Indian Journal of Animal Sciences **88** (7): 834–837, July 2018/Article

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

RAJALAXMI BEHERA[1], A K CHAKRAVARTY[2], N KASHYAP[3], BHARTI[4], S RAI[5], A MANDAL[6],
AVTAR SINGH[7] and A K GUPTA[8]

ICAR-National Dairy Research Institute, Karnal, Haryana 132 001 India

Received: 15 December 2017; Accepted: 19 December 2017

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 (T_{db}), wet bulb temperature (T_{wb}) 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

Buffaloes are the major contributors of milk production in India sharing more than 50% of the total milk produced in the country. Since 1997, India has continuously stood first globally in milk production (BAHS 2015). Buffaloes are more prone to heat stress because of their dark coloured skin, sparse hair coat and scanty sweat glands which compromises their heat dissipation capacity (Marai and Haeeb 2010). Selection for increased milk production has resulted in more metabolic heat production by the animals. Simultaneously, the alarming situation of increased environmental temperature due to global warming has put the dairy animals on high thermal load. Heat stress is a form of environmental stress that occurs when any combination of environmental factors rises the effective environmental temperature above the animal's thermo-neutral zone (Armstrong 1994) which ranges from 5°C to 25°C for lactating dairy cows (Roenfeldt 1998). Present climate models have forecasted an increase in temperature by 0.2°C per decade and rise in earth's mean surface temperature between 1.8°C to 4.0°C by 2100 (IPCC 2007). The most vital factors of heat stress are temperature and humidity (Bohmanova *et al*. 2005). There are many measures for estimating thermal load on animals and one of the most efficient ways is temperature humidity index (THI) that combines dry bulb and wet bulb temperature along with relative humidity to measure the heat stress (Thom 1959). Bouraoui *et al*. (2002) reported that milk yield drops by 0.41 kg per cow per day for each point increase in the value of THI above 69 under Mediterranean climatic conditions.

Several THI models have been developed to analyse the effect of heat stress on performance traits of animals. Bohmanova *et al.* (2007) reported that indices differ in their potential to measure thermal load on animals at different climatic conditions. The temperature humidity index bearing higher weights on humidity serves as the best indicator of heat stress in humid climate, whereas index giving higher weights on temperature is the best index for heat stress in the semi-arid climate. However, till today very less studies have been carried out on the impact of heat stress on animal productivity. None of the reported THI models are based on Indian climatic conditions. Till today, no literature available on identifying the most suitable THI model among the reported models for measuring the impact

---

Present address: [1,5]Scientist (drrajlaxmi.10@gmail.com), drsaroj.rai@gmail.com), [6]Principal Scientist (ajoymandal @rediffmail.com). [2]Head and Principal Scientist (ak_chakravarty@yahoo.co.in), Animal Genetics and Breeding Division; [7]Retired Principal Scientist (avtar54@gmail.com), [8]Principal Scientist (guptaak2009@gmail.com), ICAR-National Dairy Research Institute, Karnal, Haryana. [3]Assistant Professor (neeraj.vety@gmail.com), Department of Animal Genetics and Breeding, GADVASU, Ludhiana.[4]Assistant Professor (bharti.vet@gmail.com), GADAVASU, Ludhiana, Punjab.

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

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	291416

TDMYR, total number of daily milk yield records.

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

THI model	Reference
$THI_1 = [0.4 \times (T_{db} + T_{wb})] \times 1.8 + 32 + 15$	Thom (1959)
$THI_2 = (0.35 \times T_{db} + 0.65 \times T_{wb}) \times 1.8 + 32$	Bianca (1962)
$THI_3 = (0.15 \times T_{db} + 0.85 \times T_{wb}) \times 1.8 + 32$	Bianca (1962)
$THI_4 = (T_{db} + T_{wb}) \times 0.72 + 40.6$	NRC (1971)
$THI_5 = (0.55 \times T_{db} + 0.2 \times T_{dp}) \times 1.8 + 32 + 17.5$	NRC (1971)
$THI_6 = (1.8 \times T_{db} + 32) - (0.55 - 0.00\ 55 \times RH) \times (1.8 \times T_{db} - 26.8)$	NRC (1971)
$THI_7 = (0.8 \times T_{db}) + [(RH/100) \times (T_{db} - 14.4)] + 46.4$	(Mader *et al*. 2006)

T_{db}, dry bulb temperature; T_{wb}, wet bulb temperature; RH, relative humidity; T_{dp}, dew point temperature. T_{db}, T_{wb} and T_{dp} were measured in °C and RH was measured in %.

of heat stress on milk production traits of buffaloes in India. Considering the above facts, the present study was conducted for determining the most suitable temperature humidity index model among seven reported THI models to study the effect of heat stress on daily milk yield of Murrah buffaloes in a subtropical climate.

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 (T_{db}), wet bulb temperature (T_{wb}) 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:

$$Y_{ijklm} = \mu + P_i + PA_j + SL_k + AG_l + e_{ijklm}$$

where Y_{ijklm}, observation of mth animal of lth age group, kth stage of lactation, jth parity and ith period of calving; μ, overall mean; P_i, fixed effects of ithperiod of calving (1 to 20); Pa_j, fixed effects of jth parity (1 to 5); SL_k, fixed effects of kth stage of lactation (1 to 3); AG_l, fixed effects of lth age group (1 to 3); e_{ijklm}, random error ~ NID (0, σ^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:

$$Y_{ij} = a + b\, x_i + e_{ij}$$

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_{ij} is the random residual ~ NID (0, σ^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

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)	$7.55^{b}\pm0.002$ (291416)
Period	1994–1998	$7.70^{a}\pm0.012$ (94147)
	1999–2003	$7.39^{c}\pm0.012$ (71451)
	2004–2008	$7.65^{b}\pm0.012$ (73182)
	2009–2013	$7.45^{d}\pm0.012$ (52636)
Parity	1	$6.79^{d}\pm0.010$ (115110)
	2	$7.61^{b}\pm0.011$ (81482)
	3	$7.86^{a}\pm0.013$ (47880)
	4	$7.94^{a}\pm0.017$ (28218)
	5	$7.56^{c}\pm0.020$ (18726)
Stage of lactation	5–90	$8.75^{a}\pm0.011$ (93659)
	91–180	$7.97^{b}\pm0.011$ (95296)
	181 and above	$5.94^{c}\pm0.011$ (102461)
Age group (days at first calving)	< 1073	$7.46^{c}\pm0.002$ (16019)
	1073–1641	$7.51^{b}\pm0.006$ (240294)
	>1641	$7.69^{a}\pm0.014$ (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).

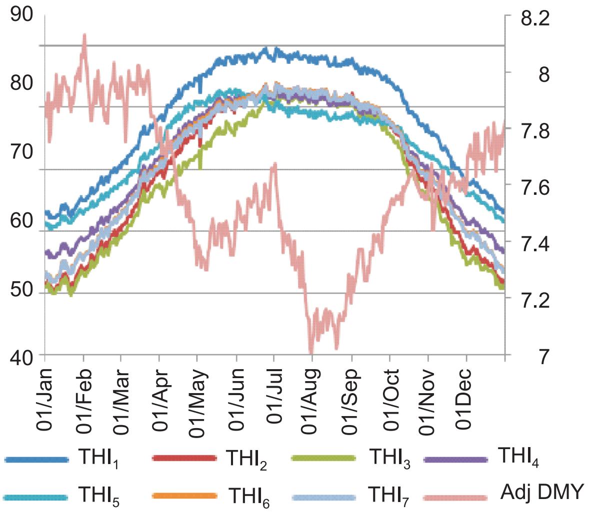

Fig. 1. Trend of daily average THI values and average daily milk yield (March 1994 to December 2013).

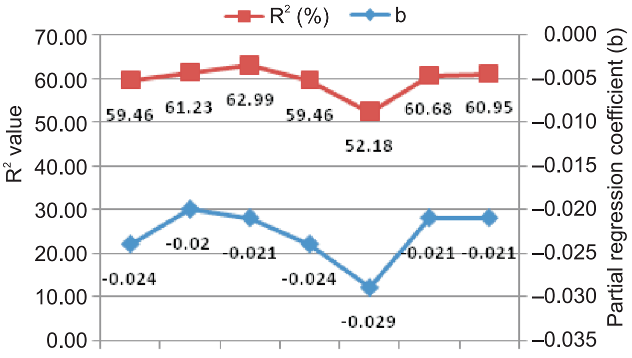

Fig. 2. Comparison of THI models based on coefficient of determination (R^2) and partial regression coefficient (b).

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. The difference in performance of the buffaloes in different periods might be due to differences in management practices, feed and fodder availability, different sires used for breeding in different periods and other environmental conditions. The literature revealing the influence of parity, stage of lactation and age group on daily milk yield in Murrah was not available.

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 and the rate of decline in DMY 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. There 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.

ACKNOWLEDGEMENTS

The authors express sincere gratitude to the Director, ICAR-National Dairy Research Institute (NDRI), Karnal for providing necessary facilities for the smooth and successful completion of the research work. Special thanks to Department of Science and Technology, Ministry of Science and Technology, Govt. of India for proving DST-INSPIRE Fellowship to the first author for conducting the study.

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 Bulletein* **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. Mimeograph 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-Brandl 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.