Identification of most suitable temperature humidity index model for daily milk yield of Murrah buffaloes in subtropical climatic condition of India

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ABSTRACT

The present study was carried out to identify the most suitable temperature humidity index (THI model) among seven reported THI models as heat stress indicator on daily milk yield (DMY) of Murrah buffaloes at subtropical climatic conditions of Karnal, India. A total of 302,101 daily milk yield records from 1,434 lactational milk yield records and pedigree records of 748 buffaloes belonging to five parities spanned over a period of about 20 years (March 1994–December 2013) were obtained from ICAR-NDRI, Karnal and weather information on dry bulb temperature (Tdb), wet bulb temperature (Twb) and relative humidity (RH in %) for the corresponding period were collected from ICAR-CSSRI, Karnal. The overall least-squares mean for daily milk yield was 7.55±0.002 kg. Average daily THI was computed using each of the seven models under study. Regression analysis was performed to determine the most suitable THI model for assessing the effect of heat stress on DMY and a negative association was found between DMY (kg) and THI. THI model 5 developed by NRC (1971) was identified as the most suitable THI model to study the impact of thermal stress on DMY of Murrah expressing maximum decrease in DMY (−0.029 kg) per unit rise in THI.

Key words: Daily milk yield, Heat stress, Murrah, Subtropical climate, Temperature humidity index
Edited data of buffaloes | Daily milk yield
---|---
No of lactational records | No of buffaloes | TDMYR
Total no of records | 1434 | 748 | 302101
Total no of records excluded | 326 | 277 | 10685
No of records included for study | 1108 | 471 | 29146

TDMYR, total number of daily milk yield records.

| THI model | Reference |
|---|---|
| THI1 = [0.4 × (Tdb + Twb)] × 1.8 + 32 + 15 | Thom (1959) |
| THI2 = (0.35 × Tdb + 0.65 × Twb) × 1.8 + 32 | Bianca (1962) |
| THI3 = (0.15 × Tdb + 0.85 × Twb) × 1.8 + 32 | Bianca (1962) |
| THI4 = (Tdb + Twb) × 0.72 + 40.6 | NRC (1971) |
| THI5 = (0.55 × Tdb + 0.2 × Tdp) × 1.8 + 32 + 17.5 | NRC (1971) |
| THI6 = (1.8 × Tdb + 32) - (0.55 –0.00 55 × RH) × NRC (1971) | (1.8 × Tdb – 26.8) |
| THI7 = (0.8 × Tdb) + [(RH/100) × (Tdb – 14.4)] + 46.4 | Mader et al. (2006) |

Tdb, dry bulb temperature; Twb, wet bulb temperature; RH, relative humidity; Tdp, dew point temperature. Tdb, Twb and Tdp were measured in °C and RH was measured in %.

### Table 1. Edited data structure for daily milk yield of Murrah buffaloes

| Edited data of buffaloes | Daily milk yield |
|---|---|
| No of lactational records | 1434 |
| No of buffaloes | 748 |
| TDMYR | 302101 |

### Table 2. Temperature humidity indices (THI) models used in the study

| THI model | Reference |
|---|---|
| THI1 = [0.4 × (Tdb + Twb)] × 1.8 + 32 + 15 | Thom (1959) |
| THI2 = (0.35 × Tdb + 0.65 × Twb) × 1.8 + 32 | Bianca (1962) |
| THI3 = (0.15 × Tdb + 0.85 × Twb) × 1.8 + 32 | Bianca (1962) |
| THI4 = (Tdb + Twb) × 0.72 + 40.6 | NRC (1971) |
| THI5 = (0.55 × Tdb + 0.2 × Tdp) × 1.8 + 32 + 17.5 | NRC (1971) |
| THI6 = (1.8 × Tdb + 32) - (0.55 –0.00 55 × RH) × NRC (1971) | (1.8 × Tdb – 26.8) |
| THI7 = (0.8 × Tdb) + [(RH/100) × (Tdb – 14.4)] + 46.4 | Mader et al. (2006) |

Tdb, dry bulb temperature; Twb, wet bulb temperature; RH, relative humidity; Tdp, dew point temperature. Tdb, Twb and Tdp were measured in °C and RH was measured in %.

### MATERIALS AND METHODS

**Source of data:** A total of 302,101 daily milk yield records from 1,434 lactational milk yield records of 748 buffaloes under first, second, third, fourth and fifth parity spanned over 20 years (March 1994- December 2013) were obtained from data maintained at ICAR-NDRI, Karnal and weather information on dry bulb temperature (Tdb), wet bulb temperature (Twb) and relative humidity for the corresponding period were collected from ICAR-Central Soil Salinity Research Institute, Karnal. The distance between the two institutes is approximately 2.9 km. The normal lactation was regarded as the period of milk production by a buffalo for at least 100 days and producing a minimum of 500 kg milk in the lactation and the buffaloes calved and dried under normal physiological conditions were included in the present study. The experimental buffaloes were excluded from the study. The edited and normalized data structure of buffaloes for DMY is presented in Table 1.

**Temperature humidity index models (THI models):** Seven reported THI models used to compute temperature humidity index are presented in Table 2. Daily THI were computed using the environmental parameters. THI model 1 used in the present study was developed by Thom (1959) while model 2 and 3 were developed by Bianca (1962). Both the workers used dry bulb and wet bulb temperature for the estimation of THI. National Research Council (1971) had developed three THI models. Model 4, model 5 and model 6 developed by NRC have used dry-bulb and wet-bulb temperature, dry bulb temperature and relative humidity and dry bulb temperature and dew point temperature. THI model 7 was developed by Mader et al. (2006) where relative humidity and dry bulb temperature are used for the estimation of THI.

**Statistical analysis:** The effects of non-genetic factors like period of calving, parity, stage of lactation and age group on normalized DMY data were estimated by using least-square analysis for non orthogonal data as suggested by Harvey (1990). The model was used with the assumption that different components being fitted into the model were linear, independent and additive. The model is follows:

\[
y_{ijklm} = \mu + P_i + P_{A} + S_{L} + A_{G} + e_{ijklm}
\]

where \(Y_{ijklm}\) observation of \(m^{th}\) animal of \(l^{th}\) age group, \(k^{th}\) stage of lactation, \(j^{th}\) parity and \(i^{th}\) period of calving; \(\mu\), overall mean; \(P_i\), fixed effects of \(i^{th}\)period of calving (1 to 20); \(P_{A}\), fixed effects of \(i^{th}\)parity (1 to 5); \(S_{L}\), fixed effects of \(k^{th}\)stage of lactation (1 to 3); \(A_{G}\), fixed effects of \(l^{th}\)age group (1 to 3); \(e_{ijklm}\) random error ~ NID \((0, \sigma^2_e)\).

**Estimation of least squares means and adjustment of data:** The least-squares means and standard errors of daily milk yield were estimated. Difference of least-squares means between sub-classes for each effect was tested by modified Duncan’s Multiple Range Test (Kramer 1957). Daily milk yield data were further adjusted with the sub-class constants for significant non-genetic factor(s).

**Identification of the best THI model:** The best THI model among the seven reported models was identified by applying the regression analysis as described below:

\[
y_i = a + b x_i + e_i
\]

where, \(a\) is intercept, \(b\) is regression coefficient or slope of regression line which represents the change in daily milk yield per unit change in average daily THI value and \(e_i\) is the random residual ~ NID \((0, \sigma^2_e)\). The THI model which showed the maximum decline in daily milk yield (kg) per unit change in average daily THI value, was identified as the best THI model for studying the effect of heat stress on daily milk yield of Murrah buffaloes.

### RESULTS AND DISCUSSION

In all the seven THI models, the daily THI value was found low till April first week and started to increase from 10th April onwards, remained high till 30th September and gradually decreased from first week of October. The average daily milk yield showed a gradual decreasing trend from second week of April, remained declined till last week of
September followed by a gradual increase from first week of October. The overall 20 year’s average daily milk yield of Murrah buffaloes was 7.56 kg. Daily THI values with seven different THI models along with the corresponding daily milk yield are presented in Fig. 1. No literature is available on impact of heat stress on daily milk of Murrah buffaloes.

The overall least-squares means daily milk yield of Murrah buffaloes was estimated as 7.55±0.002 kg. The least squares means of daily total milk yield under different sub classes (period, parity, stage of lactations, and age group) is presented in Table 3. The analysis of variance (Table 4) showed highly significant effect (P<0.01) of the non-genetic factors, viz. period, parity, stage of lactations, and age group on daily milk yield of Murrah buffaloes in the present study.

Reports on influence of environmental factors on daily milk yield are scanty. However, significant influence of period of calving and parity on test day milk yield was reported by Jamuna et al. (2015). Khosla et al. (1984) reported that period of calving had significant effect on test day 5 milk yield. Lathwal (2000) had reported significant effect of parity on 305 days or less milk yield of Murrah buffaloes.

A negative association was found between average DMY of Murrah buffaloes and average daily THI values. The coefficients of regression, coefficients of determination for DMY and THI under seven reported THI models under the present study are represented in Fig. 2. The decrease in DMY (kg) per each unit rise in average daily THI values ranged from –0.020 kg to –0.029 kg under the seven THI models. THI model 5 indicated the maximum decrease (–0.029 kg) and THI model 2 showed the minimum decrease (–0.020 kg) in DMY per unit rise in THI. This indicated THI model 5 as the best temperature humidity index model for studying the effect of heat stress on daily milk yield of Murrah buffaloes.

### Table 3. Least-Squares means and standard errors of daily milk yield (kg) in Murrah buffaloes under different periods of calving, parities, stage of lactation and age group

| Effect                  | Sub-classes | Mean±SE                  |
|-------------------------|-------------|--------------------------|
| Overall (µ)             |             | 7.55±0.002 (291416)      |
| Period                  |             |                          |
| 1994–1998               | 7.70±0.012 (94147) |
| 1999–2003               | 7.39±0.012 (71451) |
| 2004–2008               | 7.65±0.012 (73182) |
| 2009–2013               | 7.45±0.012 (52636) |
| Parity                  |             |                          |
| 1                       | 6.79±0.010 (115110) |
| 2                       | 7.61±0.011 (81482) |
| 3                       | 7.86±0.013 (47880) |
| 4                       | 7.94±0.017 (28218) |
| 5                       | 7.56±0.020 (18726) |
| Stage of lactation      |             |                          |
| 5–90                    | 8.75±0.011 (93659) |
| 91–180                  | 7.97±0.011 (95296) |
| 181 and above           | 7.94±0.011 (102461) |
| Age group (days at 1st calving) |         |
| < 1073                  | 7.46±0.002 (16019) |
| 1073–1641               | 7.51±0.006 (240294) |
| >1641                   | 7.69±0.014 (35103) |

SE, Standard error. Figures in parenthesis represent number of daily milk yield records. Similar superscripts indicate non-significant and dissimilar superscripts indicate significant difference among subclasses (P<0.01).

### Table 4. Analysis of variance (M.S. values) of daily milk yield in Murrah buffaloes

| Sources of variation | Daily milk yield (kg) |
|----------------------|-----------------------|
| Period               | 11548.78"** (3)       |
| Parity               | 15510.96"** (4)       |
| Stage of lactation   | 208969.79"** (2)      |
| AFC                  | 568.32"** (2)         |
| Error                | 6.607 (291781)        |

Figures in parentheses indicate respective degree of freedom (P<0.01).

Fig. 1. Trend of daily average THI values and average daily milk yield (March 1994 to December 2013).

Fig. 2. Comparison of THI models based on coefficient of determination (R²) and partial regression coefficient (b).
is no report available on identifying the most suitable THI model to assess the impact of thermal stress on buffaloes.

The present investigation concluded that different temperature humidity indices have different ability to measure heat load on Murrah buffaloes and differ in their potential to measure the impact of heat stress on daily milk yield of Murrah buffaloes. THI was found negatively associated with daily milk yield. THI model 5 \[THI = (0.55 \times T_{db} + 0.2 \times T_{dp}) \times 1.8 + 32 + 17.5\] which was developed by National Research Council in 1971 using dry bulb and dew point temperature was identified as the best THI model to study the effect of heat stress on daily milk yield of Murrah buffaloes after evaluating seven reported THI models in subtropical climatic conditions of Karnal, India.

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REFERENCES

Armstrong D V. 1994. Heat stress interaction with shade and cooling. *Journal of Dairy Science* **77**: 2044–50.
Basic Animal Husbandry Statistics. 2015. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India.
Bianca W. 1962. Relative importance of dry- and wet-bulb temperatures in causing heat stress in cattle. *Nature* **195**: 251–52.
Bohmanova J, Misztal I, Tsuruta S, Norman H D and Lawlor T J. 2005. National genetic evaluation of milk yield for heat tolerance of United States Holsteins. *Interbull Bulletin* **33**:160–62.
BohmanovaJ, Misztal I and Cole J B. 2007. Temperature humidity indices as indicators of milk production losses due to heat stress. *Journal of Dairy Science* **90**(4):1947–56.
Bouraoui R, Lahmar M, Majdoub A, Djemali M and Belyea R. 2002. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. *Animal Research* **51**: 479–91.
Harvey W R. 1990. Guide for LSMLMW, PC-1 Version, mixed model least squares and maximum likelihood computer programme. Mineograph Ohio State University, USA.
IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change Synthesis Report; Summary for Policymakers. Retrieved from: http://www.ipcc. ch/pdf/assessment-report/ ar4/syr/ar4_syr_spm .pdf.
Jamuna V, Chakravarty A K and Patil C S. 2015. Influence of non-genetic factors on performance traits in Murrah buffaloes. *Indian Journal of Animal Research* **49**(3): 279–83.
Khosla S K, Gill S S and Malhotra P K. 1984. Effect of some non-genetic factor on age at first calving and service period in herd book registered Murrah buffaloes under village conditions. *Indian Journal of Animal Sciences* **54**: 1–5.
Kramer C Y. 1957. Extension of multiple range tests to group correlated adjusted means. *Biometrics* **13**: 13–18.
Lathwal S S. 2000. Optimum levels of economic traits for maximizing the profit function in Murrah buffaloes. Ph.D. Thesis, NDRI (Deemed University), Karnal, Haryana, India.
Mader T L, Davis M S and Brown-Brandt T. 2006. Environmental factors influencing heat stress in feedlot cattle. *Journal of Animal Sciences* **84**: 712–19.
Marai I F M and Haeeb A A M. 2010. Buffalo biological functions as affected by heat stress - a review. *Livestock Science* **127**: 89–109.
National Research Council. 1971. A guide to environmental research on animals. National Research Council. National Academy of Science, Washington, DC.
Roenfeldt S.1998. You can’t afford to ignore heat stress. *Dairy Manage* **35**: 6–12.
Thom E C. 1959. The discomfort index. *Weatherwise* **12**: 57–60.