Biotechnology in Animal Husbandry 34 (2), p 159-170 , 2018
Publisher: Institute for Animal Husbandry, Belgrade-Zemun
ISSN 1450-9156
UDC 636.083.6
https://doi.org/10.2298/BAH1802159B

ENVIRONMENTAL SOURCE OF STRESS IN LIVESTOCK PRODUCTIVITY – A STUDY OF MINNA CLIMATE DATA

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Original scientific paper

Abstract: Stress emanating from environment is a factor limiting livestock productivity in the Tropics because of elevated temperature year round; hence this study took a look at Minna climate data for evaluation of Temperature-Humidity-Index (THI) as a way of identifying climate source of stress on livestock production. Climate Normals for Minna between years 1961 and 2018 were obtained, and the data were analyzed using general formulae for calculating Temperature-Humidity-Index for livestock production. Relationships between production parameters on commercial farms and the THI data indicated that heat stress is a potential cause of oxidative stress in the area. The THI showed that the environmental conditions in the study area has potential for heat stress on animals, and that it can aggravate oxidative stress in livestock under production in the study area, hence there is need for further studies to identify the pathophysiological mechanisms of heat stress so as to develop mitigation strategies for improved animal performance and productivity. The study suggested that instead of the penchant for importing exotic breeds of livestock with the aim of upgrading the indigenous breeds, the way forward could be the utilization of genetic expression of heat and oxidative stress genes in animals as candidate markers for improvement of their productive potentials.

Keywords: Temperature-Humidity-Index, Heat Stress, Oxidative Stress and Animal Productivity

Introduction

Temperature-Humidity-Index (THI) is an indicator for determining temperature comfort zone which integrate the relative effects of temperature and humidity for optimum livestock performance and productivity. It also has to do with environmental temperature and heat generation as factors controlling energy metabolism and exchange; hence avoidance of its extremes above and or below comfort zone, can influence animal health and production because it is also a measure of the relationship between environmental temperature and animal thermoregulatory status. The application of THI has been used for determination of comfort zones for humans and different livestock species including dairy cattle, swine, turkeys, laying hens, broilers and rabbits *(Ogunjimi et al., 2008; Joseph et al., 2014; Behura et al., 2016*). An evaluation of THI is a contribution for identification of the suitable environmental conditions under which animals will not be susceptible to oxidative stress damage which is a leading biochemical consequence of heat stress. Therefore, this study obtained climate data of Minna for evaluating THI and determine heat stress conditions under which animals can be produced in the area for prevention of oxidative stress damage and establishing basis for use of antioxidants in animal production operations in the study area.

Materials and Methods

Minna climate data for years between 1961 and 2018 were obtained from National Oceanic and Atmospheric Administration (*NOAA*, *2016*). Data on parameters including mean monthly temperature, relative humidity and dew points temperature from these sources were compare with data of Nigeria Metrological Agency (NIMET) for Minna. From these data, Temperature-Humidity-Index (THI) was calculated on monthly basis for cattle and rabbits using the formulae i and ii, respectively:

$$THI = t + (0.36 \times Dt) + 41.2 \quad \text{.......................................} \ i$$

(**Source:** *Dairy Australia, 2016*)

Where t = dry bulb temperature (^oC), Dt = dew point temperature (^oC)

$$THI = t - \left[\left(0.31 - 0.31 \left(\frac{RH}{100} \right) \right) (t - 14.40) \right] \quad \text{..................} \ ii$$

(**Source:** *Marai et al., 2001*)

Where t = dry bulb temperature (^oC), RH = Relative Humidity (%)

Production data for a period of 21 months were obtained from a commercial dairy farm located in Minna. The farm operate an intensive livestock production management where 250 heads of dairy cattle are being kept. The cattle include 50 Holstein Friesian – HF cows, 150 Red Holstein – RH cows, and 50 Cross Bred – CB cows (crosses of Nigeria indigenous cattle and Holstein Friesian and Red

Holstein). The data obtained were used to determine average production and performance of the cattle. Descriptive relationships were further established between the production performance and the THI determined for the study area.

Results and Discussion

From the available dataset monthly Temperature-Humidity-Index (THI) values for Minna were determined using the equations above and are presented in the Table 1 and Figure 1. Average highest monthly environmental temperature occurs annually in the month of March (33.65 ^{o}C) while the lowest environmental temperature occur annually in the month of August (27.02 ^{o}C). Highest dew point temperature occurs during the month of July (19.70 ^{o}C) while the lowest dew point temperature occurs during month of February annually. The highest Temperature-Humidity-Index occurs annually in the month of April which followed the month having the highest environmental temperature while the lowest Temperature-Humidity-Index occurs annually in the month of January.

Table 1. Monthly Temperature-Humidity-Index (THI) values of Minna (Cattle)

Months	TEMP	DP	RH	THI
Jan	31.15	5.20	24.00	74.22
Feb	33.05	4.70	21.00	75.94
Mar	33.65	10.70	30.00	78.7
Apr	32.30	15.40	44.00	79.04
May	30.05	18.30	58.00	77.83
Jun	28.35	19.20	66.00	76.46
Jul	27.30	19.70	72.00	75.59
Aug	27.02	20.00	73.00	75.42
Sep	27.45	19.10	70.00	75.52
Oct	29.15	18.40	62.00	76.97
Nov	30.65	11.80	39.00	76.09
Dec	30.70	6.70	28.00	74.31

TEMP –Temperature, **DP** – Dew Point Temperature, **RH** – Relative Humidity

The result showed that animals are always under stressful condition throughout the year in the study area going by the classification of *Kulkarni et al. (2017)* which stated that THI values in degree Fahrenheit below 70 is No stress, THI values between 70 and 75 is Mild Stress, THI values between 76 and 80 is Semi-Moderate Stress, THI values between 81 and 85 is Moderate Stress and THI values between 85 and 90 is Severe Stress. This also agrees with the THI classification reported by *Ogunjimi et al. (2008),* that THI values in degree celcius below 27.8 is no stress, 27.8 to 28.9 is moderate stress, 29 to 30 is severe stress and above 30 is very severe stress.

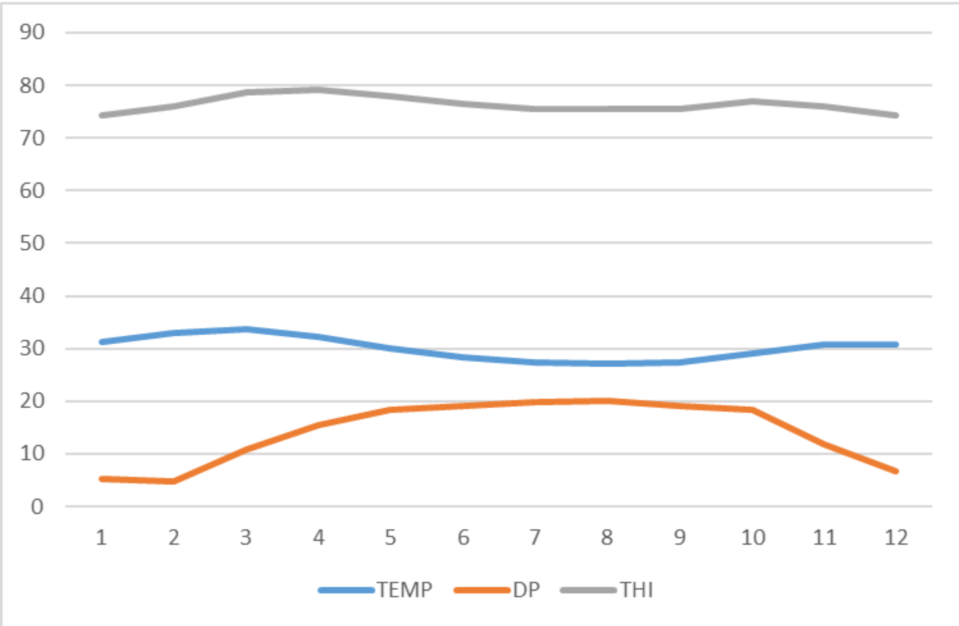

Figure 1. Monthly Temperature (TEMP), Dew Point temperature (DP) and THI (in ^{o}F)

Values of the THI as revealed in this study showed that throughout the year, heat stress is a potential threat to dairy cattle productivity because according to guidelines of heat stress management by Dairy Australia (2016), when the THI exceeds 72, cows are likely to begin experiencing heat stress and their in-calf rates will be affected. When the THI exceeds 78, milk production is seriously affected and when the THI rises above 82, very significant losses in milk production are likely, cows will show signs of severe stress and may ultimately die.

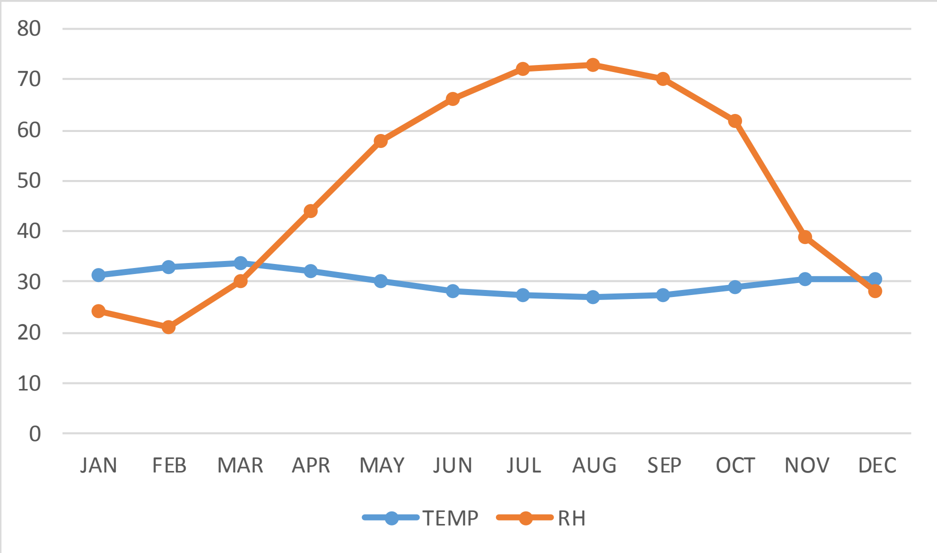

Figure 2. Monthly mean temperature and relative humidity of the study area

The relationship between temperature and relative humidity using the trends between January and March (Figure 2) annually confirmed that the period can be described as the safest time for animals in the study area. This is an indication that the THI analysis done in this study is correct and gives an understanding of heat stress condition of Minna as it affect animal performance and productivity. Although the temperature is still high, but because the relative humidity is lower than 40 % hence the THI indicated mild stress. This biologically can be confirm through performance and production capacities of animals under traditional management in the study area. Livestock in this area including cattle, sheep and goats mostly give birth to younger ones during this period which is a natural biological response of the animals to environmental challenge of heat stress.

Production and performance data obtained from the commercial dairy farm located in the study area gave an average monthly milk production for Holstein Friesian (HF) as 240.50 litres, Red Holstein (RH) as 454.80 litres and Crossbred (CB) as 123.50 litres. Gestation length was 9 months for all the breeds while conception rates upon artificial insemination were 50 % for HF, 70 % for RH and 50 % for CB; culling rates were 90 %, 35 % and 10 % for the HF, RF and CB respectively as well as other performance and production parameters as presented in Table 2.

Table 2.Monthly production and performance of dairy cattle on commercial dairy farms in the study area

Breeds	Average monthly milk production (Litre)	Conception rates (%)	Calving rate (%)	Culling rate (%)
Holstein Friesian	240.50	50.00	45.00	90.00
Red Friesian	454.80	70.00	65.00	35.00
Crossbred	123.50	50.00	70.00	10.00

From the analysis of the THI for the study area, it showed that there exist a direct positive relationships between monthly mean temperatures and the monthly THI. The higher the monthly mean temperature, the higher the THI as presented in Figure 3 and Figure 4. A similar relationship also exist between dew point temperature and the THI; as the dew point temperature increases, so the THI increases. Biological confirmation of these relationships can be deduced from performance of the dairy cattle on a commercial dairy farm located in Minna as presented in Figure 3. The figure showed that the THI is high and constant throughout the year and this can be linked to the reasons why milk production of the cattle was low.

From 21 months lactation records obtained from the commercial dairy farm; it is possible to deduce that production and performance parameters of the exotic cattle were poor which can be linked to environmental stressors such as oxidative stress on the animals. Holsteins are high performing dairy animal worldwide but their reproductive and productive performance in Tropical countries are always different from their achievable performance in Europe. What was obtained as mean daily milk production for the cattle as presented in Table 2 is similar to daily milk production of 8.38 litres reported by *Haftu (2015)* for Holstein cattle in Ethiopia. It is also similar with what was reported for Holsteins in Sudan as reported by Abdel *Rahman and Alemam (2008).*

However, these breeds are reported as excellent dairy cattle because of their superior genetic composition which is a reason why their choice for upgrading of indigenous cattle is a common livestock improvement practices (*Ogundipe and Adeoye, 2013).* Therefore, harsh environmental conditions such as high and unbearable THI and other different climatic conditions rather than poor management systems could be responsible for the poor production as revealed in this study. Confirmation of this observation is higher milk yield recorded (35 litres per day) in an experimental unit on the commercial farm where temperature control was carried out (18 ^{o}C – 20 ^{o}C); it is however unsustainable for the farm to run such facilities for full scale production considering associated cost.

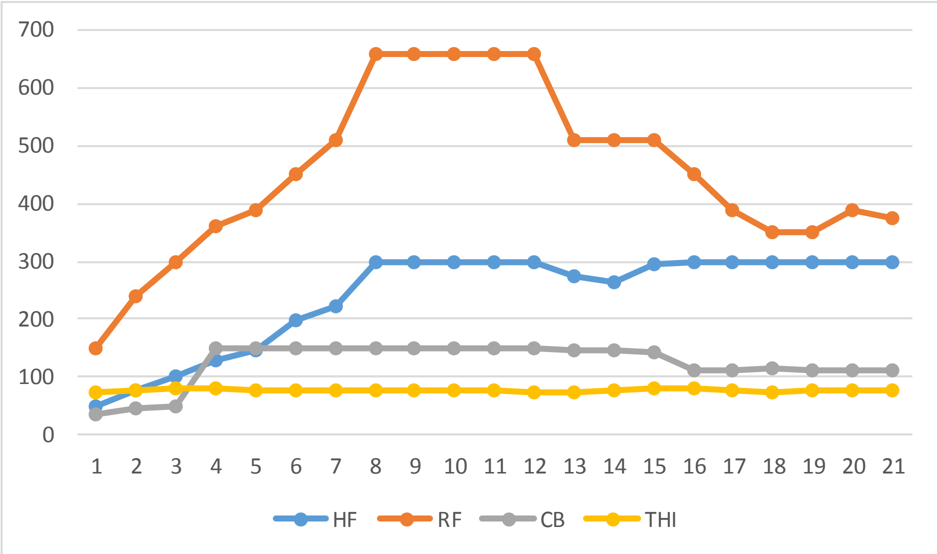

Figure 3. Monthly milk production of dairy cattle and relative THI of Minna

The relationship between monthly THI and corresponding milk production by the cattle showed that the THI negatively affected milk production capacity of the cattle. From Figure 3 above, it can be deduced that crossbred cattle from the exotic breeds and the indigenous cattle breed have highest tolerance to the effect of THI because despite the THI constantly being high, the milk production of the crossbred remained relatively constant except by the 16th month which correspond with April of the second year of production when the production level drops and remained unchanged till the 21st month. Ability of the crossbred to display this tolerance is not far-fetched from the adaptation of the local breed used for the crossing (White Fulani) to the environmental conditions obtainable in Minna. This is further expressed in the high calving rate (70 %) and low culling rate (10 %) of the crossbred. This means that in spite of the consistently high THI, there is strong capability of the crossbred to survive which confers an added advantage for it over both imported breed.

This is a pointer that with careful selective breeding, the indigenous White Fulani cattle can be made to improve on its milking capacity. If farmers must import, then it should be semen for artificial insemination as keeping imported animals has implication on production cost. This is because, there will then be the need to engage in microclimate ameliorative practices. The high culling rate and lover calving rate when compare to the crossbred makes keeping the exotic breed *in-situ* on the farm uneconomical.

In rabbit production, elevated level of THI correspond with higher heat and moisture production especially in mature rabbits. Hence, to maintain optimum rabbit production in the study area maintenance of THI value below 27 ^{o}C will be optimum for rabbit as calculated using the Livestock Production Heat Stress Indices (*LPHSI, 1990*) formular which was reportedly modified for rabbit by *Marai et al. (2001)* is a must in order to provide comfortable environment for the animal. Following recommendations of *Ogunjimi et al. (2008)*, physiological and productive conditions of rabbits are both susceptible to heat stress because under heat stress condition, there is reduced feed intake and continuous use of Metabolizable Energy (ME) for non-productive activities such as panting and faster respiration rates for the purpose of survival (*El-Raffa, 2005; Ogunjimi, 2007*) which shows that environmental conditions in the study area as presented in Table 3 is not too suitable for rabbit production without modifications.

Table 3. Monthly Temperature-Humidity-Index (THI) values of Minna (rabbit)

Months	TEMP	DP	RH	THI
Jan	31.15	5.20	24.00	27.20
Feb	33.05	4.70	21.00	28.49
Mar	33.65	10.70	30.00	29.49
Apr	32.30	15.40	44.00	29.19
May	30.05	18.30	58.00	28.00
Jun	28.35	19.20	66.00	26.87
Jul	27.30	19.70	72.00	26.17
Aug	27.02	20.00	73.00	26.00
Sep	27.45	19.10	70.00	26.23
Oct	29.15	18.40	62.00	27.61
Nov	30.65	11.80	39.00	27.80
Dec	30.70	6.70	28.00	27.05

TEMP –Temperature, **DP** – Dew Point Temperature, **RH** – Relative Humidity

In Figure 6 below, it showed that only four months of the year is when the THI was below 27.00 (June – September) which is an indication that for excellent performance of rabbit in the study area, antioxidative management practices such as the use of antioxidant diets and drugs, modification of housing to encourage cross ventilation and care for animals to ameliorate stress conditions are highly important husbandry practices.

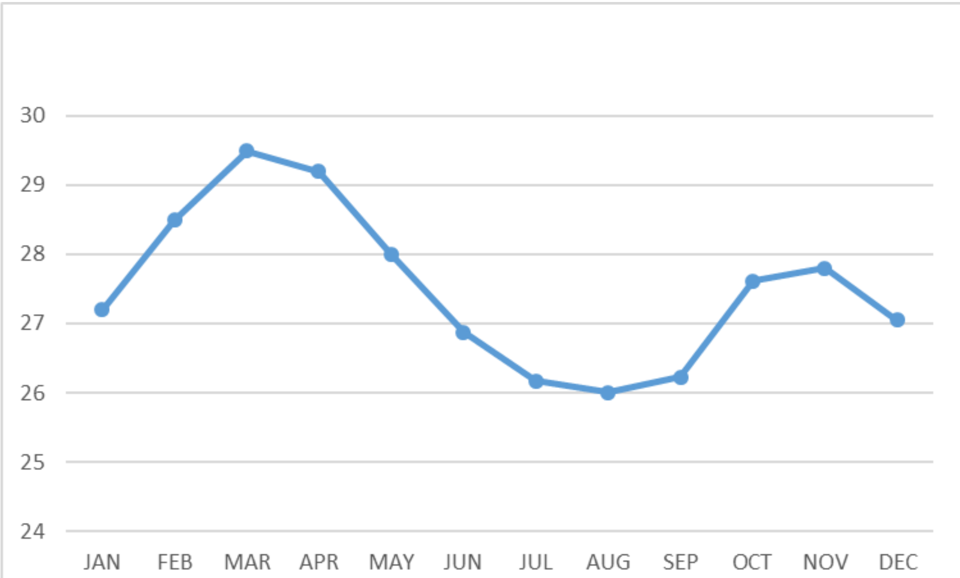

Figure 6: Monthly temperature-humidity-index for rabbits using climate data of Minna

Exposure to heat stress could lead to poor growth and reproduction because it decrease live weight gain, daily weight gain, feed intake, litter size at weaning, pre and post weaning weight gain in rabbits. In fact under heat stress, conception rates, overall nutrients digestibility as well as productivity loss is associated with incidence of heat loss in rabbit. Production loss involving conception rates, pre – weaning mortality of rabbit kits, litter weight at weaning are reported to be 70 % in a reproductive cycle of rabbit doe. This represent huge economic loss requiring multidimensional solution in housing, animal care and handling, nutrition and health management for a rabbit enterprise to be profitable (*Marai et al., 2001*).

Conclusion

Analysis of basic climate data between years 1961 and 2018 for Minna revealed that for most part of the year (nine months), animals in the study area live under heat stress and hence their potential for food production is under threats thereby contributing to food insecurity. Plans for improving animal productive performance should form basis for livestock production research in the area. Environmental modifications including cooling systems or modifications of housing facilities may not be the only feasible approaches to heat stress management in the study area considering associated costs. As a result, nutritional manipulations that promote animal health and production capacities is suggested as additional option worthy of exploration. Instead of the penchant for importing exotic breeds of livestock with the aim of upgrading the indigenous breeds, the way forward could be the utilization of the heat shock protein of the animals as candidate markers for improvement of their productive potentials. Further research is suggested to investigate pathophysiological mechanisms of heat stress for the purpose of determining appropriate mitigation measures for management of heat stress in the study area.

Ekološki izvor stresa u stočarstvu - studija o klimatskim podacima za Minu

Sikiru Akeem Babatunde, Egena Sunday Sunday Acheneje, Alemede Iyabo Comfort, Makinde Olayinka John

Rezime

Stres koji proizilazi iz okoline je faktor koji ograničava produktivnost stoke u tropskim predelima zbog povišene temperature tokom cele godine; stoga ova studija predstavlja pregled podataka o klimatskim promenama za Minu u smislu procene indeksa temperature i vlažnosti (Temperature-Humidity-Index, THI) kao način identifikacije klimatskog stresa i njegovog uticaja na proizvodnju u stočarstvu. Dobijene su klimatske norme za Minu između godina 1961. i 2018. godine, a podaci su analizirani korišćenjem opštih formula za izračunavanje THI indeksa za stočarsku proizvodnju. Odnosi između proizvodnih parametara na komercijalnim farmama i THI podaci pokazali su da je stres toplote potencijalni uzrok oksidativnog stresa u toj oblasti. THI je pokazao da uslovi životne sredine, koji su postojali tokom istraživanja, imaju potencijal da izazovu toplotni stres kod životinja i da mogu pogoršati oksidativni stres kod stoke u proizvodnji u području istraživanja, stoga postoji potreba za daljim istraživanjima za identifikaciju patofizioloških mehanizama toplotnog stresa kako bi se razvile strategije ublažavanja radi ostvarivanja poboljšanih performansi i produktivnosti životinja. Studija je pokazala da umesto želje za uvozom egzotičnih rasa stoke u cilju oplemenjivanja autohtonih rasa, napredak bi mogao da se ostvari korišćenjem

genetske ekspresije gena za toplotni i oksidativni stres kod životinja kao marker kandidata za poboljšanje njihovog proizvodnog potencijala.

Ključne reči: indeks temperature i vlažnosti, toplotni stres, oksidativni stres, produktivnost životinja

Acknowledgement

The authors will like to acknowledge and thank the management of commercial farms visited during the course of this study especially Maizube Farms Ltd., Minna.

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Received 18 April 2018; accepted for publication 2 June 2018