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Impact of temperature humidity index (THI) on blood gas and electrolytes of dairy cows in late gestation[#]

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Abstract

The study was carried out to assess the impact of heat stress on dairy cows in late gestation and their newborn calves. Study was conducted in two phases in crossbred cattle during last trimester of pregnancy, maintained in University Livestock Farm and Fodder Research Development Scheme, Mannuthy, KVASU. December to February with minimum THI was taken as season 1 and March to May with maximum THI as season 2 of the study. Microclimatic data in the animal shed was recorded three times at three days intervals. The ambient temperature, relative humidity and THI obtained during season 2 was significantly ($p<0.01$) *higher than season 1 in both macro and microclimatic data. Partial pressure of carbon dioxide (pCO_2) was low in season 2 but there was no significant difference in potassium (K^+), sodium (Na^+), bicarbonate (HCO_3^-) and partial pressure of oxygen (pO_2) between the seasons.*

Keywords: *Heat stress in cattle, THI, blood gases, electrolytes, late gestation*

Climate change and global warming can cause serious problems to the cattle population. The homeostasis of the animal can get disrupted due to high environmental temperature. This disruption in normal physiology creates certain adjustment to the electrolyte levels and blood gases in the animal's body. The balance between blood gases and electrolytes is necessary to maintain homeostasis especially when the animal is in advanced stage of pregnancy (Antanaitis *et al*., 2024).

Pregnancy period especially during last trimester is considered stressful for all animals. The pregnancy involves hormonal fluctuations, changes in body weight, and various discomforts such as fatigue and respiratory distress. Additionally, factors like nutrition, environmental conditions, and management practices can influence the overall health and stress levels of pregnant cows. The pregnant cows in hot summer months had increased occurrence of mastitis, respiratory problems and retained placental membranes (Thompson and Dahl, 2012). The studies on effect of thermal stress on blood gases and electrolytes in crossbred cattle is scanty in Kerala. The changes in electrolytes and blood gas

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concentration can alter homeostasis and the well-being of animals. Therefore, it is necessary to study the electrolyte and blood gas level in cattle during late gestation for ensuring health of the dam as well as the developing foetus.

Materials and methods

The research work was conducted at University Livestock Farm and Fodder Research and Development Scheme (ULF & FRDS), Mannuthy, KVASU, Thrissur district in Kerala state. The research was conducted in two phases: Phase I (December 2022 to February 2023) was marked by a relatively modest influence of heat stress (season 1) and Phase II (March 2023 to May 2023) with highest THI. As the control group, a set of six crossbred cattle in the final trimester of pregnancy in December were chosen. To guarantee that the animals in the second group would be classified as heat-stressed, cattle in the last trimester of pregnancy in March were chosen for the experiment. Using an electronic digital logger (Testo 174H, Testo SE & Co., KGaA, German), the temperature (°C) and relative humidity (%) was recorded within the shelter three times at three days interval (11:00 AM, 2:00 PM, and 5:00 PM) throughout the study period. Temperature Humidity Index was calculated using the formula given by National Research Council, 1971 (NRC, 1971). The ®EPOC blood gas analyser (Epocal Inc., Ottawa, ON Canada) was used to analyse venous blood samples in vials containing heparin for blood gases (pO_2 and pCO_2) and electrolytes (Na+, K+, and HCO_3-).

Statistical analysis

Means (± SE) were used to express the results. Using the programme Statistical Product and Service Solutions (SPSS), version 24.0, the statistical significance of the difference or relationship between the seasons was examined using a mixed model analysis test.

Results and discussion

Temperature humidity index in animal house

Highest THI was obtained at 2.00 PM and lowest THI at 11.00 AM. Temperature humidity index calculated during season 2 was significantly higher ($p \leq 0.01$) than season 1 (Table 1).

Season 2 recorded highest THI (85.80) than season 1 (80.96). Both seasons recorded highest THI at 2.00 PM and lowest at 11.00 AM. Harikumar *et al.* (2018) recorded highest THI of 82.35 in summer (March to May) and lowest THI of 77.73 in winter (December to February). Zarina (2016) recorded highest THI of 82 in March and April and lowest (76.5) in December. Sruthi *et al.* (2019) showed a similar increasing trend in THI from January to May.

Sodium ion (Na^+) concentration

The overall mean Na^+ levels of cattle during the two seasons were within the normal range (126-144 m*M*/L) and no significant difference in Na^+ concentration was observed between the two seasons or days of observation (Table 2).

The Na^+ levels of animals during the two seasons under study were within the normal range and there was no significant difference between the Na^+ levels of animals in two seasons and across last trimester period. As per the results of the present study the THI of 85.8 during season 2 did not produce any change in Na^+ concentration in pregnant crossbred cattle. This observation is contrary to

Table 1. Mean (±SE) temperature humidity index in animal house during different seasons

Time	Season 1			Season 2		
	Month			Month		
	December	January	February	March	April	May
11 am	81.12±0.64	77.72±0.48	81.46±0.52	82.52±0.19	84.27±0.30	84.67±0.20
2 pm	81.49±0.52	81.82±0.56	84.42±0.82	88.07±0.44	89.24±0.62	85.23±0.32
5 pm	81.50±0.72	82.04±0.54	77.73±0.57	87.43±0.76	85.39±0.43	85.39±0.51
Overall	$80.96±0.24^{B}$			$85.80±0.36^{A}$		
p-value	0.0006**					

*** Significant at 0.01 level. Means having different superscript differ significantly within a row.*

Table 2. Mean (±SE) of Sodium ion concentration (m*M*/L) at fortnight intervals during season 1 and season 2 (n=6)

Day / Seasons	0	14	28	42	p-value
1	$139.83±0.44^{Aa}$	$140.16±0.44^{Aa}$	$140.33±0.44^{Aa}$	$140.66±0.44^{Aa}$	0.599^{ns}
2	$139.50±0.44^{Aa}$	$139.16±0.44^{Aa}$	$140.00±0.44^{Aa}$	$139.66±0.44^{Aa}$	0.599^{ns}
p-value	0.601^{ns}	0.122^{ns}	0.601^{ns}	0.122^{ns}	

ns: non-significant. Means having different small letter as superscript differ significantly within a column. Means having different capital letter as superscript differ significantly within a row.

the findings of Chetia *et al*. (2016) and Yamin *et al*. (2021) who observed a decrease in sodium ion concentration during summer stress.

Potassium ion (K^+) concentration

The K^+ levels of cattle during the two seasons were within the normal range (3.6-5.8 m*M*/L) and are depicted in table 3. The K^+ level was significantly ($p \leq 0.05$) low during initial day of last trimester in the second season (3.76 m*M*/L) compared to season 1 (4.20 m*M*/L). A significant ($p \leq 0.05$) reduction was observed in overall mean K^+ levels in season 2 (3.92 m*M*/L) compared to season 1 (4.13 m*M*/L).

The K^+ levels of animals under study during the two seasons were within the reported normal range. A reduction in K^+ was observed on day 0 in both seasons. On day 14, day 28 and day 42 the K^+ levels were similar in both seasons. The decreased overall K^+ level in season 2, might be the reflection of reduced K^+ level observed on day 0, of observation. In the present study K^+ levels were not affected by THI of 85.8 during season 2. Srikandakumar and Johnson (2004) observed increase in potassium ion level and Kumar *et al*. (2010) observed decrease in potassium ion level during thermal stress.

Bicarbonate level in blood during both seasons were within the normal range. There was no significant difference in HCO_3^- level of animals in both seasons and across the last trimester period in both seasons. This result was contradictory to the findings of Yamin *et al*. (2021), Sivakumar *et al.* (2010) and Srikandakumar *et al.* (2003). The pCO_2 observed in this study was decreased due to increased respiratory rate which might cause alkalosis. The HCO_3^- concentration observed in the present study was within normal range. This might be due to renal excretion of HCO_3^- developed as a compensatory mechanism to maintain acid-base balance.

The overall comparison of Na^+, K^+ and HCO_3^- between the two seasons are represented in table 5.

Partial pressure of oxygen (pO_2)

The mean pO_2 values of venous blood during both seasons are given in table 6. The pO_2 level observed during both seasons were below the normal range. The overall mean pO_2 levels of cattle during the two seasons (45.92 mmHg and 46.43 mmHg in season 1 and season 2, respectively) had no significant difference between them. The pO_2 did not differ significantly between the days of observation in each season.

Table 3. Mean (±SE) Potassium ion concentration (m*M*/L) at fortnight intervals during season 1 and season 2 (n=6)

Day / Seasons	0	14	28	42	p-value
1	4.20±0.13^{Aa}	4.18±0.13^{Aa}	4.11±0.13^{Aa}	4.00±0.13^{Aa}	0.732^{ns}
2	3.76±0.13^{Ab}	4.08±0.13^{Aa}	3.96±0.13^{Aa}	3.86±0.13^{Aa}	0.423^{ns}
p-value	0.026*	0.596^{ns}	0.428^{ns}	0.481^{ns}	

**Significant at 5% level, ns: non-significant. Means having different small letter as superscript differ significantly within a column.Means having different capital letter as superscript differ significantly within a row.*

Table 4. Mean (±SE) Bicarbonate ion concentration (m*M*/L) at fortnight intervals during season 1 and season 2 (n=6)

Day / Seasons	0	14	28	42	p-value
1	23.55±0.8^{Aa}	22.81±0.89^{Aa}	22.18±0.89^{Aa}	22.70±0.89^{Aa}	0.728^{ns}
2	23.65±0.8^{Aa}	22.65±0.89^{Aa}	22.40±0.89^{Aa}	22.25±0.89^{Aa}	0.654^{ns}
p-value	0.937^{ns}	0.896^{ns}	0.865^{ns}	0.723^{ns}	

ns: non-significant. Means having different small letter as superscript differ significantly within a column. Means having different capital letter as superscript differ significantly within a row.

Bicarbonate ion (HCO_3^-) concentration

The overall mean HCO_3^- levels of cattle during the two seasons were within the reported normal range (18-25 m*M*/L) and no significant difference in HCO_3^- concentration was observed between the two seasons and days of observation (Table 4). Season 1 recorded overall mean HCO_3^- concentration of 22.81 m*M*/L compared to 22.74 m*M*/L in season 2.

Overall mean Na+, K+ and HCO3- (mM/L) during season 1 and season 2 are given in table 5.

Table 5. Overall mean (±SE) Na^+, K^+ and HCO_3^- (m*M*/L) during season 1 and season 2 (n=6)

Season	Na^+	K^+	HCO_3^-
1	140.25±0.24^{a}	4.13±0.05^{a}	22.81±0.50^{a}
2	139.58±0.24^{a}	3.92±0.05^{b}	22.74±0.50^{a}
p-value	0.078^{ns}	0.029*	0.918^{ns}

**Significant at 5% level. ns: non-significant. Means having different small letter as superscript differ significantly within a column.*

Table 6. Mean (±SE) partial pressure of oxygen (mm of Hg) at fortnight intervals during season 1 and season 2 (n=6)

Seasons \ Day	0	14	28	42	p-value
1	41.96±3.01^{Aa}	47.59±3.01^{Aa}	47.68±3.01^{Aa}	46.35±3.01^{Aa}	0.961^{ns}
2	48.05±3.01^{Aa}	42.82±3.01^{Aa}	49.92±3.01^{Aa}	44.95±3.01^{Aa}	0.970^{ns}
p-value	0.702^{ns}	0.759^{ns}	0.885^{ns}	0.928^{ns}	

ns: non-significant. Means having different small letter as superscript differ significantly within a column. Means having different capital letter as superscript differ significantly within a row.

Table 7. Mean (±SE) Partial pressure of carbon dioxide (mm of Hg) at different intervals during season 1 and season 2 (n=6)

Seasons \ Day	0	14	28	42	p-value
1	35.88±1.56^{Aa}	36.32±1.56^{Aa}	34.87±1.56^{Aa}	38.32±1.56^{Aa}	0.371^{ns}
2	30.62±1.56^{Ab}	34.07±1.56^{Aa}	32.68±1.56^{Aa}	30.36±1.56^{Ab}	0.209^{ns}
p-value	0.023*	0.316^{ns}	0.330^{ns}	0.001**	

*** Significant at 1% level, *Significant at 5% level, ns: non-significant. Means having different small letter as superscript differ significantly within a column. Means having different capital letter as superscript differ significantly within a row.*

There was no significant difference in pO_2 between the seasons and across the period. A lower pO_2 in venous blood during both seasons suggested an increased consumption of arterial oxygen during both seasons. During pregnancy, oxygen consumption and basal metabolic rate increases which can lower the oxygen reserve of the dams (LoMauro and Aliverti, 2015). Maternal oxyhaemoglobin dissociation curve shifted to the right due to quick release of oxygen from haemoglobin as a result of increased oxygen affinity of foetal Hb as reported by Troiano (2018) and supports the observations in this study.

Partial pressure of carbon dioxide (pCO_2)

The mean pCO_2 values of venous blood during both seasons are given in table 7. The overall mean partial pressure of carbon dioxide in cattle was within the range (35-48 mmHg), during season 1 (31.93 mmHg) and significantly ($p \leq 0.05$) low during season 2 (36.35 mmHg). During day 0 of the experiment a significantly ($p \leq 0.05$) low level of pCO_2 was observed in season 2 (30.62 mmHg). Similarly, on day 42 of the study a significantly ($p \leq 0.01$) low level of pCO_2 was observed in season 2 (30.36 mmHg).

Overall pO_2 and pCO_2 during season 1 and season 2 are given in table 8.

Table 8. Mean (±SE) Overall pO_2 and pCO_2 during season 1 and season 2 (n=6)

Season	pO_2 (mmHg)	pCO_2 (mmHg)
1	45.92±1.41^{a}	36.35±0.99^{a}
2	46.43±1.41^{a}	31.93±0.99^{b}
p-value	0.815^{ns}	0.011*

**Significant at 5% level, ns: non-significant. Means having different small letter as superscript differ significantly within a column.*

Partial pressure of carbon dioxide was within the normal range during season 1 and significantly ($p \leq 0.05$) low during season 2. Low pCO_2 was observed during beginning of last trimester and during calving in season 2. Partial pressure of carbon dioxide observed in this study is in concurrence with pCO_2 recorded by West *et al*. (1991), Srikandakumar and Johnson (2004), Sivakumar *et al*. (2010), Joy *et al*. (2020) and Yamin *et al*. (2021). This reduction in pCO_2 during heat stress might be due to hyperventilation.

The comparison of overall pO_2 and pCO_2 during season 1 and season 2 is represented in table 8.

Conclusion

The micro and macro climatic THI obtained in both seasons were above 78 which is considered stressful to the animals. The in-house THI during the period of March to May was significantly ($p \leq 0.01$) higher than during December to February. A significant ($p \leq 0.05$) reduction was observed in partial pressure of carbon dioxide (pCO_2) but there was no significant difference in potassium (K+), sodium (Na+), bicarbonate (HCO3-) and partial pressure of oxygen (pO2) in cows that experienced heat stress in last trimester of gestation. Hyperventilation in response to higher THI might have caused a reduction in pCO_2. Renal excretion of bicarbonate ions might have prevented the occurrence of alkalosis during hyperventilation.

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Conflict of interest

The authors declare that they have no conflict of interest.

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