

Different Types of Heat Tolerance Indices Used in Dairy Production

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Abstract

Livestock production is affected by several factors such as environmental factors, physiological adaptations and physical characteristics of livestock. Environmental factors include temperature, humidity, solar radiation and speed of the wind. Physiological adaptations mainly concern the ability of livestock to resist environmental extremes by the means of vital parameters of the body such as rectal temperature, heart rate, and respiration rate. Physical characteristics involve body surface area, the density of sweat glands and bodycoat. The climate of a particular region mainly influences animal production and performance. In tropical areas due to high temperature and sunlight, heat tolerance indices are key in livestock production and management. Major indicators of heat stress in animals are variations in body temperature, respiration rate and heart rate. Consequently, changes in blood parameters also occur due to heat stress in form of loss of water and ion. The respiratory, circulatory, excretory, endocrine and nervous system coordinate in such a way that heat stress can be resisted which in turn may be called heat tolerance. Heat tolerance is the ability to neutralize the effect of heat stress on the body. Information regarding heat tolerance is very essential in selecting breeds for a specific region and in turn, contributes better to the production aspect of livestock. Several indices were developed to determine of

heat tolerance of animals keeping in view the accuracy of measurement and changing environmental conditions.

Key words : heat tolerance, dairy, livestock

Assessing heat tolerance level in a dairy herd:

Direct measures of the ability in dairy animals to reproduce, produce, and survive under heat-stressing conditions have been identified as a potentially useful method of selecting animals for heat-stress tolerance in hot regions.^[1-2] Heart rate, respiration rate, body temperature, and rectal or vaginal temperatures are some of the physiological parameters used. However, the collection of the parameters requires restraint and handling procedures which may cause an experimental error due to additional stress given to the animal. The manual recording to collect the physiological parameter is labour-intensive, especially in a commercial setup and this might result in more operator error and injuries to the animal^[3]. In recent days, thermographic images using infrared thermography (IRT) are a great alternative to measuring the body temperature of an animal. Intra-ruminal sensors are also introduced in organized dairy farms for taking the body temperature of ruminants.

Measures of heat tolerance in dairy herds:

Temperature-Humidity Index as a measure of heat tolerance level in a dairy herd

Temperature-humidity Index (THI)^[4] is a value that combines the effect of temperature and humidity. This index is usually understood in simple terms as the effect on the body of an animal noted by the change in temperature and

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humidity of the atmosphere. Also known as the discomfort index. Calculation of THI involves various formulae which are given as under:

$$THI = 0.4 \times (T_{db} + T_{wb}) \times 1.8 + 32 + 15$$

$$THI = 0.35 \times (T_{db} + 0.65 \times T_{wb}) \times 1.8 + 32 \quad [5]$$

$$THI = (1.8 \times T_{db} + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T_{wb} - 26.8)] \quad [6]$$

$$THI = (T_{db} + 0.36 \times T_{wb}) + 41.2 \quad [7]$$

$$THI = (0.81 \times \text{dry bulb temperature, } ^\circ\text{C}) + (\text{relative humidity}/100) \times (\text{dry bulb temperature} - 14.4) + 46.6 \quad [8]$$

$THI = 0.72(T_{db} + T_{wb}) + 40.6$ (NRC, 1971), where T_{db} = dry bulb temperature & T_{wb} = wet bulb temperature.

THI Value	Heat stress zone
<72	Comfortable
73-80	Moderate heat stress
>80	Severe heat stress
>98	Mortality

For animals to be in a comfortable state, the optimum THI should be 73.67 for crossbred cattle, 74.37 for buffalo and 75.12 for indigenous cattle.

The ability to Zebu cattle have the highest heat tolerance, followed by crossbred and exotic cattle.

The use of THI is the most standard and practical method for application in animals especially dairy herds [9]. However, there is a lag in research on heat tolerance levels as far as THI is concerned. The temperature and humidity records can be accessed easily from meteorological weather stations. Measurements from the wet and dry bulb thermometers are used in the calculation of the THI index which is utilized as an estimate of heat stress. The merit of this method is that it can be convenient to perform as no laborious work is required and also due to no stress induced by animal handling the error in heat tolerance estimation is less. The main demerit of this method is the lack of consideration of sunshine and wind speed in calculating values.

Hierarchical Bayes model as a measure of heat tolerance level

The Hierarchical Bayes model (HBM)[10] is a method of measuring tolerance to heat stress among dairy cows with differing responses to a rise in ambient temperature. By the use of the regression model, we can easily arrive at the heat tolerance by comparison of additive genetic variance for tolerance to heat stress by phenotypic regression of the performances after the comfort threshold. The assumption here is that the cows have the same threshold and the extent of the decline indifferent places and overtime. The hierarchical Bayes model (HBM) defines the animal’s level of tolerance to heat stress as the extent of decrease in performance by a cow beyond an unknown THI threshold and THI value at which a decrease in performance begins due to heat stress[11]. The merit of this method is fewer chances of error since the regression model is taken into consideration. Demerit includes very complex to perform and needs expert intervention.

Infrared thermography for heat tolerance determination in dairy cattle

In this method, rectal temperature, respiration frequency and heart rate are recorded. The panting score is taken into consideration having a 0 to 4 scale[8]. Now THI is going to be calculated by the formulae[11]. Before image collection animals should be taken immediately to the shaded area to prevent solar radiation interference. Images of each animal are taken: at the right and left area of the animal (right area), eye, lateral region of the udder, posterior region of the udder and right forelimb region in the posterior foot. Images should be taken at a distance of approximately 1.5m from the animal, in the same area of each region evaluated, using the same distance and without the incidence of solar radiation. Quick report software is used to analyze data from photos. Statistical procedures are then performed using SAS software and association between ambient temperature, relative humidity, physiological measurements and thermographic temperatures. Statistical models used in this method are useful for selecting highly heat-tolerant animals for future generations.

Blood parameters

A negative correlation between PCV, number of RBCs and Hb concentration occurs with THI which can be attributed to the haemodilution effect. Regarding heat tolerance indices the inverse relationship between the Iberia index and the number of RBCs and Hb concentration indicates that these blood constituents can be lower in the more adapted animal.

Measures of heat tolerance indices for target animals in a herd:

Iberia heat tolerance test^[12]

Animals are exposed to sunlight from 10:00 am to 03:00 pm. Rectal temperature and respiration rate were noted before and after exposure for three days under identical conditions.

HTC = 100-10 (RT-101), where HTC = Heat tolerance coefficient, RT = Avg. rectal temperature of six readings taken (°F) and $101^{\circ}\text{F} = \text{Avg. rectal temperature of cattle}$.

Inference : If the calculated value is closer to 100 then the animal is more heat tolerant than other values. If two animals have the same HTC value, then the animal having a faster respiration rate is less heat tolerant.

Merit – highly accurate as physiological parameters give a clear picture of heat tolerance.

Demerit – values may alter due to stress induced by restraining the animal.

Gaalaas heat tolerance test^[13]

Conditions for the conduction of the experiments are as mentioned above in the Iberia test.

HTI=100-14(RT-101), where HTI=Heat tolerance index, RT=Avg. rectal temperature of six readings taken (°F) & $101^{\circ}\text{F} = \text{Avg. rectal temperature of cattle}$.

Inference: Calculated value is nearer to 100 then that particular animal is more heat tolerant than others.

Benezra’s coefficient of adaptability^[14]

In this test, animals are exposed to 7 hours in clear sunlight for three days and respiration rate, rectal temperature is recorded after exposure.

BCA = RT/38.33 + RR/23, where, RT = Rectal

temperature (°C), RR = Respiration rate/min, 38.33 = Normal rectal temperature (°C), 23=Normal respiration rate/min, BCA= Benezra’s coefficient of adaptability.

Inference: The calculated value of 2 depicts maximum adaptability whereas values over 2 depict low adaptability.

Merit-More accurate as compared to Iberia and Gaalaas since respiration rate is also taken into consideration.

Demerit-Sudden weather changes may spoil experimental results.

Dairy search index^[15]

In this equal weightage is given to all three vital parameters viz. rectal temperature, respiration rate and pulse rate.

$DSI = 0.5X1/X + 0.3Y1/Y + 0.2Z1/Z$

where DSI = Dairy search index, X1 = rectal temperature after exposure, Y1=pulse rate after exposure, Z1=respiration rate after exposure & X,Y, and Z same parameters before exposure respectively.

Inference: If the calculated value is closer to one, an animal is highly heat-tolerant whereas deviation from one depicts less heat tolerance.

Merit-Highly suitable index as it includes all vital physiological parameters.

Demerit-Requires more attention since so many parameters need to be recorded.

Some other indices for heat tolerance:

R-Value/Heat tolerance test of Lee^[16]

It is also considered as laboratory equivalent of the Iberia Heat Tolerance Test. Its procedure consists of exposure of the animal to a series of atmospheric conditions at different temperatures and humidity. Simultaneously, rectal temperature is measured regularly and an expression of its mean behaviour, called the R-value is calculated. The R-value denotes the area between the x-axis and the curve in a time-rectal temperature plot. From the R-value for the different combinations of temperature and humidity, the values of the constants a, b and c are calculated using the formula:

$\text{LogR} = aT + bH + c$

Where T is the temperature and H is humidity, values of a, b and c obtained upon two different animals indicate the relative rise pattern of rectal temperature in response to atmospheric temperature for given humidity. The advantage of this test is that it is done in a controlled environment and integrated animal response.

Lines of equal effect^[16]: In this, the lines of equal effect are drawn empirically by recording separately rectal temperature, respiratory rate and respiratory volume of cattle regarding different combinations of wet and dry bulb temperature in a temperature-vapour pressure diagram. Lines change their slopes as one passes from cooler conditions to hot conditions in the same way as those obtained for humans. It is advantageous in terms that it is a very useful concept or the description of the combined effect of temperature and humidity on physiological responses. The disadvantage is that this procedure is too elaborate.

Dowling “Cooling Efficiency Test”^[18]: Since animal loses thermoregulatory control in excessive solar radiation, this test does not consider body temperature. In this test, heat tolerance is based only on an animal’s capacity for dissipating excess body heat without the complication of a simultaneous heat load from solar radiation. The procedure involves exercising the animal on a warm day for some time until the rectal temperature reaches above normal and then allowing the animal to stand in shade to cool. The rate of cooling is followed by regularly measuring rectal temperature which leads to the interpretation that the animal which shows the maximum rate of decrease of body temperature is considered to have the highest cooling efficiency.

Predicted heat tolerance from calf total moisture vaporization^[19]: This test is done for calves and its result is expressed as the ratio of total evaporation (cutaneous and respiratory) in an environment of 27°C/ total evaporation in an environment of 10°C. A higher ratio means greater heat tolerance. This test takes into consideration evaporative cooling as thermoregulatory means for cattle.

Average relative deviations (ARD)^[20]: It is based on a calculation of the average relative

deviations from normal in thermal, water and/or nitrogen imbalances of the animals (or in all traits measured) caused by exposure to hot climates. It can be mathematically expressed as:

$$\text{Adaptability (\%)} = (100 - \text{ARD}) * 100$$

Conclusion

Heat tolerance in the present era of improving milk productivity is at least worth noting due to the associated negative effects of heat stress and increasing production. The temperature-humidity index has been broadly used in several studies as a heat stress indicator. Further more, heat tolerance levels in a dairy herd can be obtained with the use of the Hierarchical Bayes Model, which is also noted to be a more realistic method of measuring heat tolerance levels in dairy herds. Before practicing genetic selection or genomic selection, heat tolerance level assessment is important because it enables the identification of animals that have superiority over others. But there is no alternative to the credibility of the heat tolerance indices calculated with the help of the physiological parameters of the animals themselves.

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