WITHDRAWN: Impact of climatic variability of the temperature-humidity index during winter, spring and summer seasons in Egypt on the growth of the native bovine calves

alsaied alnaimy habeeb

dr_alnaimy@yahoo.com

egyptian atomic enery authority

MOSTAFA ABBAS ATTA

Egyptian Atomic Energy Authority

AHMED KAMEL SHARAF

Egyptian Atomic Energy Authority

Anhar Ibrahim Aly Elhanafy

Egyptian Atomic Energy Authority

Research Article

Keywords: Calves, growth, feed intake, hormones, THI, blood components.

Posted Date: February 3rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1308671/v1

EDITORIAL NOTE:

The full text of this preprint has been withdrawn by the authors while they make corrections to the work. Therefore, the authors do not wish this work to be cited as a reference. Questions should be directed to the corresponding author.

Abstract

This research aims to check the impact of climatic variability of the THI index during the three main seasons of the year in Egypt on growth traits and biochemical blood components in native bovine calves. Eighteen Egyptian bovine calves after weaning were used in this study. The experimental design included three experimental groups according to the year's seasons. In the 1st group, sex calves were rearing under winter conditions. In the 2nd group, sex calves were kept during the spring season. In the 3rd group, sex calves were maintained during the summer season. Weekly and monthly Temperature-humidity index (THI) was calculated for the three seasons. The daily body gain (DBG) the feed intake (DMI), and water consumption (WC) were measured weekly for each calf. The highest THI value (85.5) during summer resulted in a significant ($P<0.01$) decrease in DBG, daily DMI, thyroid hormonal levels, total proteins, and glucose and a significant ($P<0.01$) increase in daily WC and levels of cortisol and urea. The rate of decline increases with increasing THI values from low THI in winter (68.1) to moderate THI during spring (74.9) and high THI (85.5) during the summer season. With increasing THI, the depression in DBG was more than the decline in daily DMI; therefore, food conversion increases when the value of THI increases. THI has highly ($P<0.01$) significant negative correlations with DBG, DMI, thyroxin (T_4), triiodothyronine (T_3), total proteins, and glucose and has highly significant ($P<0.01$) positive correlations with water intake as well as cortisol and urea concentrations.

Introduction

In the year 2050, the population within the world extents to 9.6 billion and also the worldwide request for animal products is anticipated to proliferate utilizing to 70 percentages **(FAO, 2015).** Most climatic regions encompass tropical, subtropical, and temperate. The temperate region is considered the best condition for superior efficiency in farm animals. Animals could sustain a normal body temperature in a particular ecological temperature variety, recognized as the thermoneutral zone (TNZ), and succeed in nominal physiological expenses and maximal production (Kadzere et al., 2002). When the animals cannot disperse body heat adequately to stay thermal stable, heat stress occurs because of a raised ambient temperature above TNZ and high moisture (Bernabucci et al., 2010). Exceeding half stock is found within the tropics and subtropics regions, and these areas have high environmental temperature with the high relative humidity reasons considered for commercial impairment in around more than 60 percentages of the farms of animals everywhere within the world **(FAO, 2015).** Heat stress affects important losses ($2.4 billion) in animal production, and therefore the total yearly commercial losses to livestock industries affected amounted by 1.69-2.36 billion$ in the USA, of these losses, up to 1,500 million $ occur within the industry of dairy product thus, heat stress condition is that the main restriction in animal performance (St-Pierre et al., 2003). The financial harm due to the adversative result of temperature stress on the productivity of animal substitutes below two years old was $48 million each year. The harshness of heat stress problems on animals will rise as worldwide warming develops (St-Pierre et al., 2003).

Global warming has elevated the apparent temperature by approximately 0.7°C within the initial 20th century, and it's predicted that the temperature increase is going to be 1.8- 4.0°C by 2100 **(IPCC, 2014).** Weather alteration is setting out to effect discomfort concomitant with the proliferation of world glasshouse airs, and therefore the greatest serious influences of weather alteration will occur exactly between animal producers with subsistence expensive in hot areas of most developing countries (Herrero et al., 2010). By the progressively warming international weather and also the magnification of hot periods, the stock is exposed to level of extra severe warmth stress, which threatens to lessen production performance severely (Herbut and Angrecka, 2012). Both ambient temperature and relative humidity are combined and titled Temperature-humidity index (THI) and are usually used as a valuable pointer for the degree of stress on animals (Bohmanova et al., 2007). THI was measured using several equations and is sited into classes to clarify the status of heat stress (Habeeb et al., 2018c). Most research revealed that the high THI is reflected as harmfully impacting milk production (Brügemann et al., 2012 ; Prathap et al., 2017) and impacting reproductive and fertility (Dash et al., 2016; El-Tarabany et al., 2017; Wang et al., 2020). It is vital to well recognize the changes in physiological and metabolic rhythms in Egyptian native calves during different seasons to plan approaches to ameliorate the adverse effects of some seasons within the year to avoid economic losses on animal growth. Domestic animals in Egypt are exposed to a few different levels of THI, low THI during the months of the winter season; moderate THI during the months of the spring season and high THI during the months of summer. This research aims to check the impact of climatic variability of the THI index during the three main seasons of the year in Egypt on daily body gain, feed intake, water intake, and a few biochemical blood components in native bovine calves.

Materials And Methods

1- Experimental location:

The experimental work was carried out in Bovine Farm, Biological Application Department, Radioisotopes Applications Division, Nuclear Research Centre, Atomic Energy Authority, Inshas, Cairo, Egypt (latitude 31º12' N to 22º 2'N, longitude 25º53' E to 35º53'E).

2. Experimental ethics:

Experimental animals were carried using husbandry guidelines derived from the Egyptian Atomic Energy Authority standard operating procedures. The experimental work was reviewed and approved by the Animal Care and Welfare Committee of the Egyptian Atomic Energy Authority.

3. Animals feeding:

This research used eighteen healthy Egyptian male bovine calves after weaning with nearly same age and an average live body weight of 200.0±5.4 kg. The calves were provided for the ration contained concentrate feed mixture (CFM) plus rice hay (RH). CFM ration including crushed yellow maize, wheat bran, un-decorticated cottonseed meal, flaxseed gain, Di-calcium phosphate, iodized salt, trace mineral mixture and vitamin AD3E at the rate of 40, 25, 25, 7.0, 1.0, 1.0, 0.50 and 0.50%, respectively. Each kg of CFM contains 0.8% calcium, 0.6% phosphorus, 0.07% magnesium and 0.65% potassium. Each kg of vitamins and mineral mixture (premix) consists of 12000, 000 IU Vit A; 2000, 000 IU Vit D_3; 10g Vit. E; 2 g Vit k_3; 1000 mg Vit B_1; 49g Vit B_2; 105 g Vit B_6; 10 mg Vit B_{12}; 10 g Pantothenic acid; 20 g Niacin; 1000 mg Folic acid; 50 g Biotin; 500 mg Choline Chloride, 30 g Fe; 40 g Mn; 3 g Cu; 200 mg Co; 100 mg Si and 45 g Zn.

The chemical composition of the CFM (on a dry matter basis %) used in the feeding of the experimental groups during the experimental period was passed by **AOAC (1990)** and the values were 15.2, 3.0, 20.5, and 13.5% for the crude protein, crude fat, NDF and ADF respectively. CFM is offered in the morning once daily at the rate of 2.5 kg CFM /100 kg according to body weight and daily gain **(NRC, 1981).** RH was presented *ad libitum.* Fresh drinking water was available spontaneously all-time to the experimental calves.

4. Meteorological data during the three experiments:

Under the natural conditions of the farm at mid-day, environmental temperature (AT, °C), relative humidity (RH %), values were recorded weekly and monthly using a digital Thermo-hygrograph (Italy). THI values using AT and RH values were estimated by the equation of Kendall and Webster (2009) as following:

THI = (1.8*AT + 32) - [(0.55-0.0055*RH) **x** (1.8*AT-26)], where AT = air temperature (°C), and RH = relative humidity (%) and then THI thresholds for heat stress in cattle as following: comfort (THI<68), mild discomfort (68<THI<72), discomfort (72<THI<75), alert (75<THI<79), danger (severe heat stress) (79<THI<84), and emergency (very severe heat stress) (THI > 84) and emergency (THI > 84).

5. Experimental procedure:

The research was conducted on eighteen Egyptian male bovine calves after weaning at 8.0±0.5 months with nearly an average live body weight of 200.0±5.4 kg. The three trials of the three seasons sustained for nine months (January to September). The experimental design was including three experimental groups according to the season of the year. In the 1st group, sex calves reared under the winter season from the beginning of January to 31 of March. In the 2nd group, sex calves were kept under the spring season from the 1st of April to the end of June. In the 3rd group, sex calves were maintained during the summer season from the 1st of July to the end of September. The calves in three groups were managed similarly and conducted with similar protocols. The experimental groups were tied with troughs during experimental months in one isolated yard (40 x 60 meters) enclosed by a wire fence (2-meter height), and one-third of the surface area was roofed with a concrete shading in the middle (3-meter height). The yard was divided into ten parts by hardwood, and each calf was in a separate part provided a container for fresh drinking water. The calves in each experiment were weighed before the morning feeding by pen on a platform scale at the initial and final day of each month and dividing by days of each month to obtain monthly and then seasonally body weight gain of each calf.

Feedstuff intake (FI) was measured individually for each calf four times monthly by subtracting the residual of feed from that offered for the calf in the previous day and averaged to obtain monthly and then seasonally FI. Dry matter intake (DMI) was determined from the weight difference before and after oven drying overnight at 105°C for 24 hours in each of samples from CFM or BH. DMI was calculated by multiplying fresh feed intake with the DM percentages (92.0 and 88.5%, respectively) and then monthly and seasonally DMI was obtained. Water consumption (WC) was measured individually for each calf four times monthly during the experimental period by subtracting the residual of water in the container from that offered for each calf in the previous day and seasonally water intake for each calf was calculated.

6- Blood sampling and biochemical and hormonal analysis:

At the end of each experiment, one blood sample had taken from the write Jugular vein of each calf before the morning feed using disposable syringes without anticoagulants substance. Blood samples were placed immediately on the ice-box and were transferred to the laboratory. Blood samples were centrifuged at the rate of 2000x g for 30 min and then transferred to a tube and saved at –20°C. By the Radioimmunoassay method (RIA), thyroxin (T_4), triiodothyronine (T_3), and cortisol hormones were determined using the commercial kits and antibody-coated tubes were labeled with ^{125}I (Diagnostic Product Corporation, Los Angeles, USA). After the period of incubation, the liquid contents in the tubes are aspirated, and the radioactivity is counted in a Computerized Gamma Counter.

Glucose, total protein and urea levels were determined by Biochemical Reagent Kits purchased from Diamond Diagnostic Company, Egypt.

7- Statistical analysis:

According to the analysis of variance in SAS software (SAS 2003), data were analyzed. The effect of the independent variable (THI; categorized into three levels; low, moderate and high) on the dependent variables (DBG, DMI, WC, T_4, T_3, cortisol, total protein, glucose, and urea) was studied. Duncan's new multiple ranges test confirmed the significance of the difference among the means (Duncan 1955). Pearson correlation coefficients between THI values during the experimental months and different factors were designed by the CORR facility in SAS.

Results

1. THI values with relation to the three main seasons of the year in Egypt:

Environmental variables were recorded and used to represent monthly climatological variations during the period of the study during the three seasons; winter, spring and summer. In this study, the experimental calves were exposed to the three different levels of THI, the first group (6 calves) exposed to lower THI (68.1) value during the months of the winter season; and the second group (6 calves) exposed to moderate THI (74.9) value in spring season and the third group (6 calves) exposed to higher THI value (85.5) during the months of the summer season of Egypt. Conferring to Kendall and Webster (2009) that low: THI < 70 comforts; moderate: THI greater than 70 and less than 75 (discomfort) and high: THI greater than 80 (severe or very severe heat stress or emergency).

In this study the calves are exposed to comfort (group 1), discomfort (group 2) and severe heat stress (group3) during winter, spring and summer seasons, respectively. In spring and summer, the THI indices were significantly higher than in winter, with the highest value in summer, followed by spring (Table 1).

Table 1
Monthly averages of ambient temperature (AT, °C), relative humidity (RH %) and THI values recorded for the experimental months at the Inshas district, Sharkia Government, Egypt.

Experimental months	Environmental parameters			THI thresholds for heat stress
	Ambient Temperature (AT, º C)	Relative Humidity (RH %)	Temperature humidity index (THI)*	
January	20.5 ± 0.29	67.2±2.2	66.94	Comfortable
February	21.0 ± 0.41	62.7±2.2	67.38	Comfortable
March	23.0 ± 0.29	58.0±1.8	69.84	Comfortable
Winter season 68.1 (<70)				
April	25.5±0.33	56.0±2.4	73.12	Discomfort
May	27.0±0.25	55.5±2.0	75.18	Discomfort
June	28.0 ± 0.41	55.0±1.44	76.30	Discomfort
Spring season 74.9 (>70 - >80)				
July	35.5 ±0.25	54.0± 0.58	86.42	Very severe heat stress
August	36.5 ± 0.29	55.5±0.48	88.17	Very severe heat stress
September	33.0 ± 0.29	52.0±0.48	82.05	Very severe heat stress
Summer season 85.5 (80<)				Very severe heat stress

Each value from air temperature and relative humidity was the average of four times recorded each month in natural conditions of the Farm at mid-day.

2. THI values with relation to daily gain, feed intake and water consumption:

A highly significant (P<0.01) decrease in DBG and daily DMI in the calves due to higher THI was detected. The amount of deterioration in DBG increases with increasing THI. DBG decreased significantly (P<0.01) by 18.6% at THI of 74.9 (spring season) and by 41.1% at THI of 85.5 during the summer season compared to THI of 68.1 (winter season). Moreover, DBG decreased significantly (P<0.01) by 27.6% at THI of 85.5 during the summer season compared to THI of 74.9 during the spring season **(**Table 2**).**

Table 2
Daily body gain (DBG), dry matter intake (DMI) and water intake (WI) in growing bovine calves with the response of various THI values.

Traits	**Temperature-humidity index (THI)**				
	Low THI (67.3±0.97) (Winter season)	**Moderate THI (72.8±2.7) (Spring season)**	**[1]Change due to moderate THI**	**High THI (85.8±1.3) (Summer season)**	**[2]Change due to high THI**
DBG (g/day)	587^{a}±10.2	478^{b}±35.6	- 18.60 (P<0.01)	346^{c}±7.52	- 41.10(P<0.01)
DMI (kg/day)	3.98^{a}±0.09	3.62^{b}±0.02	-9.05 (P<0.05)	3.13^{c}±0.04	- 21.40(P<0.01)
WI (l/day)	19.10^{c}±0.5	24.60^{b}±1.1	+28.80 (P<0.01)	31.20^{a}±0.72	+63.40(P<0.01)
a, b ...Means in the same column having different superscripts differ significantly.					
[1]Change= [(spring value- winter value)/ winter value) x100].					
[2]Change = [(summer value-winter value)/ winter value) x100].					

The degree of decline in daily DMI also increases with increasing THI values. Daily DMI decreased significantly (P<0.05) by 9.05% at THI 74.9 (spring season) and by 21.4% (P<0.01) at THI 85.5 during the summer season compared to THI 68.1 (winter season). DBG decreased significantly by 13.5% at THI 85.5 during the summer season, when compared to DBG at THI 74.9 during the spring season. DMI was decreased daily by 36.0 g and 85 g during the spring and summer seasons, respectively, compared to winter. These results designate that the extreme deteriorating effect of heat stress on both DBG and daily DMI was detected in the summer season.

The degree of decline in daily DMI also increases with increasing THI values. Daily DMI decreased significantly by 9.05% at THI 74.9 (spring season) and by 21.4% at THI 85.5 during the summer season compared to THI 68.1 (winter season). DBG decreased significantly by 13.5% at THI 85.5 during the summer season, when compared to DBG at THI 74.9 during the spring season. DMI was decreased daily by 36.0 g and 85 g during the spring and summer seasons, respectively, compared to winter.

Water consumption (L/day) significantly increased (P<0.01) by 28.8% at THI 74.9 during the spring season and by 63.4% at greater THI (85.5) during the summer season compared to those at low THI 68.1 in winter **(**Table 2**).**

3-THI values with relation to DMI /DBG, DMI/WI and gain/WI ratios:

The effectiveness of conversion of DMI to DBG ratio was improved significantly (P<0.05) by 13.1% at THI 74.9 during the spring season and by 33.6% (P<0.01) at THI 85.5 during the summer season compared to those in winter 68.1. With increasing THI, the depression in DBG was more than the decline in daily DMI; therefore, food conversion (DMI/DBG) increases when the value of THI increases. The percentage decline in DMI was less than the percentage increase in WI; therefore DMI/WI ratio (g/100ml) decreased significantly with increasing THI values. DMI/WI ratio decreased during the spring season by 27.8% and during the summer season by 51.7% (P<0.01) compared to the winter season **(**Table 3**).**

Table 3

DMI /DBG, DMI/WI and gain/WI ratios in growing bovine calves with the response of various THI values

Traits	**Temperature-humidity index (THI)**				
	Low THI (67.3±0.97) (Winter season)	**Moderate THI (72.8±2.7) (Spring season)**	**[1]Change due to moderate THI**	**High THI (85.8±1.3) (Summer season)**	**[2]Change due to high THI**
DMI/DBG ratio (FC)	6.78^{c}±0.04	7.67^{b}±0.14	+13.10(P<0.05)	9.06^{a}±0.11	+33.6(P<0.01)
DMI/WI ratio (g/l00 ml)	2.09^{a}±0.01	1.51^{b}±0.01	-27.80(P<0.01)	1.01^{c}±0.01	-51.7(P<0.01)
Gain/WI ratio (g/100 ml)	3.08^{a}±0.01	2.01^{b}±0.01	- 34.70(P<0.01)	1.11^{c}±0.01	- 64.0(P<0.01)
a, b ...Means in the same column having different superscripts differ significantly.					
[1]Change= [(spring value- winter value)/ winter value) x100].					
[2]Change = [(summer value-winter value)/ winter value) x100].					

4. THI values with relation to T_4, T_3 and cortisol levels:

At THI 74.9 during the spring season, T_4 and T_3 levels were significantly (P<0.01) decreased by 8.22 and 13.2%, respectively, compared with those values at low THI 68.1 during the winter season. At greater THI (85.5) during the summer season, T_4 and T_3 levels were significantly decreased (P<0.01) by 24.2 and 33.8%, respectively, compared with those values at low THI (68.1) during the winter season. Furthermore, at greater THI (85.5) during the summer season, T_4 and T_3 levels were significantly (P<0.01) decreased by 17.5 and 23.7%, respectively, compared with those values at THI 74.9 during the spring season **(**Table 4**).**

Table 4
Hormonal levels in growing bovine calves with the response of various THI values.

Traits	Temperature-humidity index (THI)				
	Low THI (67.3±0.97) (Winter season)	Moderate THI (72.8±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.8±1.3) (Summer season)	[2]Change due to high THI
T_4 (nmol/l)	98.60^a±1.5	90.50^b±2.5	-8.22 (P<0.05)	74.70^c±2.6	-24.20 (P<0.01)
T_3 (nmol/l)	6.80^a±0.10	5.90^b±0.20	-13.20 (P<0.01)	4.50^c±0.20	-33.80 (P<0.01)
T_4/T_3 ratio	14.50^c±0.14	15.30^b±0.03	+5.51 (P>0.05)	16.60^a±0.06	+14.50 (P<0.05)
Cortisol (nmol/l)	41.70^c±1.2	53.60^b±1.2	+28.5(P<0.01)	67.30^a±1.30	+61.40 (P<0.01)
a, b ...Means in the same column having different superscripts differ significantly.					
[1]Change= [(spring value- winter value)/ winter value) x100].					
[2]Change = [(summer value-winter value)/ winter value) x100].					

At THI 74.9 during the spring season, cortisol level was significantly (P<0.01) increased by 28.5% compared with that value at low THI 68.1 during the winter season. At greater THI (85.5) during the summer season, cortisol level was significantly increased (P<0.01) by 61.4% compared with that value at low THI (68.1) during the winter season. Furthermore, at greater THI (85.5) during the summer season, cortisol level was significantly (P<0.01) increased by 25.56% compared with that value at THI 74.9 during the spring season (Table 4).

5. THI values with relation to blood biochemical components:

At THI 74.9 during the spring season, total proteins and glucose concentrations were insignificantly decreased by 4.06 and 4.8%, respectively, compared with those values at low THI (68.1) during the winter season. At greater THI (85.5) during the summer season, total proteins and glucose concentrations were significantly decreased by 15.1 and 15.7%, respectively, compared with those values at low THI (68.1) during the winter season (Table 5).

At greater THI (85.5) during the summer season, total proteins and glucose concentrations were significantly decreased by 11.5 and 9.8% compared with those values at THI 74.9 during the spring season. At THI 74.9 during the spring season, urea level was significantly increased by 18.3% compared with those values at low THI (68.1) during the winter season. At greater THI (85.5) during the summer season, urea level was significantly increased by 64.2% compared with those values at low THI (68.1) during the winter season. At greater THI (85.5) during the summer season, urea level was significantly increased by 38.8% compared with those values at THI of 74.9 during the spring season (Table 5).

Table 5

Blood biochemical components in growing calves with the response of various THI values

Traits	Temperature-humidity index (THI)				
	Low THI (67.3±0.97) (Winter season)	**Moderate THI (72.8±2.7) (Spring season)**	**[1]Change due to moderate THI**	**High THI (85.8±1.3) (Summer season)**	**[2]Change due to high THI**
Total proteins (g/dl)	$8.13^a \pm 0.09$	$7.80^a \pm 0.06$	- 4.06 (P>0.05)	$6.90^b \pm 0.06$	- 15.1(P<0.05)
Glucose (mg/dl)	$87.20^a \pm 2.0$	$83.00^a \pm 1.4$	- 4.80 (P>0.05)	$74.90^b \pm 0.8$	- 15.7(P<0.05)
Urea-N (mg/dl)	$36.60^c \pm 0.8$	$43.30^b \pm 1.9$	+18.30 (P<0.05)	$60.10^a \pm 1.3$	+ 64.2(P<0.01)

a, b ...Means in the same column having different superscripts differ significantly.

[1]Change= [(spring value- winter value)/ winter value) x100].

[2]Change = [(summer value-winter value)/ winter value) x100].

6. Correlations coefficient between THI with different parameters:

THI has highly significant negative correlations with DBG, DMI, T_4, T_3, total proteins, and glucose and has highly significant positive correlations with water intake as well as cortisol and urea concentrations. DBG has highly significant positive correlations with DMI, T_4, T_3, total proteins and glucose and has highly significant negative correlations with water intake, cortisol and urea concentrations.

DMI has highly significant positive correlations with T_4, T_3, total proteins, and glucose and has highly significant negative correlations with water intake, cortisol, and urea concentrations. WC has highly significant negative correlations with T_4, T_3, total protein, and glucose and has highly significant positive correlations with cortisol and urea concentrations.

Table 6
Correlations coefficient between THI and each of DBG, DMI, WI, T_4, T_3, cortisol, total proteins, glucose and urea-N in growing bovine calves

Items	DBG (g/day)	DMI (g/day)	WI (l/day)	T_4 (nmol/l)	T_3 (nmol/l)	Cortisol (nmol/l)	T. P (g/dl)	Glucose (mg/dl)	Urea-N (mg/dl)
THI values	-0.952	-0.953	0.960	-0.988	-0.985	0.958	-0.966	-0.940	0.974
DBG (g/day)		0.977	-0.996	0.967	0.983	-0.993	0.908	0.949	-0.949
DMI (g/day)			-0.969	0.972	0.969	-0.957	0.923	0.956	-0.909
WI (l/day)				-0.977	-0.991	0.998	-0.914	-0.947	0.957
T_4 (nmol/l)					0.992	-0.969	0.949	0.957	-0.956
T_3 (nmol/l)						-0.989	0.956	0.950	-0.971
Cortisol (nmol/l)							-0.915	-0.937	0.966
T. proteins(g/dl)								0.874	-0.927
Glucose (mg/dl)									-0.928
All correlation coefficient values are significant at P<0.01.									

T_4 has a highly significant positive correlation with T_3, total protein, and glucose and has a highly significant negative correlation with cortisol and urea concentrations. T_3 has a highly significant positive correlation with total protein and glucose and has a highly significant negative correlation with cortisol and urea concentrations.

Cortisol has highly significant negative correlations with total protein and glucose and has a highly significant positive correlation with urea concentration. Total protein has a highly significant positive correlation with glucose concentration and has a highly significant negative correlation with urea concentration. Glucose concentration has a highly significant negative correlation with urea concentration (Table 6).

Discussion

1-Effect of varying THI on DBG and DMI:

The results indicated that the rate of decline in DBG and DMI increases with increasing THI values. DBG in native bovine calves decreased significantly by 18.6% at THI 74.9 during the spring season and by 41.1% at THI 85.5 during the summer season compared to THI 68.1 during the winter season. These results indicate that the most deteriorating effect of warmth stress on both DBG and DMI was observed in the summer season. Nardone et al. (1993) found that 86 THI from 10.00 to 18.00 hours for ten weeks determined a decrease in DMI (7.9%) and a reduction in DBG (26.1%) in Holstein Friesian calves. **West (1993)** reported that the range of THI values from 71 to 81 caused significant decreases in the consumption of TDN of protein in cattle. A decrease of 0.57, 0.51, 0.48, 0.42 and 0.29 kg DMI daily for every unit rise in THI for Asia, South America, Oceania, Europe and North America, respectively **(**Chang-Fung-Martel et al., 2021). West et al. (2003) found that THI deleteriously affected feed intake, where a THI>72.1 resulted in an exceedingly decrease in the feed intake of Holstein and Jersey cows by 0.51 kg and 0.47 kg, respectively, for every unit of increase in THI within the range of 72 to 84. Bouraoui et al. (2002) found that the average DMI reduced significantly by 9.6% (1.73 kg) from 18.0 to 16.27 kg/day in lactating Friesian-Holstein cows when THI increased from 68 in spring to 78 in summer. Calves suffering a mean THI <50 gained more (0.67 kg/d) than calves suffering an average THI from 50 to 69 (0.62 kg/d), or ≥70 (0.59 kg/d) (Shivley et al., 2018). Higher mean THI was related to a lower DBG at the calf market, and the DBG values at THI of >75 were significantly below those at THI of ≤50 or THIs starting from 56 to 60 (Nabenishi and Yamazaki, 2017). Xue et al. (2010) confirmed that the DMI values increased from 18.5 to 19.8 kg daily when THI increased from 42 to 68% and then decreased from 19.8 to 15.8 kg daily when the THI increased from 68 to 80%. The authors concluded that DMI increases slowly with the rise in THI until the critical point and decreases severely with the rise THI. **Habeeb et al. (2018 a, b)** reported that the important effect of warmth stress on livestock is the decrease of feed intake to provide less metabolic heat and eventually reduced growth by quite 10-20% **(Habeeb et al., 2018 a, b).** The DMI of animals generally begins to decrease when the ambient temperature reaches 25°C and severely decreases when the environmental temperature exceeds 40°C, after which DMI is around 20–40% less than the regular intake (Habeeb et al., 2018c).

The depression in DMI and growth performance of animals during heat stress may be due to redistributing energy to heat regulation through a series of physiological and metabolic responses, like elevated blood insulin and protein catabolism, enhanced respiration rate, and panting accelerate the loss of CO_2, leading to altered blood acid-base chemistry and alkalosis (Wang et al., 2020). Besides, the high THI prompted some alterations in rumen motility and microbiota which affects feed digestibility and rumen fermentation, causing the change of feed digestibility and rumen fermentation (Wang et al., 2020). Under high ambient temperatures, livestock is predicted to decrease DMI to cut back their metabolic heat production. Reduced internal secretion concentration in heat-stressed animals may result in reduced feed intakes which results in deleterious energy balance making energy levels not adequate for normal growth synthesis (Habeeb et al., 2020).

2-Effect of varying THI values on water consumption (WC):

The increase in water consumption (WC) increases with increasing THI values. WC significantly in native bovine calves increased by 28.8% at THI 74.9 during the spring season and by 63.4% at greater THI 85.5 during the summer season compared to those at low THI 68.1 in winter.

Nardone et al. (1993) found that 86 THI from 10.00 to 18.00 hours for ten weeks determined an increase in WC (29.1%) in Holstein Friesian calves. Kadzere et al. (2002) observed that WC augmented by 3.3 liters per day when THI elevated from 70.01 to 87.72%. In a controlled chamber for seven days on Korean calves, Kim et al. (2018) observed that WC was significantly increased at THI 82.92 to 84.05 compared to that at THI 74.22. Habeeb et al. (2018a) found that WC was increased by 30% or more during heat stress conditions compared to that in the absence of heat stress conditions.

The most effective way of heat dissipation when animals are exposed to high-temperature is increasing the rate of evaporative heat exchange. The loss of water by sweating and stimulates water consumption (Kadzere et al., 2002).

3-Effect of varying THI on food conversion (DMI/DBG), DMI/WI and DBG/WI:

The efficacy of conversion of DMI to DBG was increased significantly by 13.1% during the spring season and by 33.6% during the summer season compared to those in winter. With increasing THI, the depression in DBG was more than the decline in daily DMI; therefore, food conversion (DMI/DBG) increases when the value of THI increases.

DMI/WC ratio decreased during the spring season by 27.8% and during the summer season by 51.7% compared to the winter season. The percentage decline in DMI was less than the percentages increase in WI; therefore, the DMI/WC ratio decreased significantly with increasing THI values.

The Gain/WC ratio decreased significantly with increasing THI levels. Gain/WC ratio decreased significantly by 34.7 and 64.0% during the spring and summer seasons, respectively, compared to during the winter season. The share decline in WC was less than the odds increase in gain; therefore, the Gain/WI ratio decreased significantly with increasing THI values. The results of the DMI/WI ratio indicates that at low THI (THI <70) in the winter season, each 2.09 g DMI need to 100 ml drinking water while at THI (70< - >80) in the spring season, each 1.51 g DMI need 100 ml water while at greater THI (80<) in the summer season, each 1.01 g only need 100 ml drinking water.

The Gain/WI ratio also decreased significantly with increasing THI levels. Gain/WI ratio decreased significantly by 34.7 and 64.0% during the spring and summer seasons, respectively, compared to during the winter season. Each 3.08 g gain at low THI (THI <70) needs 100 ml drinking water while at THI 74.9, each 2.01 g gain needs 100 ml water, and at greater THI 85.5, each 1.11 g only need 100 ml drinking water.

The utilization of feed efficiency indexes aims to spot and choose animals with a significant economic amount, and feed efficiency would vary with an index of THI (Veerkamp, 1998**).** The regression of y on x indicates that when the worth of THI increases the food efficiency per kg food increases (Könyves et al. 2017). An animal's efficiency in converting feed into products is influenced by environmental factors that lead to individual variation in energy expenditure (Habeeb et al., 2018a).

4-Effect of varying THI values on hormonal levels:

Thyroid hormones decreased significantly and cortisol increased significantly with increasing THI. T_4 and T_3 levels in native bovine calves were significantly decreased by 8.22 and 13.2% during the spring season and were significantly decreased by 24.2 and 33.8%, respectively, during summer compared with those values during the winter season. The results showed that with increasing THI, the decrease in T_3 was over the decline in T_4; therefore, the T_4/T_3 ratio increases significantly when the worth of THI rises. The cortisol hormone levels were increased significantly by 28.5 and 61.4 during the spring and summer seasons, respectively, compared with the winter season. These results indicate that the foremost deteriorating effect of warmth stress on hormonal levels was observed within the summer season. During the warmth stress conditions, O'Brien et al. (2010) found that T_4 and T_3 levels in growing cattle are decreasing significantly compared with THN conditions. Silanikove (2000**)** found that T_3 and T_4 concentrations in domestic ruminants decreased by 25% due to heat stress conditions. When the THI was higher, the thyroid hormones levels in blood serum were below the conventional range and when the THI was in comfort, the T_3 and T_4 levels in body fluid were increased (Kohli et al., 2014). The study of Wankar et al. (2019) was conducted on adult buffaloes and found that thyroid hormones declined and glucocorticoids increased at 35°C and 40°C. Kim et al. (2018) found that at THI of 84.05 to 87.72, serum cortisol level was significantly higher than at THI of 70.01 to 82.92. The decline in T_4 and T_3 levels at THI is consistent with the decline in metabolic rate, feed intake, growth and milk production (Agarwal and Upadhay, 2013**).** Exposure of the Indian goats to high environmental temperature adversely affects the endocrine activity because of its high sensitivity to environmental heat variations, consequently resulting in declined T_3 and T_4 levels (Sejian and Srivastava 2010**).** The decline in thyroid activity is combined with a decrease in hormone to scale back metabolic activity and body heat increment. The hypothalamus-pituitary-adrenal axis stimulation results in the rise within the secretion of corticotropin from the pituitary and consequently starts the synthesis and secretion of cortisol hormone (Lakhani et al., 2018; Li et al., 2020).

5- Effect of varying THI values on blood biochemical components:

The concentrations of total protein and glucose within the calves decreased significantly with increasing THI. During the summer season, the concentrations of total protein and glucose were significantly lower by 15.1 and 15.7%, respectively than those values during the winter season. Levels of plasma glucose and total proteins in the blood of Egyptian native calves at low and moderated THI levels were maintained relatively stable, while a significant reduction was observed at high THI.

The urea concentration decreased significantly with increasing THI. Under the spring season, urea levels in bovine calves increased significantly by 18.3%, while under the summer season, urea levels increased significantly by 64.2% compared with under the winter season.

The serum glucose level at THI of 82.92 was significantly higher than at THI of 70.01 to 76.51(Kim et al. 2018). The reduced energy intake as a result of reduced feed intake and increased cost for the thermoregulation process may be caused by the decrease in serum glucose level at high THI. The negative effect of the energy at high THI may be increased gluconeogenesis as an endocrine acclimation to hot conditions (Abeni et al. (2007). In Egyptian goats, El-Tarabany et al. (2017) found the same reduction in glucose and total protein concentrations at high THI levels as compared with low and moderate THI levels and clarified that decline to the augmentation in the plasma volume as a sequel of warmth shock which ends in decreased protein concentration.

6. Correlations coefficient between THI with different parameters:

THI has highly significant negative correlations with DBG, DMI, T_4, $T_{3,}$ total proteins, and glucose and has highly significant positive correlations with water intake also as cortisol and urea concentrations. DBG has highly significant positive correlations with DMI, T_4, $T_{3,}$ total proteins and glucose and has highly significant negative correlations with water intake, cortisol and urea concentrations. DMI has highly significant positive correlations with T_4, $T_{3,}$ total proteins, and glucose and has highly significant negative correlations with water intake, cortisol, and urea concentrations. THI had a significant negative correlation with the DMI of cows in the south-eastern of the US (Holter et al., 1997).

THI had a significant negative correlation (r = - 0.82) with the DMI of cows (Chang-Fung-Martel et al., 2021). Davina and Eileen (2017) reported that THI had negative effects on daily DMI, daily CP intake, daily ME intake and feed efficiency. THI had a positive correlation with WC in lactating dairy cows (Ammer et al., 2018). The same authors mentioned that WC increased between 0.96 and 1.08 liter per rising THI one unit. El-Tarabany et al. (2017) found that THI values were negatively correlated with serum glucose and total protein. Li et al. (2020) found that negative significant correlations of THI with cortisol 0.624 and located also that cortisol was positively significantly correlated with T4 (0.814). Kim et al. (2018) found a significantly positive association between THI and cortisol. THI had a positively correlation with cortisol and thyroxin hormonal levels (Bouraoui et al., 2002).

Conclusion

High THI in the spring and summer season affects physiological body functions, affecting the DMI and feed efficiency, blood biochemistry components, blood hormones, and eventually leading to decreasing Egyptian male bovine calves performance. This indicates that stress starts when the THI is above 68.1 and becomes serious above 74.9 lastly. In conclusion, summer was the season with the highest hazard native calves, and the summer heat stress negatively affects DBG, DMI, and concentrations of blood biochemical components and hormonal levels in Egyptian native calves. Therefore, management plans are necessary to decrease the effects of warmth stress conditions, especially, during the hot summer season to succeed in optimal growth of calves under the climate of Egypt.

Declarations

1-**Funding:**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. All authors decided that no any fund was offered for complete this manuscript but this research was Supported by Biological Applications Department, Nuclear Research Center, Egyptian Atomic Energy Authority, Cairo, Egypt.

2- Conflicts of Interest

No potential conflict of interest was reported by all the authors. All authors decided that no acknowledge any financial interest or benefit we have arising from the direct applications of our research.

3- Ethics approval

Experimental animals were carried using husbandry guidelines derived from the Egyptian Atomic Energy Authority standard operating procedures. The experimental work was reviewed and approved by the Animal Care and Welfare Committee of the Egyptian Atomic Energy Authority

4- Consent to participate

All authors were participated to complete this manuscript. All authors of this research paper have directly participated in the planning, execution & analysis of this study. All authors of this paper have read and approved the final version submitted

5- Consent for publication

All authors were accepted for publication this manuscript. The content of this manuscript is not now under consideration for publication elsewhere. The content of this manuscript will not be copyrighted, submitted, or published elsewhere, while acceptance by the journal is under respect. There are no directly related manuscripts published or unpublished by any authors of this manuscript. All authors gave explicit agreement to submit and obtained approval from the Egyptian Atomic Energy Authority where the manuscript has been agreed upon **before** the manuscript is submitted.

6-Availability of data and material (data transparency)

All authors confirmed that availability of data and materials support their published claims and comply with field standards.

7- Code availability (software application or custom code)

All authors confirmed that availability of software application or custom code support their published claims and comply with field standards.

8- Author’s contribution statement

1-The suggestion of the idea and design of the protocol of the study was carried by Alsaied Alnaimy Habeeb

2-Collection of the data and make the statistical analysis of the data was carried by Ahmed K. Sharaf

3- Interpretation of the data and drafting of the article was carried by Mostafa Abbas A. Atta

4- Revising the article critically for important intellectual content was carried by Anhar Elhanafy.

5- Final approval of the version to be submitted was carried by Alsaied Alnaimy M. Habeeb.

Disclosures and declarations

1- Our study-specific approval by the appropriate ethics of Egyptian Atomic Energy Authority committee for research involving animals, and a statement on welfare of animals

2-Our work submitted for publication not has any implication for public health or general welfare

References

1. Abeni F, Calamari L, Stefanini L, 2007. Metabolic conditions of lactating Friesian cows during the hot season in the Po valley. 1. Blood indicators of heat stress. International Journal of Biometeorology, 52: 87–96.
2. Agarwal A, Upadhay R, 2013. Heat stress and hormones. Heat Stress and Animal Productivity. Springer, India, p27–51.
3. Ammer S, Lambertz C, von Soosten D, Zimmer K, Meyer U, Danicke S, Gauly M., 2018. Impact of diet composition and temperature–humidity index on water and dry matter intake of high-yielding dairy cows. Journal of Animal Physiology and Animal Nutrition, 102: 103–113. DOI: 10.1111/jpn.12664.
4. Association of Official Analytical Chemists, 1990. Official methods of analysis, 14th ed., AOAC, Washington DC, USA.
5. Bernabucci U, Lacetera N, Baumgard LH, Rhoads RP, Ronchi B and Nardone A., 2010. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal, 4(7):1167–1183. doi: 10.1017/S175173111000090X
6. Bohmanova J, Misztal I, Cole JB., 2007. Temperature-Humidity Indices as indicators of milk production losses due to heat stress. Journal of Dairy Science, 90:1947–1956, doi:10.3168 /jds.2006-513.
7. Bouraoui R, Lahmar M, Majdoub A, Djemali M, Belyea R., 2002. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research, 51: 479–491. DOI: 10.1051/animres:2002036
8. Brügemann KE, Gernand U, König von B and König S., 2012. Defining and evaluating heat stress thresholds in different dairy cow production systems. Arc Tierzucht 55(1): 13–24.
9. Chang-Fung-Martel J, Harrison MT, Brown JN, Rawnsley R, Smith AP, Meinke H., 2021. Negative relationship between dry matter intake and the temperature-humidity index with increasing heat stress in cattle: a global meta-analysis. International Journal of Biometeorology, 65(12):2099–2109. doi: 10.1007/s00484-021-02167-0.
10. Dash S, Chakravarty AK, Singh A, Upadhyay A, Singh M, Yousuf S., 2016. Effect of heat stress on reproductive performances of dairy cattle and buffaloes: A review, Veterinary World, 9(3): 235–244. doi: 10.14202/vetworld.2016.235-244

11. Davina LH, Eileen W., 2017. Weather influences feed intake and feed efficiency in a temperate climate. Journal of Dairy Science, 100:2240–2257. https://doi.org/10.3168/jds.2016-11047.
12. Duncan DB., 1955. Multiple range and multiple F-test. Biometrics 11: 1–42.
13. El-Tarabany MS, El-Tarabany AA, Atta MAA., 2017. Physiological and lactation responses of Egyptian dairy Baladi goats to natural thermal stress under subtropical environmental conditions. International Journal of Biometeorology, 61:61–68.DOI 10.1007/s00484-016-1191-2.
14. Food Agriculture Organization of the United Nations (FAO), 2015. Livestock and the environment. http://www.fao.org/livestock environment/en/2015.
15. Habeeb AA, Gad AE, Atta AM., 2018c. Temperature-humidity indices as indicators to heat stress of climatic conditions with relation to production and reproduction of farm animals. International Journal of Biotechnology and Recent Advances 1(2): 35–50. doi: 10.18689/IJBR-1000107
16. Habeeb AA, EL-Tarabany AA, Gad AE, Atta MAA., 2018b. Negative Effects of Heat Stress on Physiological and Immunity Responses of Farm Animals. International Technology and Science Publication 2: 1–18.
17. Habeeb AA, Gad AE, EL-Tarabany AA, Atta MAA., 2018a. Negative Effects of Heat Stress on Growth and Milk Production of Farm Animals. Journal of Animal Husbandry and Dairy Science, 2 (1): 1–12.
18. Habeeb AAM, Osman SF, Gad AE., 2020. Signs of heat stress and some steps to reduce the negative effects on animals. Advanced Research and Reviews, 4(1): 46–58.
19. Herbut P, Angrecka S., 2012. Forming of temperature-humidity index (THI) and milk production of cows in the free-stall barn during the period of summer heat. Animal Science Papers and Reports 30(4): 363–372.
20. Herrero M, Thornton PK, Notenbaert AM, Wood S, Msangi S., 2010. Smart investments in sustainable food production: Revisiting mixed crop–livestock systems. Science 327, 822–825. doi: 10.1126/science. 1183725.
21. Holter JB, West JW, Mcgilliard ML., 1997. Predicting ad libitum dry matter intake and yield of Holstein cows. Journal of Dairy Science, 80: 2188–2199. doi: 10.3168/jds.S0022-0302(97) 76167–8
22. IPCC (Intergovernmental Panel on Climate Change., 2014. Climate Change: Synthesis Report; Summary for Policymakers. Available from: https://www.ipcc.ch/pdf/ assessment-report/ar5/syr/AR5_SYR_FINAL_ SPM.pdf.Last accessed on 25-12-2015.
23. Kadzere CT, Murphy MR, Silanikove N, Maltz E., 2002. Heat stress in lactating dairy cows: a review. Livestock Production Science 77(1):59–91.
24. Kendall PE, Webster JR., 2009. Season and physiological status affects the circadian body temperature rhythm of dairy cows. Livestock Science, 2009; 125, 155–160.
25. Kim WS, Lee JS, Jeon SW, Peng DQ, Kim YS, Bae MH, Jo YH, Lee HG., 2018. Correlation between blood, physiological and behavioral parameters in beef calves under heat stress. Asian-Australas Journal of Animal Science, 31(6):919–925. https://doi.org/ 10.5713/ ajas. 17.0545.
26. Kohli S, Atheya UK, Thapliyal A., 2014. Assessment of optimum thermal humidity index for crossbred dairy cows in Dehradun district, Uttarakhand, India, Veterinary World, 7(11): 916–921. doi: 10.14202/vetworld.2014.916-921.
27. Könyves T, Zlatković N, Memiši N, Lukač D, Puvača N, Stojšin M, Halász A, Miščević B., 2017. Relationship of temperature-humidity index with milk production and feed intake of Holstein-Frisian cows in different year seasons. Thai Journal Veterinary Medicine, 47(1): 15–23.
28. Lakhani P, Alhussien MN, Lakhani N, Jindal R, Nayyar S., 2018. Seasonal variation in physiological responses, stress and metabolic-related hormones, and oxidative status of Murrah buffaloes. Biological Rhythm Research,

49:844–852.doi:10.1080/092910162018. 1424775.

29. Li M, Hassan F, Guo Y, Tang Z,Liang X, Xie F, Peng L, Yang C., 2020. Seasonal Dynamics of Physiological, Oxidative and Metabolic Responses in Non-lactating Nili-Ravi Buffaloes Under Hot and Humid Climate. Frontiers Veterinary Science, 7:1–11, doi:10.3389/fvets.2020.00622
30. Nabenishi H,Yamazaki A., 2017. Effects of temperature–humidity index on health and growth performance in Japanese black calves. Tropical Animal Health &Production, 49:397–402. DOI 10.1007/s11250-016-1207-2
31. Nardone A, Lacetera NG, Ronchi B, Bernabucci U.., 1993. Feed intake and weight gain in female calves exposed to thermal stress. AGRIS, FAO, Universita della Tuscia, Viterbo Istituto di Zootecnica, Italy.
32. National Research Council (Subcommittee on Environmental Stress), 1981. Effect of environment on nutrient requirements of domestic animals. National Academy Press, Washington, pp:168.
33. O'Brien MD, Rhoads RP, Sanders SR, Duff GC, Baumgard LH., 2010. Metabolic adaptations to heat stress in growing cattle. Domestic Animal Endocrinology, 38 (2): 86–94.
34. Prathap P, Archana PR, Aleena J, Sejian V, Krishnan G, Bagath M, Manimaran A, Beena V, Kurien EK, Varma G, Bhatta R., 2017. Heat stress and dairy cow: Impact on both milk yield and composition. International Journal of Dairy Science, 12: 1–11.
35. SAS, 2003. SAS/STAT Users Guide. SAS Institute INC, Cary, NC 27513, USA.
36. Sejian V, Srivastava R., 2010. Interrelationship of endocrine glands under thermal stress: effect of exogenous glucocorticoids on mineral, enzyme, thyroid hormone profiles and phagocytosis index of Indian goats. Endocrine Regular, 44:101–107. doi: 10.4149/endo _2010_03_101.
37. Shivley CB, Lombard JE, Urie NJ, Kopral CA, Santin M, Earleywine TJ, Olson JD, Garry FB., 2018. Preweaned heifer management on US dairy operations: Part VI. Factors associated with average daily gain in pre-weaned dairy heifer calves. Journal of Dairy Science, 101:9245–9258. https://doi.org /10.3168/jds.2017-14022
38. Silanikove N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livestock Production Science, 67: 1–18.
39. St-Pierre NR, Cobanov B Schnitkey G., 2003. Economic losses from heat stress by US livestock industries. Journal of Dairy Science, 86 (5):E52-77. https://doi.org/10.3168/jds.S0022-0302 (03)74040-5
40. Veerkamp RF., 1998. Selection for economic efficiency of dairy cattle using information on live weight and feed intake: a review. Journal of Dairy Science, 81(4):1109–1119.
41. Wang J, Li J, Wang F, Xiao J, Wang Y, Yang H, Li S, Cao Z., 2020. Heat stress on calves and heifers: a review. Journal of Animal Science and Biotechnology 11:79–87. https://doi.org/10.1186/s40104-020-00485-8
42. Wankar AK., Singh G, Yadav B., 2019. Effect of temperature x THI on acclimatization in buffaloes subjected to simulated heat stress: physio-metabolic profile, methane emission and nutrient digestibility PP: 1–15. DOI: 10.1080/092910162019.1673652
43. West JW, Mullinix BG, Bernard JK., 2003. Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. Journal of Dairy Science, 86:232–342. https://doi.org/10.3168/jds.S0022-0302 (03)73602-9
44. West JW., 2003. Effects of heat-stress on production in dairy cattle. Journal of Dairy Science, 86: 2131–2144.
45. Xue B, Wang ZS, Li SL, Wang LZ, Wang ZX.., 2010. Temperature-humidity index on performance of cows. China Animal Husbandry Veterinary Medicine, 37:153–157.