Effect of heat stress on physiology and production of dairy cow

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Abstract

Dairy farming has become very popular in Bangladesh and most of the farmers reared high yielding dairy breed in their farm. Bangladesh is one of the tropical countries in this South-east Asia where heat stress is a matter of great concern as regard to exotic breed and global warming. The objective of this study was to asses the effect of heat stress on physiology and productive performance of dairy cows. A total of 162 dairy cows at different 28 dairy farm under Chattogram district were studied. The physiological parameters mainly rectal temperature, heart rate, urine specific gravity and respiration rate of individual cows were assessed. The frequency of respiration rate was higher than normal however, the value of other parameters was found in normal range. The frequency of some important behavioral sign related to heat stress like panting, drooling of saliva, tongue protrusion and neck extension were measured. The presence of panting, drooling of saliva, tongue protrusion and neck extension were respectively, 19.14%, 31.48%, 4.94%, and 96.91%. The result showed that extension of neck was most prevalent at the studied farms. Milk yield data of farm showed that 96 cows (59.26%) milk yield over 10 liter per day hence 66 cows (40.74%) milk yield below 10 liter per day. Relationship among rumination rate, panting, drooling of saliva along with respiration rate was compared and result was significantly ($p<0.05$) related. This study was concluded that the effect of heat stress changes in physiological parameters and may also reduce the productive performance of dairy cows. Proper management regarding heat stress should be taken to reduce heat stress that will help both farmers economic condition as well as welfare of dairy cows.

Keywords: Heat stress, Physiology, Productive performance, Dairy cow, Chattogram.

Chapter 1: Introduction

Climate change is considered to be the most unpredictable threat to our planet. It has become one of the biggest problems faced by the world now. Due to global warming, the temperature of the earth is increasing and this become threatened to all living matters on earth. The effects of high ambient temperatures on animals once thought to be limited to tropical areas, but due to global warming it extended into temperate areas (Polsky *et al*., 2017). Environmental temperatures have increased by 1.0^{o}c since the 1800s and are expected to continue to rise by another 1.5^{o}c between 2030 and 2052 (IPCC 2018). In addition to temperature, relative humidity plays an important role since it regulates the latent heat exchange from animals (Ramón *et al*., 2021). Heat stress is an important factor that negatively affects on performance and productivity traits of dairy cattle, especially in hot climate during summer in very areas of the world (Atrian *et al*., 2012).

From an animal perspective, heat stress may be defined as the sum of external forces acting on an animal that causes an increase in body temperature and evokes a physiological response (Dikmen *et al*., 2009). High external air temperature, humidity and exposure to solar radiation can lead a cattle to accumulate heat. In this situation cattle attempt to maintain constant body temperature by regulating thermal energy balance (Fournel *et al*., 2017). To maintain thermal energy balance, the heat generated through metabolism (maintenance, exercise, lactation, growth, gestation, feed intake) must equal to the heat lost to the environment. When the animal is unable to dissipate the heat that metabolically produced or absorbed, then thermal imbalance occur (Bernabucci *et al*., 2014). The interaction between the thermal environment and the body of an animal influences behaviour, physiology, reproduction and productivity (Hempel et al., 2019). Animal welfare can be negatively affected when dairy cattle introduce to heat stress. Both lactating cows and dry cows are affected by this. Sudden heat stress episodes more difficult for dairy cow to cope with because cows may require weeks to fully adapt to heat stress conditions (Perano *et al*., 2015). Lactating cows are affected by heat stress during peak of milk production and dry cows mostly during transition period (Atrian *et al*., 2012). In some conditions, the stress can lead the animal to death if it is not managed properly.

Bangladesh is an agricultural country and more than half of people in Bangladesh work in agriculture and livestock farming (Hossain *et al*., 2022). According to DLS the contribution of livestock in GDP is 1.90% (2021-22) fiscal year. Although the livestock population is increasing yearly, but there is lack of livestock products like milk and meat (DLS, 2022). The overgrowth of population in Bangladesh is one of the major causes for this situation. People in Bangladesh live on dairy products, which are an important part of farming systems (Hossain *et al*., 2022). As milk is considered nutritious and beneficial to health. The demand of milk in Bangladesh is 156.68 lakh metric ton but the production is 103.74 lakh metric ton (DLS, 2022).

Heat stress is a significant issue for the wellbeing of dairy cattle and has a number of effects on milk production (Ramón *et al*., 2021). Heat stress reduces dairy farm profitability and lead to significant decrease in milk yields in dairy cows and some metabolic disorders (Atrian *et al*., 2012). Macro- and microclimatic variables, their length and severity, the habitats in which they occur, and the biological traits of the animal all have a role in the biological effects of heat stress in cattle. Due to intense metabolic processes, high yielding dairy cows are highly susceptible to the effects of heat stress (Herbut *et al*., 2021). An animal in a shaded area receives heat from incoming solar radiation as well as radiation from the ground, which is both released by heated soil and reflected (Berman, 2019). The ability of animals to cope with heat stress resulting from solar radiation rely on the physical characteristics of their skin and coats (Da Silva *et al*., 2010). Modifications in behavior, physiology and production indicate disturbances in their capacity to regulate their body temperature. The expression of thermoregulatory behavior, such as a decrease in activity and feed consumption, a desire for cooler environments, or changes in reproductive behavior, may be crucial signs of animal welfare (Herbut *et al*., 2021). A cow gives the best performance in her comfort zone. Cows are adversely affected when the ambient temperature is more than their thermo-neutral zone (Atrian *et al*., 2012).

Now a days during summer season the temperature is quite high in Bangladesh due to global warming. The environmental high temperature generates stress to dairy cows and it leads to physiological changes as well as downgrade the productive performance. This issue creates an alarming situation to the dairy farmers as their profitability loss. For above mentioned reasons, an attempt was made to study about effect of heat stress on physiology and production of dairy cows

The objectives of this study:

1) To know the effect of heat stress on physiological parameters in dairy cows.
2) To study the effect of heat stress on productive performance of dairy cows.

Chapter 2: Materials and Method

2.1 Study area and Period

The study was conducted in four different area namely Chattogram metropolitan area, Raozan, Boalkhali and Banskhali under Chattogram district of Bangladesh. The areas are rich in dairy population, and this type of study was not conducted before in these areas, that's why the areas are selected for this study. The timeline for this study was from 18th March to 8th May, 2022 in the study area. The study time was selected on the base of summer season of Bangladesh to detect heat stress on animals.

2.2 Study population

A total of 162 cows were studied from 28 different dairy farms under Chattogram district.

2.3 Study design

The farms were chosen in random manner. A total of 162 dairy cows were studied from 28 dairy farm Chattogram district. Both rural and urban areas farm were studied in this study.

2.4 Farm location and population

In table -1, farms location and population of each farm were described. Farm population varies farm to farm rather it depends on farmers capacity, experiences, willingness of farming, profit of farming etc. Here most farms were located mainly near to main cities.

Figure 1: Geographical location of Chattogram district on Bangladesh map

Table 1: Farm location and population in the studied area

Name of the dairy farm	Location	Number of cows
Faiza dairy unit-1	Bahaddarhat	3
Faiza dairy unit-2	Bahaddarhat	2
Green harvest agro unit-1	2 no. gate	6
Green harvest agro unit-2	2 no. gate	2
Nizam dairy unit-1	Wazedia	7
Nizam dairy unit-2	Wazedia	3
Zarif dairy	Neyamot ali Road	18
Iftekhar dairy unit-1	Sagorika	2
Iftekhar dairy unit-2	Sagorika	1
Iftekhar dairy unit-3	Sagorika	1
Iftekhar dairy unit-4	Sagorika	2
Irfan dairy	Bahaddarhat	4
Arshi dairy unit-1	Banskhali	5
Arshi dairy unit-2	Banskhali	3
Molla dairy.unit-3	Patenga	11
Molla dairy.unit-2	Patenga	11
Molla dairy.unit-3	Patenga	8
Molla dairy.unit-3	Patenga	3
Molla dairy.unit-4	Patenga	6
Molla dairy.unit-4	Patenga	6
Sajid dairy farm	Boalkhali	7
Anzuman ara dairy.unit-1	Patenga	13
Anzuman ara dairy.unit-2	Patenga	6
Homeland dairy	Wazedia	11
Enam dairy.unit-1	Patenga	2
Enam dairy.unit-1	Patenga	2
Chabila krishi farm	Raozan	10
Abu Bakar dairy farm	Patenga	5
	Total cows:	162

2.5 Data Collection

A questionnaire was made according to the objectives of the study. Maintaining the information related to the prepared study, the questionnaire was built. The data were collected by face-to-face interview. The physiological data of cow were mostly emphasized during the questionnaire building. In this study total data were collected from 28 different farms based on random selection. Here some farm demographic data like source of drinking water, fresh drinking water supply, water supply, shower frequency, Roof insulation material, presence of ceiling and exhaust fan, shed surroundings and shed height were recorded. Cow data (rectal temperature, heart rate, urine specific gravity, respiration rate, rumination rate, panting, drooling of saliva, tongue protrusion, neck extension and milk yield) of total 162 cows were recorded for this study. Data for individual cow were taken using stethoscope, thermometer, and urinometer. Some data collected by close inspection of individual animal like panting, drooling of saliva, tongue protrusion, neck extension.

2.5 Statistical analysis

The collected data were analyzed with mainly in tabular method. The collected data were calculated and analyzed in MS excel software. The frequency, percentages, means were calculated to explain data scientifically. Associations in different factors were done by t-test in STATA-14 (stata corps, Texas, USA). The probability level of significance was considered as $p<0.05$. Relationship between rumination rate and respiration rate was calculated by t-test. The relationship of panting and drooling of saliva with respiration rate were also calculated separately by t-test.

Figure 2: Recording rectal temperature

Figure 3: Observing heart rate by auscultation

Figure 4: Measuring respiration rate

Figure 5: Calculating specific gravity of urine by urinometer

Chapter 3: Results

Table 2: Demographic information in a studied dairy farm (N=28)

Traits	Category	Frequency (%)	Confidence Interval
Source of drinking water	Tubewell	22 (78.57)	59.15-91.7
	Pond	4 (14.29)	4.03-32.66
	WASA	2 (7.14)	0.88 - 23.5
Fresh drinking water supply	Two times/day	12 (42.86)	24.46-62.82
	Three times/day	2 (7.14)	0.87-23.5
	Four times/day	4 (14.29)	4.03-32.66
	Available whole day	10 (35.71)	18.64-55.93
Water supply	With feed	5 (17.86)	6.06-36.89
	Water supplied separately	1 (3.57)	0.09-18.34
	Both separately and with feed	22 (78.57)	59.05-91.7
Shower	Once/day	2 (7.14)	0.87-23.5
	Two times/day	12 (42.86)	24.46-62.82
	Three times/day	8 (28.57)	13.22-48.66
	Four times/day	6 (21.43)	8.29-40.95
Roof Insulation material	Aluminum Foam Sheet	10 (35.71)	18.64-55.93
	Bamboo	14 (50)	30.64-69.35
	No material	4 (14.29)	4.03-32.66
Presence of ceiling fan	Present	22 (78.57)	59.05-91.7
	Absent	6 (21.43)	8.29-40.95
Exhaust fan	No exhaust fan	23 (82.14)	63.11-93.93
	Two fans	3 (10.71)	2.27-28.22
	Four fans	2 (7.14)	0.88-23.5
Shed surroundings	All open	12 (42.86)	24.46-62.82
	At least one side is closed	16 (57.14)	37.17-75.53
Shed height	≤ 10 feet	9 (32.14)	15.87-52.35
	> 10 feet	19 (67.86)	47.64-84.12

In table 2, demographic data of different farms is shown. From table 2, it was found that the water supply of cows majorly from tubewell (78.57%) some from pond (14.29%) and WASA (714%). The supply water mainly found into 2 categories. One was 2 times a day (42.86%) and the other was available whole day (35.71%). Some farmers reported supply the water 3 (7.14%) or 4 (14.29%) times a day.

The shower of cows founded into four categories once (7.14%), two times (42.86%), Three times (28.57%) and four times (21.43%) in a day. In this table showed that there are 2 types of material used as roof insulation purpose. One was Aluminum foam sheet (35.71%) and the other was bamboo (50%) some farmers used no insulation material in farm and the percentage of this (14.29%). In this table showed that both ceiling fan and exhaust fan were used in farm but mainly ceiling fan is used. The shed surroundings were all open (42.86%) and at least one side closed (57.14%). The information about shed height also found in this table. The percentage of shed height over 10 feet was (67.86%) and below 10 feet was (32.14%).

Table 3: Physiological parameters of individual dairy cow (N=162)

Traits	Category	Frequency (%)	Confidence Interval
Rectal temperature of cow	Normal range *(100.4-102.8 °F)	160 (98.77)	95.61-99.85
	Above 102.8 °F	2 (1.23)	0.15-4.39
Heart rate	Normal **(48-54/min)	146 (90.12)	84.45-94.24
	Rapid (>84/Min)	16 (9.88)	5.76-15.55
Urine Specific Gravity	Normal ***(1.03-1.045)	162 (100)	97.74-100
	Abnormal	0 (0.00)	0-2.26
Respiration rate	Normal ****(26-50/minute)	37 (22.84)	16.61-30.08
	Rapid (>50/min)	125 (77.16)	69.92-83.39

*Robertshaw, 2004; **Detweiler and Erickson, 2004; ***Reece, 2015; ****Reece, 2004.

In table 3, result of individual cow data (n=162) was shown. This table showed some physiological data of cow like (rectal temperature, heart rate, urine specific gravity, and respiration rate). This data sheet normal range of physiological parameters of cows is included along with reference. As we found that the temperature of cow was within normal range in 160 cows (98.77%) among 162 cows. The heart rate of cows was found normal condition in 146 cows (90.12%) and rapid condition in 16 cows (9.88%). The value of urine specific gravity was found in normal range of all cows (100%). But in case of respiration rate, the respiration rate of cow sample was found 37 (22.84%) within normal range on the other hand 125 cows (77.16%) was found in rapid condition.

Table 4: Behavioral signs and milk production data of studied cow (N=162)

Traits	Category	Frequency (%)	Confidence Interval
Panting	Yes	31 (19.14)	13.38-26.05
	No	131 (80.86)	73.95-86.62
Drooling of Saliva	Present	51 (31.48)	24.42-39.23
	Absent	111 (68.52)	60.77-75.58
Tongue Protrusion	Present	8 (4.94)	2.15-9.50
	Absent	154 (95.06)	90.50-7.85
Neck Extension	Present	157 (96.91)	92.94-98.99
	Absent	5 (3.09)	1.01-7.06
Milk Yield	> 10 liter/day	96 (59.26)	51.27-66.90
	≤ 10 liter/day	66 (40.74)	33.10-48.73

In table 4, sign related to heat stress were collected along with the data of milk yield/ day. Panting was present in 31 cows (19.14%) and absent in 131 cows (80.86%). The drooling of saliva was present in 51 cows (31.48%), absent in 111 cows (68.52). Besides few number of cows only 8 (4.94%) showed protruded tongue but neck extension present in 157 cows (96.91%). The milk yield data of cows represented that 96 cows (59.26%) had milk production over 10 liters/day and 66 cows (40.74%) under 10 liters/day.

Table 5: Relationship between rumination rate and respiration rate (N=162)

Traits	Respiration rate		P value
	Normal** **(26-50/minute) (Mean ± SE)**	**Rapid (>50/min) (Mean ± SE)**	
Rumination rate [per minute]	1.59 ± 0.098	1.37 ± 0.043	0.048

****Reece, 2004.

The relationship between rumination rate and respiration rate is represented in table 5. It was observed that there was found significant difference ($P<0.05$) between normal and rapid respiration rate in relation with rumination rate per minute. The group within normal respiration rate had little higher rumination rate than the group which respiration rate was rapid.

Table 6: Relationship of Panting, drooling of saliva with respiration rate (N=162)

Traits	Category	Respiration rate [per minute] (Mean ± SE)	P value
Panting	Present	65.42 ± 2.03	0.0001
	Absent	55.75 ± 0.82	
Drooling of saliva	Present	61.14 ± 1.41	0.03
	Absent	55.98 ± 0.97	

The relationship of panting and drooling of saliva with respiration rate is presented individually in table 6. there was significant difference ($P<0.05$) in both relations. Panting present when the respiration rate was higher and panting absent in comparison with cow had lower respiration rate. Similarly drooling of saliva present in the group had higher respiration rate and absent in the group had lower respiration rate.

Chapter 4: Discussion

4.1 Effect of heat stress on cow physiology

The behavioral adjustments are a reaction to Heat Stress and are intended to support the physiological changes that have already been initiated in preserving homeostasis. When ambient temperatures rise above their acceptable thresholds, many species in nature might seek out a more hospitable location (Herbut *et al*., 2021). Body temperature represents a summary of all thermoregulatory processes, making it a crucial marker of livestock animals' well-being, ability to reproduce, and productivity (St-Pierre et al., 2003). An increase in body temperature may be a sign of disease, trauma, heat stress, exposure to toxins, or other health problems (Koltes et al., 2018). According to certain studies, cattle's body temperature may have a distinct circadian rhythm that ranges from 0.2 to 0.9°C (Piccione and Refinetti, 2003), body temperature is lowest in the morning and highest in the late afternoon (Kendall and Webster, 2009). Therefore, several factors influencing body temperature include overall health, environment, ambient temperature, activity level, estrus, pregnancy status, breed, eating and drinking behaviors, and excitement (Lefcourt et al., 1999). According to many researches, body temperature lags ambient temperature by 1 to 5 hours and depends on the surrounding environment, therefore utilizing body temperature as a sign of heat stress (Mader et al., 2002; Brown-Brandl et al., 2005). In this study there found almost all cows rectal temperature within normal range. The benefits of providing shade for cattle on pasture with regard to body temperature but its effectiveness may vary depending on cow breed, environmental condition and the coat color of the cow (Fisher et al., 2008). In this study we saw that many farmers use aluminum foam sheet or bamboo as a roof insulation material of cow shed. Besides many farmers allowed to shower the cows during summer season. Presence of fan in shed provides comfort zone during excessive hot summer days. In very humid climates, cattle can’t able to excrete body temperature with sweating because humidity block the sweating mechanism (Pejman et al., 2012). Other methods used in barn systems include fans, tube ventilation systems, misting and air-mixing devices, as well as water droplets from low-pressure sprinkler systems in combination with fans (Kamal et al., 2018) or cool the inlet air, e.g. cooling pads, earth-air-heat exchanger (Schauberger et al., 2020). Shed surroundings and height of shed is a major factor that related to ventilation. From the farm demographic data found that majority number of the farms

height is above 10 feet and shed surroundings are opened that facilitate proper ventilation in shed. In this study found that, there were presence of fan almost in every farm, as the ambient temperature is very high during summer in Bangladesh. So, concerned farmer kept fans in cow shed. Proper ventilation system is necessary to maintain cool environment in shed. Ventilation remove the hot air from shed and protect the animals from heat stress. During periods of excess heat in the environment of an animal, the homeostatic mechanisms of the body are activated to re-establish the thermal status of the internal environment or to regulate it to within acceptable physiological limits (Vasconcelos et al., 2020).

Increase in respiration rate is one of the most sensitive phenotypic signs of heat stress; RR >60 breaths/min is an indicator of heat stress in lactating dairy cows (Berman, 2005). Respiration rates of cattle can be influenced by several factors, including age, level of production, body condition, DMI, housing design, cooling systems, and previous exposure to hot conditions (Gaughan et al., 2000). Gaughan et al. (2000) reported that under hot conditions, a cycle of ambient temperature ranging from 24 to 39°C, the increase in RR varied from 2.8 breaths/min to 3.3 breaths/min for each 1°C increase in ambient temperature. As body condition of the cows increased the respiration rate of the cows increased by 1 breath/min in comparison to thinner animals. In this study we found 125 cows had rapid respiration rate from total 162 cows. In my study found that maximum farmer kept cross breed cows for dairy purpose. This type of breed is not fully suitable in our local climatic condition. So, this is one of the major causes of rapid respiration rate in a greater number of cows. However, the frequency of feces and urination was frequently reduced in heat-stressed cattle. Behavioral studies revealed an increase in panting, salivation, and excessive sweating rate (Ratnakaran et al., 2017).

Panting or rapid breathing is one of the major indicator signs of heat stress. A disruption in the acid-base balance results from the significant volume of carbon dioxide expelled during panting (Pejman et al., 2012). In this data sheet 31 number of cows had panting sign this might due to higher blood percentage breed and hot weather. The other signs of heat stress like drooling of saliva, tongue protrusion present in some cows. The extension of neck present in large number of cows.

4.2 Effect of heat stress on milk production of cow

Dairy cattle will exhibit an inverse association between milk output and heat stress at any level of production (Ravagnolo et al., 2000). Comparing high-producing dairy cows to lower-producing cows, high-producing cows exhibit higher sensitivity to heat stress (Kadzere et al., 2002; Kumar et al., 2011). In an effort to preserve homeostasis, the heat load may rise to the point where the body temperature rises, DMI drops, and production falls. (west, 2003). Due to their higher metabolic heat output, higher-producing cows have a lower temperature threshold when milk loss starts to occur (Berman, 2005). Rhoads et al. (2009) found that only about 50% of the milk yield decrease from heat stress comes from reduced nutrient intake, indicating that the decrease in milk production can be affected by changes not associated with energy intake. A variation in fatty acid concentration is seen when the metabolic profile of a heat-stressed cow is compared to that of a non-stressed cow on a diet comparable in energy intake (Shwartz et al., 2009). The mechanisms involved in the reduction of milk protein yield due to heat stress remain largely unknown. The researchers came to the conclusion that cows under heat stress may use systemic amino acids more often, decreasing the amount of amino acids available to the mammary gland for milk protein production. Additionally, when heat stress is generated, blood flow to the mammary gland decreases the supply of protein precursors and the nutritional partitioning accessible to the mammary gland, which changes protein synthesis (Gao et al., 2017). Changes in milk protein percentage linked to heat stress are similarly erratic. According to the findings of certain studies, cows protein percentage was lower in the summer than it was in the winter (Smith et al., 2013; Bernabucci et al., 2015). Dairy cows experiencing heat stress can have altered milk composition. Some researchers have found heat stress to be associated with a decrease in total protein and total fat yield (Bouraoui et al., 2002; Bernabucci et al., 2015).

Here from data we found that milk production is below 10 litter in 66 cows among 162 cows which is not a small number. As the feed cost considered the dairy farmers are in great danger in near future. Numerous studies focused on modifying management methods, such as ration adjustments and feeding at various times of the day, have been done by researchers in an effort to boost milk output throughout the summer. Adding fat or ionophores to the ration has been used to increase milk production in times of heat stress. In response to feeding ionophores under heat stress, propionate production will rise, perhaps improving energy efficiency (Becker et al., 2020).

However the level of fat in diet should be 5 to 7% for cows. In order to receive the maximum benefits of the dietary addition of fat, modifications to the environment should be implemented through the provision of shade, fans, cooling with water, or any combination of the 3 cooling strategies (West et al., 1999).

Conclusion

The effect of heat stress on dairy cows was observed in this studied area. The respiration rate is higher in dairy herds compare to other physiological parameters. Besides, the relationship of respiration rate along with panting, drooling of saliva, and rumination rate was found significant. Training of dairy farmers on farm management should be recommended to mitigate the heat stress and that will improve the welfare and production of dairy cows.

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