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Research Paper

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

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Abstract
Domestic animals in Egypt are exposed to a range of THI concentrations, from low levels in the winter to moderate levels in the spring to high levels in the summer. This study intends to examine the effects of climatic variability on growth traits, blood hormones, and biochemical blood components in Baladi cattle calves during the three main seasons of the year in Egypt. The experimental calves were born on the same farm by mating male Baladi bulls with Egyptian Bovine cows. Before weaning, all calves were maintained for four months in the same manner. Twenty-four Egyptian bovine calves after weaning were used in this study. Three experimental trials that corresponded to the seasons of the year were included in the experimental design. After weaning during the winter, eight calves were raised. After weaning throughout the spring, eight calves were raised. After weaning throughout the summer, eight calves were raised. The Temperature-Humidity Index (THI) was computed on a weekly and monthly basis across the three seasons. Each calf's weekly measurements of daily body gain (DBG), feed intake (DMI), and water consumption (WC) were recorded. Each calf's respiratory rate, rectal temperature, and skin temperature were measured every week. On the last day of each month of each trial, one blood sample from the right jugular vein of each calf was obtained before the morning meal. The results showed that the greatest THI value (85.5) during the summer was associated with significant ($P<0.01$) decreases in DBG, daily DMI, thyroid hormone levels, total proteins, and glucose and significant ($P<0.01$) increases in daily WC, cortisol, and urea levels. As THI levels rise from low THI in the winter (68.1) to moderate THI in the spring (74.9) and high THI (85.5) in the summer, the rate of decrease also increases. Food conversion rises when the value of THI rises because the depression in DBG with increasing THI was greater than the decline in daily DMI. Increases in THI values resulted in noticeably higher values for rectal and skin temperatures as well as respiration rates. THI shows highly significant ($P<0.01$) positive associations with water consumption, cortisol, and urea concentrations as well as highly significant ($P<0.01$) negative correlations with DBG, DMI, thyroxin (T4), triiodothyronine (T3), total proteins, and glucose. In conclusion, the summer was the most dangerous time of year for native calves, and the summer heat stress had a detrimental impact on the DBG, DMI, blood biochemical component concentrations, and hormonal levels in Egyptian native calves.

Keywords*: Calves, growth, Feed Intake, Water Intake,Hormones, THI, blood Components.*

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I. Introduction

The world's population is expected to reach 9.6 billion people in 2050, while demand for animal products is predicted to increase by 70% over that time [1]. The majority of climate zones include tropical, subtropical, and temperate climates. The temperate zone is regarded as the ideal setting for farm animals to perform better. **Kadzere et al.**[2] defined the thermoneutral zone (TNZ), which is a specific range of environmental temperatures where animals can maintain a normal body temperature while experiencing minimal physiological costs and maximum productivity. **Bernabucci et al.**[3] reported that when elevated ambient temperature levels exceed the TNZ and excessive moisture levels produce heat stress, the animals are unable to distribute body heat sufficiently to be thermally stable. More than 60% of all animal farms worldwide are located in the tropics and subtropics, where there are high ambient temperatures and high relative humidity levels that are thought to be detrimental to commercial viability [1]. Heat stress causes significant losses ($2.4 billion) in animal production, and as a result, livestock industries in the USA suffer annual commercial losses totaling $1.69 to $2.36 billion. Up to $1.500 billion of these losses are caused by the dairy industry, making heat stress the primary factor limiting animal performance [4]. An annual loss of $48 million was incurred as a result of the adverse impact of temperature stress on the production of younger animal alternatives. As global warming progresses, the severity of animals' difficulties caused by heat stress will increase [4].In the early 20th century, global warming increased the perceived temperature by around 0.7°C, and by 2100, it is expected that temperature will have increased by 1.8–4.0°C [5]. Because the spread of global glasshouse airs is intended to cause discomfort, the most significant effects of weather change will specifically affect animal producers, whose costs of living are high in hot regions of most developing countries [6].The stock is exposed to a level of extra severe heat stress as a result of the gradually rising global climate and the amplification of hot seasons, which poses a serious threat to production performance [7]. Temperature-humidity index (THI), which combines ambient temperature and relative humidity, is frequently utilized as a useful indicator of an animal's level of stress [8]. To determine the level of heat stress, THI was measured using several of formulae and is displayed in classes [9]. The majority of studies showed that elevated THI negatively impacts milk production, reproductive health, and fertility [10,11,12,13,14].To develop strategies to lessen the negative effects of particular seasons throughout the year and prevent financial losses on animal growth, it is crucial to understand how physiological and metabolic cycles change in Egyptian native calves over various seasons. The amounts of THI that domestic animals in Egypt are exposed to vary depending on the season: low levels during the winter, moderate levels during the spring, and high levels during the summer.

This study intends to examine how daily body growth, feed intake, water intake, and a few biochemical blood components in native bovine calves are affected by climatic variations of the THI index across Egypt's three main seasons.

II. Materials and Methods

Experimental site

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

Experimental ethics

Standard operating protocols for the Egyptian Atomic Energy Authority were used to guide the management of experimental animals. The Egyptian Atomic Energy Authority's Animal Care and Welfare Committee examined and authorized the experimental activity.

Animal nutrition

For this study, 24 healthy Egyptian male bovine calves were used, all of the same age and with an average live body weight of 100.05.4 kg. The calves were given a meal made up of rice hay (RH) and concentrate feed mixture (CFM). CFM ration contains wheat bran, unprocessed cottonseed meal, flaxseed meal, dicalcium phosphate, iodized salt, trace mineral mixture, and vitamin AD_3E at rates of 40, 25, 25, 7.0, 1, 1, 1, 0, and 0.50 percent, respectively. The percentages of calcium, phosphorus, magnesium, and potassium in a kilogram of CFM are respectively 0.8, 0.6, 0.07, and 0.65. 12,000,000 IU of vitamin A, 2000,000,000 IU of vitamin D3, 10 g of vitamin E, 2 g of vitamin K_3, 1000 mg of vitamin B_1, 49 g of vitamin B_2, 105 g of vitamin B_6, 10 mg of vitamin B_{12}, 10 g of pantothenic acid, 1000 mg of folic acid, 50 g of biotin, 500 mg of choline chloride, 30 g of Fe, 40 g of Mn, 3 g Cu; 200 mg Co; 100 mg Si and 45 g Zn in each kg of vitamins and mineral mixture (premix). According to AOAC [15], the crude protein, crude fat, NDF, and ADF contents of the CFM (on a dry matter basis percent) fed to the experimental groups during the trial period were respectively 15.2, 3.0, 20.5, and 13.5 %. According to body weight and daily gain increase, CFM is given in the morning once a day at a rate of 2.5 kg CFM per 100 kg [16]. RH was offered *ad libitum*. The experimental calves had free access to fresh drinking water at all times.

Weather information during the three experiments

A digital Thermo-hygrograph was used to capture weekly and monthly environmental temperature (AT, °C) and relative humidity (RH %) measurements under the farm's typical midday conditions (Italy). The equation of Kendall and Webster [17] was used to determine THI values using AT and RH values as follows: THI is calculated as follows: 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).

Experimental procedure

The experimental calves were born on the same farm in the Inshas region from Egyptian bovine Baladi cows after mating with male Baladi bulls. For four months before weaning, all calves were maintained under the same circumstances. Twenty-four Egyptian bovine calves that had recently been weaned and had an average live body weight of around 100.0 kg were employed in this investigation. Three trials were included in the experimental design, one for each season of the year. From January to September 2020, the three trials for the three seasons were ongoing. Eight calves were reared in trial one from the beginning of January to the end of March after being weaned. For the second trial, eight weaned calves were raised over the spring months of 1 April through June 30. Eight calves were raised in the third trial from the time they were weaned to the end of September during the summer. Three experiments used calves that were handled similarly and followed comparable procedures. The experimental calves were tied with troughs during the testing months in a single, isolated yard (40 x 60 meters) surrounded by a wire fence (2 meters high), and one-third of the area was roofed with concrete shading in the middle (3-meter height).Each calf was in a separate area with a container for fresh drinking water, and the yard was separated into 10 sections by hardwood. On the first and last day of each month, the calves in each trial were weighed on a platform scale before the morning feeding. The weights were divided by the number of days in each month to determine the total and body weight growth of each calf for the month as well as the season. By deducting the residual feed from the feed supplied for the calf the day before, feedstuff intake (FI) was measured four times per month separately for each calf. The average was used to calculate monthly and subsequently seasonal FI. In each of the samples from CFM or BH, the dry matter intake (DMI) was calculated from the weight difference before and after oven drying overnight at 105°C for 24 hours. DMI was determined by multiplying fresh feed intake by the corresponding DM percentages (92.0 and 88.5%), and then it was easy to calculate DMI on a monthly and seasonal basis. During the experimental period, water consumption (WC) was assessed four times monthly for each calf separately by deducting the water supplied the day before from the remaining water in the container. Seasonal water intake for each calf was also computed.

Rectal and skin temperatures were measured using a digital thermometer to examine the physiological parameters. The movement of the flank was used to measure the respiratory rate.

Blood sampling and biochemical and hormonal analysis

Before the morning feed, three blood samples from each calf's right jugular vein were obtained. They were then analyzed using disposable syringes devoid of anticoagulants to evaluate the hormone and biochemical composition of the blood. Blood samples were transported to the lab and put on the ice box right away. After centrifuging blood samples at a rate of 2000x g for 30 min, they were transferred to a tube and stored at -20°C. Thyroxin (T_4), triiodothyronine (T_3), and cortisol hormones were measured using the Radioimmunoassay method (RIA), and antibody-coated tubes were labeled with ^{125}I (Diagnostic Product Corporation, Los Angeles, USA). The liquid inside the tubes is aspirated after the incubation time. The levels of glucose, total protein, and urea were determined using biochemical reagent kits that were acquired from the Egyptian company Diamond Diagnostic. The average of the biochemical elements and hormonal concentrations was used to calculate seasonal values for each calf.

Statistical analysis

The analysis of variance function in SAS [18] was used to analyze the data. THI was examined to see how it affected the dependent variables (DBG, DMI, WC, T_4, T_3, cortisol, total protein, glucose, urea, and physiological parameters), which were divided into three levels: low, moderate, and high. The significance of the discrepancy between the means was validated by Duncan's novel multiple ranges test [19]. The CORR function in SAS was used to create Pearson correlation coefficients between THI values during the experimental months and various parameters.

III. Results

THI values during the winter, spring and summer seasons of the year in Egypt

Throughout the study period, during the three seasons of winter, spring, and summer, environmental variables were recorded and used to depict monthly climatological fluctuations. The experimental calves in this study were exposed to three different levels of THI: the first group, consisting of 8 calves, was exposed to a lower THI value (68.1) during the winter months; the second group, consisting of 8 calves, was exposed to a moderate THI value (74.9) during the spring months; and the third group, consisting of 8 calves, was exposed to a higher THI value (85.5) during the summer months in Egypt. According to Kendall and Webster (2009), low THI is defined as comfort, and moderate THI is defined as discomfort between 70 and 75 and high: THI more than 80 (severe or very severe heat stress or emergency). During the winter, spring, and summer research seasons, the calves are subjected to comfort (thermoneutrality), discomfort or mild-moderate heat stress, and severe heat stress, respectively. The THI indices were much higher in spring and summer than in winter, with summer having the greatest value followed by spring **(Table 1).**

THI values with relation to body gain, feed intake and water consumption

Due to greater THI, a highly significant (P<0.01) reduction in total gain (TG, kg/90 days), daily body gain (DBG), and daily dry matter intake (DMI) was found in the calves. With rising THI, the amount of TG and DBG degradation increases. In comparison to THI of 68.1(winter season), TG or 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 (summer season). Furthermore, TG or DBG decreased markedly (P<0.01) by 27.6% at a THI of 85.5 in the summer compared to a THI of 74.9 in the spring. When compared to DBG at THI 74.9 during the spring season, DBG at THI 85.5 during the summer season declined dramatically by 13.5% (**Table 2).**

With rising THI values, the daily DMI fall rate likewise gets worse. In comparison to THI 68.1(winter season), daily DMI fell considerably (P<0.05) by 9.05% at THI 74.9 (spring season) and by 21.40 % (P<0.01) at THI 85.5 (summer season). When compared to DBG at THI 74.9 during the spring season, DBG at THI 85.5 during the summer season declined dramatically by 13.5%. In comparison to winter, DMI fell by 36.0 g and 85 g per day in the spring and summer, respectively. These findings indicate that in the summer, extreme heat stress harms daily DMI as well as DBG.Compared to individuals with a low THI of 68.1 in the winter, water consumption increased considerably (P<0.01) by 28.8% at THI 74.9 in the spring and by 63.4% at higher THI (85.5) in the summer **(Table 2).**

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

In comparison to those in winter 68.1, the effectiveness of conversion of the DMI to DBG ratio was considerably increased (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. Since the depression in DBG with increasing THI was more than the decline in daily DMI, food conversion (DMI/DBG) rises as the THI value increases. Since the percentage of DMI reduction was less than the percentage of WI increase, the DMI/WI ratio (g/100ml) dramatically fell as THI values increased. When compared to the winter season, the DMI/WI ratio dropped by 27.8% in the spring and by 51.7% in the summer (P<0.01) (**Table 3).**

THI values with relation to T_4, T_3 and cortisol levels

Comparing T_4 and T_3 levels at moderate THI 74.9 in the spring to those at low THI (68.1) in the winter, there was a significant (P<0.01) decline of 8.22 and 13.2 %, respectively. T_4 and T_3 levels were substantially reduced (P<0.01) by 24.2 and 33.8 %, respectively, at higher THI (85.5) during the summer season as compared to similar values at lower THI (68.1) during the winter season. Additionally, T_4 and T_3 levels were significantly (P<0.01) reduced by 17.5 and 23.7 %, respectively, at higher THI (85.5) in the summer compared to similar values at lower THI (74.9) in the spring (**Table 4).**

Cortisol levels were considerably (P<0.01) elevated by 28.5 % at THI 74.9 in the spring compared to those at low THI (68.1) in the winter. Cortisol levels were considerably (P< 0.01) rose by 61.4 % with higher THI (85.5) during the summer compared to lower THI (68.1) during the winter. Additionally, the level of cortisol was substantially (P<0.01) elevated by 25.56 % at higher THI (85.5) in the summer compared to moderate THI (74.9) in the spring **(Table 4**).

THI values with relation to blood biochemical components

Total proteins and glucose concentrations declined marginally by 4.06 and 4.8 %, respectively, at THI 74.9 in the spring compared to similar readings with low THI (68.1) in the winter. Total proteins and glucose concentrations were considerably lower with higher THI (85.5) in the summer compared to lower THI (68.1) in the winter by 15.1 and 15.7%, respectively. Total proteins and glucose concentrations were both considerably lower at a higher THI (85.5) in the summer compared to those values at a moderate THI (74.9) in the spring.When compared to results at low THI (68.1) during the winter season, the urea level was significantly higher at THI (74.9) during the spring season by 18.3%. In comparison to those readings at low THI (68.1) during the winter, urea levels were significantly higher at higher THI (85.5) during the summer (64.2%). Comparing readings obtained at a THI of 74.9 in the spring to those obtained at a higher THI of 85.5 during the summer, the urea level was dramatically elevated by 38.8% (**Table 5**).

THI values concerning the physiological parameters

Due to enhanced THI, physiological measures in the calves increased in a very significant (P<0.01) way. In comparison to THI of 68.1(winter season), the respiratory rate rose considerably (P<0.05) by 16.47% at THI of 74.9 (spring season) and by 48.40% at THI of 85.5 (summer season). In addition, at a THI of 85.5 during the summer compared to a THI of 74.9 during the spring, the respiration rate rose considerably ($P<0.01$) by 27.42 %. Rectal and skin temperatures were substantially ($P<0.05$) higher at THI 74.9 in the spring than they were at low THI 68.1 in the winter. Rectal and skin temperature values were substantially ($P<0.01$) higher with higher THI (85.5) in the summer than at lower THI (68.1) in the winter. The THI of 85.5 during the summer season was substantially ($P<0.01$) higher than the THI of 74.9 during the spring season for both rectal and skin temperature values (**Table 6).**

Correlations coefficient between THI with different parameters

THI exhibits very strong inverse relationships with DBG, DMI, T_4, T_3, total proteins, and glucose and very strong inverse relationships with water intake, cortisol, and urea levels. The extremely significant correlations between DBG and DMI, T_4, T_3, total proteins, and glucose are positive, while the highly significant correlations between DBG and water intake, cortisol, and urea concentrations are negative. DMI exhibits highly significant negative relationships with water intake, cortisol, and urea concentrations and highly significant positive correlations with T_4, T_3, total proteins, and glucose. WC exhibits highly substantial positive relationships with cortisol and urea concentrations and highly significant negative correlations with T_4, T_3, total protein, and glucose.

T_4 shows a highly significant negative correlation with cortisol and urea concentrations and a highly significant positive correlation with T_3, total protein, and glucose. T_3 exhibits a highly significant negative association with cortisol and urea concentrations and a highly significant positive correlation with total protein and glucose. Cortisol exhibits significant inverse relationships with total protein and glucose and inverse relationships with urea concentration. A highly substantial negative association exists between the concentration of urea and total protein, while a highly significant positive correlation exists between the two. There is a very strong inverse relationship between glucose and urea concentrations (**Table 7).**

IV. Discussion

Effect of varying THI on DBG and DMI

According to the findings, rising THI levels are associated with a faster rate of decline in DBG and DMI. When compared to THI 68.1 in the winter, DBG in native bovine calves dramatically reduced by 18.6% at THI 74.9 in the spring and by 41.1 % at THI 85.5 in the summer. These findings suggest that the most detrimental impact of temperature stress on DBG and DMI occurred during the summer. According to **Nardone et al.**[20], 86 THI from 10:00 to 18:00 hours over ten weeks caused a decrease in DMI (7.9%) and a decrease in DBG (26.1%) in Holstein Friesian calves. According to **West**[21], cattle consumed significantly less TDN protein in the range of THI values from 71 to 81. For every unit increase in THI, there is a daily decrease in DMI for Asia, South America, Oceania, Europe, and North America of 0.57, 0.51, 0.48, 0.42, and 0.29 kg, respectively [22]. THI negatively impacted feed intake, according to **West et al.**[21], who observed that a THI>72.1 caused Holstein and Jersey cows to consume significantly less feed, by 0.51 kg and 0.47 kg, respectively, for every unit of rising in THI within the range of 72 to 84. In lactating Friesian-Holstein cows, **Bouraoui et al**. [23] discovered that when THI rose from 68 in the spring to 78 in the summer, the average DMI dramatically decreased by 9.6 % (1.73 kg), from 18.0 to 16.27 kg/day. Calves with a mean THI of less than 50 acquired greater weight (0.67 kg/d) than those with a mean THI of 50 to 69 (0.62 kg/d), or 70 (0.59 kg/d) [24]. In the calf market, a higher mean THI was associated with a lower DBG and the DBG values at a THI of >75 were significantly lower than those at a THI of 50 or THIs beginning at 56 to 60 [25].The DMI values climbed from 18.5 to 19.8 kg per day when THI grew from 42 to 68, and subsequently fell from 19.8 to 15.8 kg per day when THI increased from 68 to 80 [26]. The authors concluded that DMI increases gradually as THI rises to a crucial point before sharply declining. According to **Habeeb et al.** [27, 28], the reduction in feed intake to produce less metabolic heat and ultimately a growth reduction of roughly 10–20 % are the most significant effects of heat stress on livestock.

Animals' DMI typically starts to decline when the ambient temperature reaches 25°C and significantly declines when the environment temperature hits 40°C, at which point the DMI is typically 20–40% lower than the recommended intake [9]. Animals under heat stress may exhibit decreased DMI and growth performance as a result of redirecting energy to heat regulation through a variety of physiological and metabolic responses, such as increased blood insulin and protein catabolism, increased respiration rate, and panting, which speeds up CO_2 loss and alters blood acid-base chemistry and alkalosis [14]. Additionally, the increased THI caused changes in rumen motility and microbiota, which in turn affected feed digestibility and rumen fermentation, resulting in a change in feed digestibility and rumen fermentation [14]. It is projected that animals will reduceDMIto reduce metabolic heat output in hot environments. Animals under heat stress may consume less food, which could have a negative impact on their energy balance and leave them without enough energy to carry out optimal growth synthesis [29].

Effect of varying THI values on water consumption (WC)

With rising THI values, water consumption (WC) increases. When compared to those at low THI 68.1 in the winter, WC dramatically rose in native bovine calves by 28.8% at THI 74.9 in the spring and by 63.4 % at higher THI 85.5 in the summer. According to **Nardone et al**. [20], 86 THI from 10.00 to 18.00 hours for ten weeks caused an increase in WC (29.1%) in Holstein Friesian calves. **Kadzere et al.**[2] found that when THI increased from 70.01 to 87.72, WC increased by 3.3 liters per day on Korean calves for seven days in a controlled environment. In contrast to THI 74.22, **Kim et al.**[30] found that WC was considerably higher at THI 82.92 to 84.05. According to **Habeeb et al.**[27], WC rose under environments of heat stress by at least 30% compared to that in the absence of heat stress conditions.

When animals are subjected to extreme temperatures, increasing the rate of evaporative heat exchange is the most efficient method of heat dissipation. Sweating causes a loss of water, which encourages water drinking [2].

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

When compared to the winter, the effectiveness of converting DMI to DBG improved considerably by 13.1% in the spring and by 33.6 % in the summer. Since the depression in DBG with increasing THI was more than the decline in daily DMI, food conversion (DMI/DBG) increases as the THI value increases.

Compared to the winter season, the DMI/WC ratio is declined by 51.7% during the summer and by 27.8% during the spring. The DMI/WC ratio was reduced significantly with higher THI values because the percentage decline in DMI was less than the percentage increase in WC.

With rising THI levels, the gain/WC ratio significantly dropped. In comparison to the winter season, the gain/WC ratio was drastically reduced in the spring and summer seasons by 34.7 and 64.0 %, respectively. The gain/WI ratio declined significantly with higher THI values because the percentage decline in WC was less than the value increase in gain. The DMI/WI ratio's findings show that at low THI (THI 68.1) in the winter, each 2.09 g of DMI needs 100 ml of water, while at THI (74.9) in the spring, each 1.51 g of DMI needs 100 ml of water, and at greater THI (85.5) in the summer, each 1.01 g of DMI needs only 100 ml of drinking water.

With rising THI levels, the gain/WI ratio likewise drastically declined. In comparison to the winter season, the gain/WI ratio significantly decreased in the spring and summer seasons by 34.7 and 64.0 %, respectively. At low THI (THI 68.1), each 3.08 g gain requires 100 ml of drinking water, while each 2.01 g gain requires 100 ml at THI 74.9 and each 1.11 g requires only 100 ml at higher THI (85.5).

The purpose of just using feed efficiency indices is to identify and choose animals with considerable economic value. Feed efficiency will vary depending on the THI index [31]. Food efficiency per kg of food increases as the THI value increases, conferring to the regression of y on x [32]. Environmental factors that cause individual variation in energy expenditure have an impact on how effectively an animal converts feed into products [27].

Effect of varying THI values on hormonal levels

With increasing THI, thyroid hormones were significantly reduced while cortisol was significantly elevated. When compared to those values during the winter season, T_4 and T_3 levels in native bovine calves considerably declined by 8.22 and 13.20 % in the spring and by 24.2 and 33.8 %, respectively, during the summer. The findings indicated that as THI increased, the fall in T_3 outweighed the decline in T_4; as a result, the T_4/T_3 ratio dramatically rises as the THI value increased. In comparison to the winter season, the levels of the cortisol hormone significantly increased in the spring and summer seasons, respectively, by 28.5 and 61.4%. These findings suggest that the summer season was when hormone levels were most negatively impacted by heat stress.

According to **O'Brien et al.**[33], growing cattle's T_4 and T_3 levels significantly decrease under heat stress conditions compared to thermoneutral environments. In response to heat stress, **Silanikove**[34] observed that domestic ruminants' T_3 and T_4 concentrations dropped by 25%. Thyroid hormone levels in blood serum dropped below the normal range when the THI was greater, and when the THI was comfortable, the levels of T_3 and T_4 in body fluid increased [35]. According to a study by **Wankar et al.**[36] on adult buffaloes, the thyroid hormones decreased and the glucocorticoids rose.

According to **Kim et al.**[30], serum cortisol levels were significantly higher at THI values ranging from 84.05 to 87.72 than at THI values ranging from 70.01 to 82.92.The decrease in metabolic rate, feed intake, growth, and milk production at THI is consistent with the decrease in T_4 and T_3 levels [37]. Due to their great sensitivity to environmental heat changes, Indian goats exposed to high environmental temperatures experience severe endocrine effects, which result in decreased T_3 and T_4 levels [38]. To reduce metabolic activity and increase body heat, the thyroid's activity is declining, and hormone production is also decreasing.

The stimulation of the hypothalamus, pituitary and adrenal axis stimulate the pituitary to secrete more corticotropin, which in turn triggers the synthesis and release of the stress hormone cortisol [39, 40].

Effect of varying THI values on blood biochemical components

Increasing THI resulted in a significant reduction in the total protein and glucose concentrations in the calves. Total protein and glucose concentrations were both significantly lower in the summer than they were in the winter, by 15.1 and 15.7 %, respectively. Plasma glucose and total protein concentrations in the blood of Egyptian native calves were comparatively steady at low and moderate THI levels but significantly decreased at high THI.With an increase in THI, the urea content dramatically decreased. In comparison to the winter season, urea levels considerably increased in bovine calves during the spring season by 18.3 % and during the summer season by 64.2 %.

The serum glucose level at THI of 82.92 was substantially greater than that of THI of 70.01 to 76.51[30]. The reduction in blood glucose level at high THI may be the root cause of the lower energy intake as a result of reduced feed intake and increased costs for the thermoregulation process. Increased gluconeogenesis as an endocrine response to hot conditions may be the detrimental consequence of the energy at high THI [41]. **El-Tarabany et al**. [13] observed a similar fall in glucose and total protein concentrations in Egyptian goats at high THI levels compared to low and moderate THI levels, and they explained that this decline in the augmentation in plasma volume is a result of heat shock, which results in the development of hypoglycemia.

Effect of varying THI values onphysiologicalparameters

The rise in RR is an effort to promote respiratory evaporation and is a sign that the animals have been exposed to heat stress. If these calves were unable to attain a thermal equilibrium between body heat generation and body heat loss and were unable to lose enough heat, the rectal and skin temperatures would increase [42]. The physiological parameter values are regarded as a reliable predictor of thermal stress and can be used to evaluate how the animals react when exposed to a hot environment [43].

Correlations coefficient between THI with different parameters:

THI has very strong negative relationships with DBG, DMI, T_4, T_3, total proteins, and glucose. It also has very strong positive correlations with water consumption, cortisol and urea concentrations. DBG reveals highly significant negative correlations with water consumption, cortisol, and urea concentrations and highly significant positive correlations with DMI, T_4, T_3, total proteins, and glucose. DMI exhibits highly significant negative relationships with water intake, cortisol, and urea concentrations and highly significant positive correlations with T_4, T_3, total proteins, and glucose. In the southeast of the US, THI was significantly negatively correlated with the DMI of cows [44].

Cows' DMI had a significantly negative correlation (r = -0.82) with THI [22]. According to **Davina and Eileen**[45], THI had a detrimental impact on feed efficiency, daily DMI, daily CP intake, and daily ME intake. When dairy cows were lactating, THI and WC correlated positively [46]. The same investigators noted that for every rising THI unit, WC increased by 0.96 to 1.08 liters. According to **El-Tarabany et al.**[13], blood glucose and total protein levels were negatively correlated with THI values. **Li et al**. [47] observed a negative stronger correlation between THI and cortisol of 0.624 and found that cortisol had a positive significant correlation with T_4 (0.814). **Kim et al.**[30] discovered that THI and cortisol are strongly positively correlated. THI and hormonal levels of cortisol and thyroxin were positively correlated [23].

V. Conclusion

High THI throughout the spring and summer months impacts physiological body processes, influencing the DMI and feed efficiency, blood biochemistry components, and blood hormones, and ultimately resulting in reduced Egyptian male bovine calf performance. According to this, stress begins when the THI rises above 68.1 and therefore only becomes serious above 74.9. In conclusion, the summer was the most dangerous time of year for native calves, and the summer heat stress had a detrimental impact on the DBG, DMI, blood biochemical component concentrations, and hormonal levels in Egyptian native calves. Therefore, to achieve optimal growth of calves in the Egyptian environment, management plans are required to reduce the impacts of temperature stress conditions, especiallyduring the hot summer season.

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Data transparency (availability of data and materials): All authors agreed that the data and materials were both readily available and compliant with industry standards, supporting their published results.

Code accessibility (software application or custom code): All authors affirmed that their published statements are supported by the accessibility of software applications or custom code, which complies with regulatory requirements.

Contribution of the authors

1-Alsaied AlnaimyHabeeb was the one who proposed the idea and created the study's protocol and authorized the version to be submitted for final approval.

2- Mostafa A. Abbas Atta was responsible for data interpretation and article writing.

3-Ahmed K. Sharaf collected the data and performed the statistical analysis of the data.

4-Anhar Elhanafy carefully revised the article and examined it for significant intellectual content.

Disclosures and declarations:

1. A statement on the welfare of animals and approval of our study-specific procedures by the relevant ethical committee of the Egyptian Atomic Energy Authority for animal research.

2-Our research that was submitted for publication has no impact on public health or general welfare.

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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 (8 calves)	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(8 calves)	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 (8 calves)	85.5 (80<)			Very severe heat stress

The Farm's natural conditions at midday were recorded four times on average every month for each value of air temperature and relative humidity.

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

Traits	Temperature-humidity index (THI)				
	Low THI (68.1±0.97) (Winter season)	Moderate THI (74.9±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.5±1.3) (Summer season)	[2]Change due to high THI
Initial BW	100.0±0.31	100.0±0.38	---	100.0±0.33	---
Final BW	153.00±0.27	143.10±0.35	-6.47 (P<0.05)	131.14±0.45	-14.29 (P<0.05)
Total gain	53.00±0.46	43.10±0.38	-18.68 (P<0.05)	31.14±0.45	-41.25 (P<0.01)
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)
WC (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].

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 (68.1±0.97) (Winter season)	Moderate THI (74.9±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.5±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].

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

Traits	Temperature-humidity index (THI)				
	Low THI (68.1±0.97) (Winter season)	Moderate THI (74.9±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.5±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].

Table 5 Blood biochemical components in calves with the response of various THI values

Traits	Temperature-humidity index (THI)				
	Low THI (68.1±0.97) (Winter season)	Moderate THI (74.9±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.5±1.3) (Summer season)	[2]Change due to high THI
Total proteins (g/dl)	8.13[a]±0.09	7.80[a]±0.06	- 4.06 (P>0.05)	6.90[b]±0.06	- 15.1 (P<0.05)
Glucose (mg/dl)	87.20[a]±2.0	83.00[a]±1.4	- 4.80 (P>0.05)	74.90[b]±0.8	- 15.7 (P<0.05)
Urea-N (mg/dl)	36.60[c]±0.8	43.30[b]±1.9	+18.30 (P<0.05)	60.10[a]±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].

Table 6 Physiological parameters in calves with the response of various THI values

Physiological parameters	Temperature-humidity index (THI)				
	Low THI (68.1±0.97) (Winter season)	Moderate THI (74.9±2.7) (Spring season)	[1]Change due to moderate THI	High THI (85.5±1.3) (Summer season)	[2]Change due to high THI
Respiration rate (rpm)	32.79 ±1.3	38.19 ±1.9	+16.47 (P<0.05)	48.66±2.3	+48.40 (P<0.001)
Rectal temperature (°C)	38.44 ± 0.05	39.26 ± 0.04	+2.13 (P<0.05)	40.56±0.03	+5.52 (P<0.001)
Skin temperature (ºC)	37.25 ± 0.03	38.07 ± 0.02	+2.20 (P<0.05)	39.50±0.02	+6.04 (P<0.001)

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].

Table 7 CorrelatiEons 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. P. (g/dl)								+0.874	-0.927
Glucose(mg/dl)									-0.928

All correlation coefficient values are significant at P<0.01.