No. ACUC No: 152-2019 IPB of IPB University Bogor, Indonesia, has reviewed and approved this research procedure, which took animal welfare into account.

Location

This research was carried out in three sub-districts in West Sumatra, Indonesia. These three sub-districts were classified as low-land (Nan Sebaris District, Padang Pariaman Regency - 18m asl), moderate-land (Guguk District, 50 Kota Regency - 523m asl) and high-land (Batipuh District, Tanah Datar Regency - 1032m asl).

Objects, tools and materials

Twelve buffalo heifers (2.5–3 years old, weighing 342.25–394.02kg) were used in this study and they were housed in permanent individual pens (1.2 x 2.0m) with a water sprinkler system and buffalo house equipment. Local forages and commercial concentrate (SP 106 produced by PT. Mabar Feed Indonesia) were used as buffalo fed. Dry and wet thermometers, infrared thermometers (GM550), digital thermometers (OMRON-MC246), clinical stethoscopes, stopwatches and digital scales were also used.

Methods

A 4 x 4 replicated Latin Square Design (LSD) was used in this experimental study. F0 (buffaloes fasted for 24 hours and given ad libitum drinking water), F1 (100% grass (TDN 58-60%), F2 (30% concentrate + 70% grass (TDN 63-65%), and F3 (60% concentrate and 40% grass (TDN 68–70%)) were the numbers of feed treatments. The study lasted 60 days in total, with 20 days spent in each location, beginning with the low-land and progressing to the moderate and high-land. Buffaloes were given concentrate for 20 days, twice daily at 8:00 and 16:00, while grass and drinking water were served ad libitum. Buffaloes adjusted to the rations from days 1 to 10. The treatment was applied, and the data were measured on days 11, 14, 17 and 20. The grass was given between those days to neutralize their physiological conditions. The sprinkling system was started daily at 13:00 local time and ran for 15 minutes.

Parameters and data collection

The microclimate conditions (ambient temperature-Ta and Temperature Humidity Index-THI), feed consumption (dry matter-DM and Total Digestible Nutrient-TDN) and thermoregulatory responses (rectal temperature-Tr, mean skin surface temperature-mTs, body temperature-Tb, heart rate-HR, and respiratory rate-RR) were all measured in this study. Microclimate and thermoregulatory responses were measured at 06:00, 09:00, 12:00, 15:00, 18:00, and 20:00 local times. THI was calculated using the following formula (McDowell 1972): $THI = 0.72\ (DBT + WBT) + 40.6$, where DBT is Dry Bulb Temperature (ambient temperature = Ta) and WBT is the wet bulb temperature recorded by the dry-wet bulb thermometer.

Feed consumption consisting of dry matter (kg) and Total Digestible Nutrient (g/kgW0.75/day) calculated from forage and concentrates consumption within 24 hours based on proximate analysis at the Biochemistry and Biotechnology Laboratory, IPB University.

Rectal temperature was measured with a digital thermometer, skin surface temperature with an infrared thermometer, heart rate with a clinical stethoscope by counting the number of heartbeats, and respiration rate by counting the flank movements. $mTs = 0.25\ (A+B) + 0.32\ C + 0.18\ D$ where A is the upper trunk temperature, B is the lower trunk temperature, C is the upper limbs temperature, and D is the lower limbs temperature (Mclean et al. 1983). The equation (Mclean et al. 1983) was used to calculate Tb: $Tb = 0.86\ Tr + 0.14\ mTs$.

Data analysis

Agroclimatic conditions, feed consumption, and physiological responses were all recorded and calculated in Microsoft Excel using appropriate formulas. The data were entered into the statistical software SPSS, which analyzed descriptive data, analysis of variance (ANOVA), and Duncan's multiple range test.

RESULTS AND DISCUSSION

Microclimate

Fig. 1 depicts the microclimate conditions in the lowland, moderate-land, and high-land. Between 06:00 and 20:00, the average Ta values at those three locations were 28.48 ±2.45°C, 25.96±2.68°C and 21.72±2.23°C, respectively.

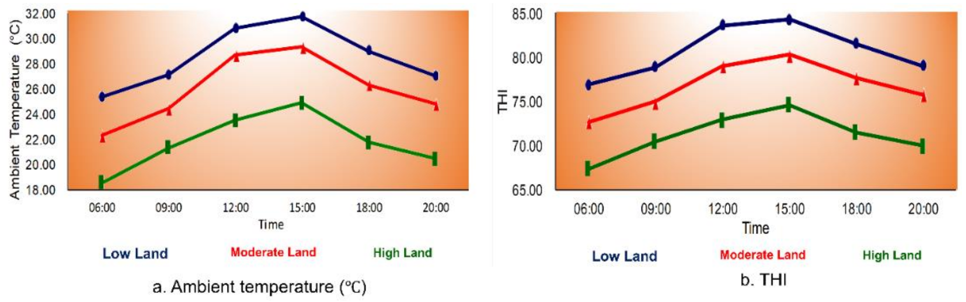

Fig. 1: Ambient temperature (a) and THI (b) in low-land (blue), moderate-land (red), and high-land (green) areas.

The average THI values were 80.74±2.91, 76.75±2.81, and 71.15±2.49, respectively. There were differences ($P<0.05$) in Ta and THI between the altitudes. The Ta difference occurs because the altitude difference among each location is more than 505-1014m asl. According to Vitasse et al. (2010), the ambient temperature drops by 0.4°C for every 100 meters of elevation above sea level. The study discovered that the Ta decreases 0.5-0.83°C every 100-meter elevation increase. The temperature and humidity index, THI, is affected by temperature differences.

Ta and THI in the lowland, moderate-land, and high-land reached their highest values at 15:00 local time and their lowest at 06:00 local time, as shown in Fig. 1. Soneye et al. (2019) found similar results in Nigeria (a tropical country), where the highest temperature occurred at 15.00. Yetmaneli et al. (2020) found that the highest ambient temperature and THI in lowland and high-land West Sumatra occurred at 13:00 and 16:00 local time, respectively. According to another report (Susanty 2018), the highest ambient temperature in West Java was reached at 12:00 (mid-day) local time, with variations between low, moderate, and high-land. According to the finding by Adeniyi et al. (2012), this difference could be due to differences in data collection times, as there are differences in the peak of solar radiation throughout the year, which affects ambient temperature.

Microclimate conditions strongly influence animal physiological reactions (Susanty et al. 2018). Crudeli (2011) predicts a comfort temperature of 21°C, while Payne (1990) notes that the best climatic conditions for buffalo growth and reproduction are temperatures of 13-18°C paired with an average relative humidity of 55-65%. According to Umar et al. (2021), buffaloes suffer heat stress faster than cows, with buffaloes feeling comfortable at THI<67, mild stress at THI 68-72, moderate stress at THI 73-76, and severe stress at THI≥77. As a result of this study, buffaloes in the low-lands experienced severe heat stress from 06:00 to 20:00 local time. From 12:00 to 18:00, buffalo in the moderate-land are subjected to severe heat stress. Heat stress, on the other hand, has no effect on buffaloes in the highlands. According to Athaíde et al. (2020), buffaloes in non-shading areas in Brazil experienced hyperthermia between 10 am and 2 pm.

Feed consumption

Dry Matter (DM) and TDN intake in low-land, moderate-land, and high-land are presented in Table 1. Data show that DM and TDN intake was higher in high-land areas than in moderate-land and low-land areas; however, statistical analysis revealed no significant differences ($P>0.05$) in DM and TDN intake across altitudes. This finding contradicts the findings of Ahmad et al. (2017) and Omran et al. (2019), who found that

Table 1: Dry matter and TDN intake of heifer buffaloes in low-land, moderate-land, and high-land

Feed components/ Treatments	Locations			
	Low-land	Moderate-land	High-land	P Value
Dry Matter (kg/d/head)				
F0	0^a	0^a	0^a	
F1	$5.55±0.90^b$	$5.33±1.45^b$	$6.24±0.64^b$	0.270
F2	$6.09±0.65^b$	$6.66±1.04^{bc}$	$7.42±0.96^c$	0.076
F3	$7.18±0.86^c$	$6.96±0.41^c$	$7.45±1.09^c$	0.448
Average	4.71±2.94	4.74±3.01	5.28±3.27	
Total Digestible Nutrient (g/d/kg.$W^{0.75}$)				
F0	0^a	0^a	0^a	0
F1	$39.50±4.86^b$	$38.19±8.56^b$	$43.05±2.65^b$	0.293
F2	$46.78±2.78^c$	$51.74±8.53^c$	$54.90±3.89^c$	0.083
F3	$58.10±7.19^d$	$56.71±2.20^c$	$58.93±6.0^c$	0.602
Average	36.10±22.95	36.66±23.60	39.22±24.39	0.098

Different superscript letters within the same column indicate a significant difference ($P<0.05$).

buffaloes kept in lower Ta and THI environments consume more feed than buffaloes kept in higher Ta and THI environments.

According to Bhimte et al. (2021) buffaloes raised in colder environments consume more feed to get more energy to maintain their body temperature. The increased feed intake increases metabolism and heat production (Yáñez-Pizaña et al. 2020). On the other hand, heat stress suppresses the hunger point in the hypothalamus, resulting in decreased feed intake (Kumar et al. 2018), to prevent excessive metabolic heat production for maintaining optimal physiological conditions (Mushawwir et al. 2020). High environmental temperature and humidity reduce feed intake by 9-13% (Savsani et al. 2015).

The insignificant difference in buffaloes' feed consumption in the three study areas showed that the buffaloes can still adapt to microclimate differences. They did not require additional feed to maintain their physiological stability. Dry matter and TDN consumption at F0, F1, F2 and F3 treatment in each study area showed a significant difference ($P<0.05$). The higher DM and TDN intake in F2 and F3 than in F1 at each location was due to feeding concentrates containing 30% and 60% more dry matter and TDN than grass, respectively.

Thermoregulatory responses

Table 2 shows the Tr, mTs, Tb, Hr, and RR values. The findings revealed that the microclimate had a significant effect ($P<0.05$) on all thermoregulatory parameters except heart rate. The F0 treatment had the lowest thermoregulatory parameters, while the F3 treatment had the highest. The thermoregulatory responses in the F0 treatment were mainly influenced by the day's environment and feed consumption on the previous day.

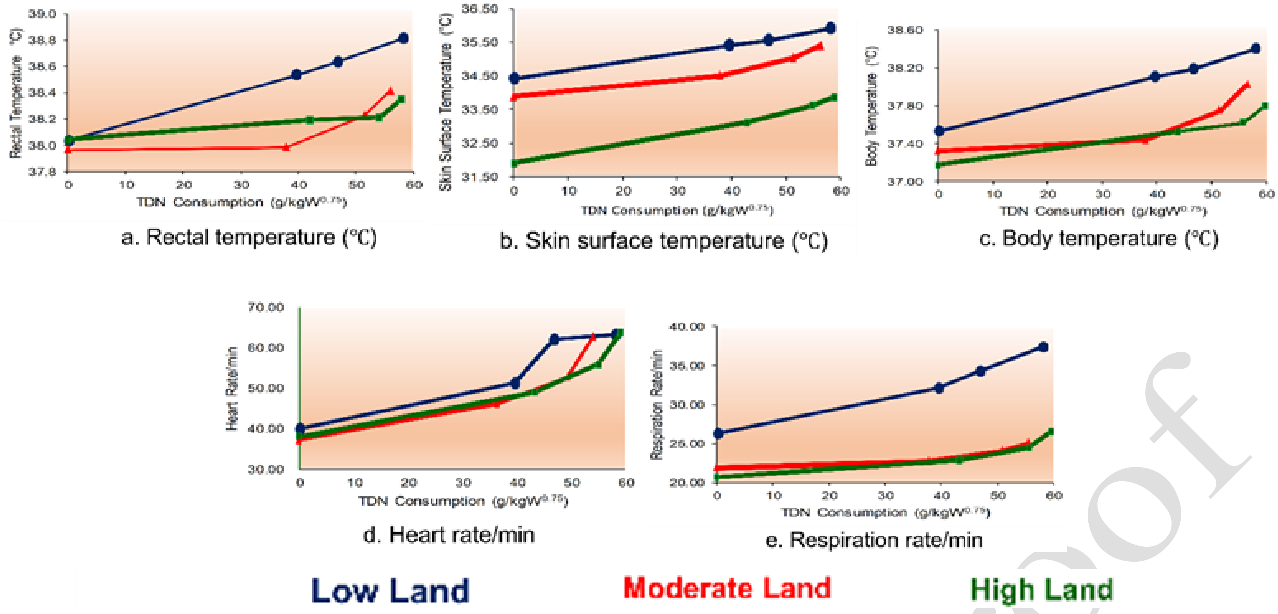

Fig. 2: Thermoregulatory responses and TDN intake of heifer Swamp buffaloes in different microclimate.

Meanwhile, the F3 treatment had the highest thermoregulatory response due to higher DM and TDN intake compared to the other treatments. According to Susanty et al. (2018), this higher thermoregulatory response may be due to buffalo's higher metabolic heat production. These findings were similar to those by Suherman and Purwanto (2015), who found that buffalo fed higher TDN concentrate had higher thermoregulatory responses. This finding demonstrated that increasing TDN intake affects thermoregulatory responses.

The average thermoregulatory responses of buffaloes had the highest value in the lowlands, which could be due to the higher ambient temperature and THI, even though there was no significant difference (P>0.05) between DM and TDN intake. The results are in line with the report of Singh et al. (2014), which showed that the physiological response of buffaloes under environmental conditions with higher THI was higher in dry summer than in winter. Li et al. (2020) reported that skin surface temperatures and respiratory rates were higher in summer than in spring, autumn, and winter, but rectal temperatures were relatively similar. Another finding reported by Wankar et al. (2019) showed significant differences in rectal temperature, skin surface temperature, and respiratory frequency in buffalo kept in an environment with an ambient temperature of 25, 30 and 40°C.

According to Mishra (2023), the physiological responses that animals immediately exhibit in response to climate stress are rectal temperature, respiration rate, heart rate, sweating rate, skin temperature, digestion, and nutrient absorption. Rectal temperature is a sensitive physiological state predictor in domestic species exposed to climate stress. Respiration rate is the most reliable biomarker among the various physiological reactions animals exhibit when subjected to climate stress. According to Hossain et al. (2022), when THI increases by one point, the rectal temperature rises by 0.069°C.

Fig. 2 depicts the relationship between buffalo thermoregulatory responses and TDN intake in low, moderate, and high-land areas. The thermoregulatory response of buffaloes increased as TDN intake increased.

Table 2: Thermoregulatory responses of heifer Swamp buffaloes in different microclimate and feed intake

Parameters/ Treatments	Locations		
	Low-land	Moderate-land	High-land
Rectum Temperature (Tr)			
F0	38.03±0.13^{ab}	37.93±0.28^{a}	38.13±0.18^{b}
F1	38.53±0.33^{b}	37.96±0.16^{a}	38.32±0.37^{b}
F2	38.63±0.43^{b}	38.25±0.25^{a}	38.34±0.35^{a}
F3	38.81±0.37	38.51±0.56	38.52±0.57
Average	38.50±0.42^{b}	38.16±0.40^{a}	38.33±0.38^{ab}
Skin Surface Temperature (mTs)			
F0	34.41±0.06^{c}	33.69±0.28^{b}	31.82±0.84^{a}
F1	35.41±0.62^{c}	34.40±0.31^{b}	33.16±0.40^{a}
F2	35.54±0.08^{b}	34.99±0.67^{b}	33.72±1.08^{a}
F3	35.88±0.57^{b}	35.41±0.62^{b}	34.02±0.90^{a}
Average	35.31±0.68^{c}	34.62±0.80^{b}	33.18±1.15^{a}
Body Temperature (Tb)			
F0	37.53±0.11^{b}	37.33±0.27^{a}	37.24±0.24^{a}
F1	38.10±0.25^{b}	37.46±0.17^{a}	37.60±0.33^{a}
F2	38.19±0.37^{b}	37.79±0.30^{a}	37.69±0.45^{a}
F3	38.40±0.39^{b}	38.08±0.56^{ab}	37.89±0.61^{a}
Average	38.05±0.43^{b}	37.67±0.44^{a}	37.61±0.45^{a}
Heart Rate (HR)			
F0	39.90±7.42	37.26±6.81	38.26±8.56
F1	51.30±4.10	46.31±9.79	50.75±12.20
F2	62.03±9.99^{b}	52.82±12.66^{a}	58.43±11.89^{ab}
F3	63.16±9.47	63.23±12.65	67.37±12.04
Average	54.10±12.12	49.90±13.72	53.70±14.95
Respiration Rate (RR)			
F0	26.30±5.72^{b}	21.95±2.26^{a}	21.05±4.32^{a}
F1	32.05±11.30^{b}	22.99±3.24^{a}	23.36±5.38^{a}
F2	34.32±9.12^{b}	24.61±3.33^{a}	24.86±5.63^{a}
F3	37.33±13.70^{b}	25.82±6.70^{a}	27.04±7.25^{a}
Average	32.50±10.18^{b}	23.84±4.08^{a}	24.07±5.61^{a}

Different superscript letters within the same row indicate a significant difference (P<0.05).

Although there were similarities in the changes in thermoregulatory responses between altitudes, the values differed between altitudes with similar TDN intake. Even though TDN intake was relatively similar, Buffalo's thermoregulation response line in the lowlands was always above the other lines. It could be due to other factors affecting buffalo physiology, such as THI, which is the combined effect of temperature and humidity.

Conclusion

The thermoregulatory response of buffaloes (rectal temperature, skin surface temperature, body temperature, and respiration rate) was sensitive to feed intake and microclimate changes. This research could help buffalo-raising managers manage buffalo productivity levels in various microclimates.

Authors' contributions

R Reswati conducted the research, collecting and analyzing data and writing the initial manuscript. BP Purwanto guided and supervised the research team throughout the project, contributed to the study design and methodology, and reviewed and provided critical feedback on the manuscript. R Priyanto assisted in developing the research methodology, provided insightful and helpful suggestions during data analysis, and reviewed and revised the manuscript. W Manalu provided expertise in a specific study area, helped interpret research findings, and reviewed and provided feedback on the manuscript. RI Arifiantini provided overall supervision and guidance throughout the research process, assisted in acquiring research resources, and reviewed and approved the final manuscript version.

Competing interest

All researchers involved in the study declare that they have no competing interests.

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