Comparison of different temperature-humidity index as heat stress indicator in crossbred dairy calves in a tropical environment

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Abstract: The Temperature Humidity Index (THI) was first used to evaluate human beings and later it was adapted to be used in production animals, especially dairy cows. The efficiency of this index is not known for dairy calves, especially the crossbred ones. The aim of this study was to compare different equations of temperature-humidity index as heat stress indicator in crossbred dairy calves in tropical environment. Twenty-seven crossbred dairy calves, males and females, housed in Argentine model's calf, were evaluated to respiratory rate, rectal temperature and surface body temperature on 2nd, 15th, 30th and 60th days of live, totalizing 108 observations. The environment was evaluated at the moment of each animal data collection and the dry bulb temperature and wet bulb temperature were recorded, and used to estimate relative humidity, partial air vapour pressure and dew point temperature. Nine different equations of temperature-humidity index were calculated. ANOVA followed by Tukey test of mean comparison with 5% of significance and Pearson correlation analysis were performed using the Action program. Respiratory rate, rectal temperature and surface body temperature did not differ between the ages. Only in 4.62% of the observations calves had a respiratory rate between 60 to 80 movements per minute, which represents a moderate heat stress, and in 5% of the observations calves had a rectal temperature above 39.5 °C, indicating that they were not able to maintain homeothermy. In 25% of the observations presented smaller gradients between surface body temperature and environmental temperature, indicating that in 75% of observations the convective heat loss was favored. The average temperature (21 °C) was near the maximum temperature recommended to dairy calves of European origin, which ranges of 5 °C to 20 °C, but the thermal comfort temperature is not known for crossbred dairy calves in a tropical environment. The majority mean values of THI indicated a comfort situation. The correlation of dry bulb temperature and the physiological parameters was positive and significant. The respiratory rate and surface body temperature had a significant and positive correlation with the temperature humidity indexes. The correlations of physiological data with THI sensible heat-based were higher than the others. The THI sensible heat-based is the equation that better represents the comfort situation of crossbred dairy calves in a tropical environment.

Keywords: dairy cattle, thermal index, THI.

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Introduction

The Temperature Humidity Index (THI) was developed by Thom (1959) to evaluate human beings and later it was adapted to be used in production animals. THI equations can take into account the dry bulb temperature (T_{db}), wet bulb temperature (T_{wb}), dew point temperature (T_{dp}) or relative humidity (RH) (BERMAN et al., 2016).

Calculation of THI has the main advantage of temperature and humidity records can be usually obtained in the farm or from a meteorological station located nearby instead of data from thermal radiation received by the animal and wind speed that are not publicy available and more difficult to the producer record (BOHMANOVA et al., 2007).

There are a lot of researches studying THI as indicator of milk production losses in lactation cows, or the malefic effects of heat stress on reproduction, but the efficiency of this index is not known for dairy calves, especially the crossbred ones. Calf rearing has to be treated as one of the most important activities in the farm because the continuing of the production system will depend on the availability of calves to the renewing of herd.

The aim of this study was to compare different equations of temperature-humidity index as heat stress indicator in crossbred dairy calves in tropical environment.

Material and Methods

The experiment was conducted at the Gloria Experimental Farm of the Federal University of Uberlândia (18° 56’ 56” S and 48° 12’ 47” W and 925 m altitude) from August 2016 and March 2017, this region has a dry, cold and with low rainfall intensity winter, while the summer is hot and rainy. Twenty-seven dairy crossbred calves, males and females, housed in Argentine model’s calf were evaluated on 2nd, 15th, 30th and 60th days of live, totalizing 108 observations.

During the mornings (between 7:30 to 8:30 a.m.) of each day of evaluation the respiratory rate of the animals were monitored by the observation of respiratory movements per minute, the rectal temperature was recorded with a clinic digital thermometer and the surface body temperature was recorded with an infrared digital thermometer (Instrutherm TI-550).

The environment was monitored at the moment of each animal data collection. Dry bulb temperature (T_{db}) and wet bulb temperature (T_{wb}) were recorded with analogic thermohygrometer (Incoterm), and used to estimate relative humidity (RH), partial vapour pressure (P_v) and dew point temperature (T_{dp}), and the wind velocity was measured with an anemometer (Instrutherm AD-250).

Nine equations of temperature-humidity index (THI) were calculated, and all the temperatures were in degree Celsius, as follows:

$$\text{THI 1} = 0.4 \text{ x } (\text{Tdb} + \text{Twb}) \text{x } 1.8 + 32 + 15 \text{ (Thom, 1959)}$$

$$\text{THI 2} = \text{Tdb} + (0.36 \text{ x Tdp}) + 41.2 \text{ (Yousef, 1985)}$$

$$\text{THI 3} = (0.8 \text{ x Tdb}) + (\text{RH} / 100)\text{x } (\text{Tdb} - 14.4) + 46.4 \text{ (Mader et al., 2006)}$$

$$\text{THI 4} = (\text{Tdb x } 0.15 + \text{Twb x } 0.85) \text{ x } 1.8 + 32 \text{ (Bianca, 1962)}$$

$$\text{THI 5} = (\text{Tdb x } 0.35 + \text{Twb x } 0.85) \text{ x } 1.8 + 32 \text{ (Bianca, 1962)}$$

$$\text{THI 6} = 0.72 \text{ x } (\text{Tdb} + \text{Twb}) + 40.6 \text{ (NRC, 1971)}$$

$$\text{THI 7} = (1.8 \text{ x Tdb} + 32) - [(0.55 - 0.0055 \text{ x RH}) \text{ x } (1.8 \text{ x Tdb} - 26.8)] \text{ (NRC, 1971)}$$

$$\text{THI 8} = (0.55 \text{ x Tdb} + 0.2 \text{ x Tdp}) \text{ x } 1.8 + 32 + 17.5 \text{ (NRC, 1971)}$$

$$\text{THI sensible heat} - \text{based} = 3.43 + 1.058 \text{ x Tdb} - 0.293 \text{ x RH} + 0.0164 \text{ x Tdb x RH} + 35.7 \text{ (Berman et al., 2016)}$$

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Maximum and minimum values, mean and standard deviation was estimated to each variable. It was performed an ANOVA followed by Tukey test of mean comparison with 5% of significance. Then, Pearson correlation analysis was performed. All analyses were performed using the Action program that is descripted by Ayres et al (2007).

Results and Discussion

Respiratory rate, rectal temperature and surface body temperature did not differ between the ages ($p>0.05$). The basal respiratory rate of bovines is about 20 breaths per minute and between 60 to 80 movements per minute the animal is under moderate heat stress (SILANIKOVE, 2000). During the experiment the average respiratory rate was 40 movements per minute (Table 1), and in only 4.62% of the observations calves had a respiratory rate between 60 to 80 movements per minute.

The rectal temperature in dairy cattle ranges from 38 °C to 39.3 °C, indicating that animals with temperatures above 39.4 °C are not able to maintain homeothermy because of the insufficiency of the mechanisms of heat release (COSTA et al., 2015). In this study only in 5% of the observations calves had a rectal temperature above 39.5 °C, the average of rectal temperature was 38.6 ºC (Table 1).

Table 1: Descriptive statistics of calves’ physiological measurements, environment data and THI

Variables	Mean	SD	Minimum	Maximum
Respiratory rate (movements/minute)	40	10	20	80
Rectal temperature (ºC)	38.6	0.4	38.0	39.9
Surface body temperature (ºC)	27.5	3.7	16.8	36.6
T_{db} (ºC)	21	2	11	26
T_{wb} (ºC)	17	2	7	22
RH (%)	74	16	35	91
P_v (k.Pa)	1.87	0.5	0.74	2.57
T_{dp} (ºC)	18	4	3	24
Wind velocity ($m.s^{-1}$)	1.17	0.9	0	5
THI 1	75.2	3.5	59.9	80.8
THI 2	69.0	3.5	53.3	74.8
THI 3	68.4	3.6	53.3	74.6
THI 4	65.2	4.9	45.6	72.4
THI 5	66.4	4.6	47.1	73.5
THI 6	68.8	3.5	53.6	74.4
THI 7	68.5	3.6	53.5	74.7
THI 8	77.1	3.6	61.5	82.8
THI sensible heat-based	65.6	5.2	44.4	74.6

T_{db}:dry bulb temperature, T_{wb}: wet bulb temperature, RH: relative humidity, P_v: partial vapour pressure, T_{dp}: dew point temperature, THI: temperature humidity index.

The environment temperature below the surface body temperature favors the convective heat loss. When the gradient of surface body temperature and environmental temperature decreases, the convection heat loss also decreases (SOUZA JUNIOR et al., 2010). In this study, only in 25% of the observations

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presented smaller gradients between surface body temperature and environmental temperature, indicating that in 75% of observations the convective heat loss was favored.

The average temperature (Table 1) was near the maximum temperature recommended by NRC (2001) for dairy calves of European origin, which ranges of 5 °C to 20 °C. But the thermal comfort temperature is not known for crossbred dairy calves in a tropical environment.

Temperature humidity index is classified into classes that indicates level of heat stress (BOHMANOVA et al., 2007). However, there are different classifications between authors. Thom (1959) categorized THI as 70 to 74 uncomfortable, 75 to 79 very uncomfortable and above 80 serious discomfort. Huhnke et al. (2001) divided THI into two categories: 79 to 83 dangerous situation and above 84 emergency situation. Costa et al (2015) categorized as less than 70 indicate thermal comfort , 70 to 72 is alert state , 72 to 78 is critical, 78 to 82 is danger and above 82 is emergency state. Except for the mean values of THI 1 and 8 all of the others THI mean values (Table 1) indicated a comfort situation.

Table 2: Correlation coefficients between environment and physiological data from crossbred dairy calves

Environment	Respiratory rate	Rectal temperature	Surface body temperature
Tdb	0.28 **	0.24 **	0.60 **
Twb	0.12 ns	-0.05 ns	0.30 **
RH	-0.13 ns	-0.31 **	-0.20 *
Pv	0.05 ns	-0.16 ns	0.16 ns
Tdp	0.04 ns	-0.15 ns	0.15 ns
Wind speed	-0.17 ns	-0.03 ns	-0.19 *

T_{db}:dry bulb temperature, T_{wb}: wet bulb temperature, RH: relative humidity, P_v: partial vapour pressure, T_{dp}: dew point temperature.
*p < 0.05. **p < 0.01. ns: non-significant.

The correlation of dry bulb temperature and the physiological parameters was positive and significant, being the correlation with surface body temperature higher than the others (Table 2). This indicates that rising in temperature will increase the values of physiological parameters of crossbred dairy calves.

Table 3: Correlation coefficients between THI and physiological data from crossbred dairy calves

Index	Respiratory rate	Rectal temperature	Surface body temperature
THI 1	0.21 *	0.10 ns	0.48 **
THI 2	0.25 *	0.10 ns	0.48 **
THI 3	0.25 **	0.14 ns	0.54 **
THI 4	0.14 ns	-0.01 ns	0.35 **
THI 5	0.18 ns	0.05 ns	0.43 **
THI 6	0.21 *	0.10 ns	0.48 **
THI 7	0.26 *	0.15 ns	0.55 **
THI 8	0.21 **	0.10 ns	0.48 **
THI sensible heat-based	0.28 **	0.19 ns	0.58 **

THI: Temperature Humidity Index.
*p<0.05. **p < 0.01. ns: non-significant.

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Respiratory rate and surface body temperature had a significant and positive correlation with the temperature humidity indexes (Table 3). However all the correlations of physiological data with THI sensible heat-based was higher than the others indexes correlations, indicating that this index represented better the comfort and discomfort situations that the calves were exposed.

Conclusions

The THI sensible heat-based is the equation that better represents the comfort situation of crossbred dairy calves at the tropical environment.

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