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Identification of best temperature humidity index model for assessing impact of heat stress on milk constituent traits in Murrah buffaloes under subtropical climatic conditions of Northern India

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ABSTRACT

The present study was conducted to identify the most suitable temperature humidity index (THI) model among seven reported THI models for analyzing the impact of thermal stress on monthly test day fat % (MTDF%), monthly test day SNF% (MTSNF%), monthly test day fat yield (MTDFY) and monthly test day SNF yield (MTDSNFY) of Murrah buffaloes at subtropical climatic conditions of Karnal, India. A total of 8868 MTDF% and 8606 MTDSNF% records from 1107 lactational records of Murrah buffaloes under five parities were included in the present study and weather information on dry bulb temperature (T_{db}), wet bulb temperature (T_{wb}) and relative humidity (RH in %) for the corresponding period of 20 years (March 1994- December 2013) were collected from ICAR-NDRI and ICAR-CSSRI, Karnal, respectively. The overall least-squares means for MTDF% ranged from 7.71 ± 0.067 in TD1 to 8.10 ± 0.08 in TD 9 and MTDSNF% ranged from 9.61 ± 0.01 in TD5 and TD 6 to 9.65 ± 0.01 in TD 8. The overall least squares means of MTDFY (g) ranged from 411.23 ± 14.74 to 745.98 ± 13.57 while for MTDSNFY (g) the value ranged from 491.90 ± 17.21 to 922.16 ± 15.17. Monthly average THI was computed for each of the seven models. The lowest monthly average THI value was found in January, while either May, June or July showed the highest average THI value for all seven THI models. Regression analysis was performed for identifying the best THI to assess the impact of heat stress on milk constituent traits under study anda negative association was found between the milk constituent traits and monthly average THI values.The THI model[$THI = (0.55 \times T_{db} + 0.2 \times T_{dp}) \times 1.8 + 32 + 17.5$]developed by NRC(1971)was identified as the most suitable THI model to assess the impact of heat stress on milk composition traits of Murrah indicating maximum decline in MTDF% (-0.005), MTDFY (-0.68 g),MTDSNF% (b=-0.0008) and MTDSNFY (-2.25 g) per unit rise in THI.

Key words: THI, Heat stress, Milk constituent traits, Fat %, SNF%, Murrah, Subtropical climate.

INTRODUCTION

Buffaloes contribute the highest share (51 %) to national milk pail of India for which globally India stands first in milk production (BAHS, 2015). Buffaloes because of their morphological and anatomical characteristics *viz.* dark skin, sparse hair coat, less dense sweat glands, have poor heat dissipation capacity and hence are very prone to heat stress(Marai and Haeeb, 2010). In North India, buffaloes get exposed to severe weather conditions where temperature gets elevated to as high as 47^{0}C in summer and declined to as low as 1-2^{0}C in winter. Heat stress occurs when any combination of environmental factors cause the effective temperature of the environment to be higher than the animal's thermo-neutral zone (Armstrong, 1994).The thermo neutral zone of lactating dairy cows ranges from 5^{0}Cto 25^{0}C (Roenfeldt, 1998) and cows are exposed to heat stress, when temperature goes above 25 to 26^{0}C in a subtropical climate (Berman *et al.*, 1985). Heat stress may be caused by different environmental factors like temperature, relative humidity, solar radiation, air movement and precipitation. The most important factors of heat stress are temperature and humidity (Bohmanova *et al.*, 2007). 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).

There are several THI models developed to study the impact of heat stress on performance traits of animals in different climatic conditions. Bohmanova *et al.* (2007) reported that different temperature humidity indices have differed potential in measuring the heat stress to animals at different climatic conditions. The index with higher weights on humidity serves as the best temperature humidity index in humid climate, while index with bearing higher weights on temperature serves as the best indicator of heat stress in the arid and semi-arid climates. However, till today very few studies have been conducted in the aspect of influence of heat stress on animal productivity and most of them are based

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on small font of observations. Among the reported THI models, none is based on Indian climatic conditions. Furthermore, there is no report on identifying the most suitable THI model among the reported THI models for measuring the impact of heat stress on milk constituent traits of buffaloes in India. Considering these facts, the present study was carried out to identify the best Temperature Humidity Index model among seven reported THI models to assess the impact of heat stress on milk constituent traits (monthly test day fat%, fat yield,monthly test day SNF% and SNF yield) of Murrah buffaloes in a subtropical climate.

MATERIALS AND METHODS

Source of data: Monthly test day fat% (MTDF%), monthly test day SNF %(MTDSNF%) and monthly test day milk yield (MTDMY) data of 9864 in each spanned over 20 years (March 1994- December 2013) on 1405 lactations belonging to first, second, third, fourth and fifth parities along with the pedigree records of buffaloes were obtained from data maintained at ICAR-NDRI, Karnal. Climatological data *viz.* dry bulb temperature (^{0}C), wet bulb temperature (^{0}C), relative humidity (%), vapour pressure (mm Hg) for the corresponding periods were collected from Central Soil and Salinity Research Institute (CSSRI) which is located 2.9 km from ICAR-NDRI, Karnal. The abnormal records of buffaloes showing abortion, dystocia, retained placenta and other reproductive disorders were not included in the study. Buffaloes with less than 100 days of lactation or with less than 500 kg lactational milk yield and experimental buffaloes were excluded from the study. The standardized data that includeda total of 8868 MTDF%, 8606 MTDSNF% and 8665 MTDMY records belonging to 1107 lactational records ofMurrah buffaloeswere arranged monthly test day wise. The test day data were normalized for monthly test day fat % using the standard deviation of the trait. The edited and normalized data structure of buffaloes for the MTDF %, MTDSNF% and MTDMY is presented in Table 1.

Temperature Humidity Index models (THI models): Seven models used to compute Temperature Humidity Index are presented in Table 2. Daily THI were computed using the environmental parameters from environmental parameters recorded from ICAR-CSSRI, Karnal. Monthly average THI was estimated from the calculated daily THI for the seven THI models using all the seven THI models under study.

THI model 1, 2 and model 3 which are used in present study were developed by Thom (1959) and Bianca (1962). Both the workers used dry bulb and wet bulb temperature for the estimation of THI. National Research Council (1971) developed three different THI models namely model 4, model 5 and model 6 by using dry-bulb and wet-bulb temperature, dry bulb temperature and relative humidity and dry bulb temperature and dew point temperature separately. THI model 7 was developed by Mader *et al.* (2006) by using relative humidity along with dry bulb temperature in the formula for the estimation of THI.

Statistical analysis: The effects of non-genetic factors like year of calving, parity and age group on normalized MTDF%, MTDSNF% and MTDMY were estimated by using least-square analysis for non-orthogonal data as suggested by Harvey, (1990). The model was used with the assumption

Table 1: Normalized data structure of monthly test day Fat % and SNF%

Monthly Test Day	Range of date of recording Test Day	Average Date of recordingTest Day	No. of Records	
			Fat %	SNF %
1	6-30	19	822	817
2	31-60	45	991	985
3	61-90	76	1007	998
4	91-120	106	969	964
5	121-150	136	930	924
6	151-180	165	911	900
7	181-210	195	877	866
8	211-240	225	815	812
9	241-270	255	747	743
10	271-305	287	599	597
Total			8668	8606

Table 2: Temperature Humidity Indices (THI) Models

THI Models	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

Where, T_{db}= dry bulb temperature, T_{wb}= wet bulb temperature, RH = relative humidity, T_{dp}= Dew point Temperature. Tdb, Twb and Tdp were measured in 0C and RH was measured in %.

that different components being fitted into the model were linear, independent and additive. The model is follows:

Y_{ijkl} = $\mu + Yr_i + PA_j + AG_k + e_{ijkl}$

Y_{ijklm} = observation of l^{th} animal of k^{th} age group, j^{th} parity and i^{th} year of calving

μ = overall mean

$(Yr)_i$ = fixed effects of i^{th} year of calving (1 to 20)

Pa_j = fixed effects of j^{th} parity (1 to 5)

AG_k = fixed effects of k^{th} age group (1 to 3)

e_{ijkl} = random error ~ NID (0, σ^2_e)

Estimation of least squares means and adjustment of data: The least-squares means and standard errors monthly test day fat %, SNF% and 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).

Adjustment of Data: Monthly test day fat %, SNF% and test day milk yield data were further adjusted with the sub-class constants for significant non-genetic factor(s).

Effect of Test Day on MTDF %, MTDSNF% and MTDMY and adjustment of data for effects of Test Day

The effects of test day on adjusted MTDF %, MTDSNF% and MTDMY for non-genetic factors (age group, parity and year) was estimated by using least-square analysis for non orthogonal data as suggested by Harvey (1990).

$Y_{ij} = \mu + TD_i + e_{ij}$

Y_{ij} = observation of j^{th} animal i^{th} test day

μ = overall mean

e_i = random error ~ NID (0, σ^2_e)

The data on monthly test day parameters showing significant effect of test days were further adjusted for the significant effect of test days.

Computation of monthly test day fat yield and monthly test day SNF yield: Based on the corrected monthly test day fat % and the corresponding test day milk yield, monthly test day fat yield (MTDFY) was estimated. Similar procedure was used for estimating the monthly test day SNF yield (MTDSNFY).

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

$Yij = a + b\ xi + eij$

where, a is intercept, b is regression coefficient or slope of regression line which represents the change in monthly test day fat %/monthly test day SNF%/monthly test day fat yield/ monthly test day SNF yield with per unit change in monthly average THI value and e_{ij} is the random residual ~ NID (0, σ^2_e). The THI model which showed the maximum decline in the above said milk constituent traits with respect to unit change in monthly average THI value, was identified as the best THI model for studying the effect of heat stress on milk constituent traits of Murrah buffaloes.

RESULTS AND DISCUSSION

The overall least-squares means for monthly test day fat% ranged from 7.71 ± 0.067 in Test Day1 to 8.10 ± 0.08 in Test Day 9 and for monthly test day SNF% it ranged from 9.61 ± 0.01 in Test Day 5 and Test Day 6 to 9.65 ± 0.01 in Test Day 8. Overall least squares mean for Monthly Test Day Fat % (MTDF %) and Monthly Test Day SNF% (MTDSNF %)of Murrah buffaloes were estimated as 7.84±0.01 and 9.63 ± 0.002. The overall least squares means of Monthly Test Day Fat Yield (MTDFY) ranged from 411.23 ± 14.74 g to 745.98 ± 13.57 g while for Monthly Test Day SNF Yield (MTDSNFY) the value ranged from 491.90 ± 17.21 g to 922.16 ± 15.17 g. The year of calving had significant effects (P<0.01) on MTDFAT%, MTDFY, MTDSNF% and MTDSNFY at all the test days. Age group at first calving influenced MTDFAT% and MTDFY only at TD 6 (P<0.05). Kumar *et al.* (2016) reported a significant effect (p<0.01) of the age group on MTDFY-3; significant (p<0.05) for MTDFY-2, MTDFY-5, MTDFY-6 and rest TD have non-significant effect of age groups. Chitra (2015) reported non-significant impact of age group on monthly test day fat % in all the test days. Parity influenced significantly MTDFY at TD1 to TD7 (P<0.01) and TD8 (P<0/05) while TD9 and TD10 were not significantly influenced. Singh *et al.* (1979) observed the non-significant effect of parity on fat percentage in Murrah buffaloes. Pawar *et al.* (2012) reported non-significant effect of parity and significant effect of year of calving on yearly average fat % (P<0.05). Chitra (2015) reported significant effect of period of calving significantly influenced the trait (P<0.01). Parity had significant effect (P<0.01) on monthly test day SNF %at TD 5 and SNF yield at test day 1 to 7 while age group at first calving had no significant effect on MTDSNF% but significantly influenced MTDSNFY at test day 3 and 8. Chitra *et al.* (2015) reported significant effect of period of calving on SNF% while age group and parity did not affect the trait significantly. The least-squares means of monthly test day fat%, SNF%, monthly test day milk yield, fat yield and SNF yield and their standard errors are being mentioned in Table 3.

The effects of test day on adjusted MTDF %, MTDSNF% and MTDMY for non-genetic factors (age group, parity and year) was estimated by using least-square analysis for non orthogonal data as suggested by Harvey (1990) and it was found that effect of test day significant on monthly test day fat%, fat yield and SNF yield while it was non-significant for monthly test day SNF%. The least-squares means and standard errors for effect of test day on the above said milk constituent traits are presented in Table 4.

Based on the date of testing of monthly milk fat % and SNF% the monthly average THI values were estimated and are represented in Figure 1. The monthly average THI varied from 63.46 in January to 89.30 in June in THI model 1. Livestock Weather Safety Index have estimated THI using

Table 3: Least-squares means and standard errors of Monthly Test Day milk composition traits (Fat%, SNF%, Fat Yield and SNF Yield) in Murrah buffaloes using fixed model (before adjustment for test day)

Monthly Test Day Milk composition traits	TD1	TD2	TD3	TD4	TD5	TD6	TD7	TD8	TD9	TD10
Fat%	7.71 ± 0.067 (822)	7.81 ± 0.06 (991)	7.84 ± 0.06 (1007)	7.78 ± 0.06 (969)	7.82 ± 0.06 (930)	7.88 ± 0.06 (911)	7.98 ± 0.06 (877)	7.95 ± 0.07 (815)	8.10 ± 0.08 (747)	7.99 ± 0.08 (599)
SNF%	9.62± 0.01 (817)	9.64 ± 0.01 (985)	9.62 ± 0.01 (998)	9.62 ± 0.01 (964)	9.61 ± 0.01 (924)	9.61 ± 0.01 (900)	9.64 ± 0.01 (866)	9.65 ± 0.01 (813)	9.65 ± 0.08 (743)	9.61 ± 0.02 (595)
Milk Yield	8.92± 0.18 (824)	9.55 ± 0.15 (991)	9.22 ± 0.16 (1006)	9.02 ± 0.5 (968)	8.21 ± 0.15 (930)	7.69 ± 0.14 (910)	6.99 ± 0.15 (878)	6.23 ± 0.15 (817)	5.59 ± 0.16 (746)	5.10 ± 0.16 (595)
Fat Yield	684.55 ± 15.41 (822)	745.98 ± 13.57 (991)	721.10 ± 13.62 (1007)	701.26 ± 13.22 (969)	641.44 ± 13.40 (930)	602.95 ± 12.52 (911)	557.35 ± 12.49 (877)	498.29 ± 12.98 (815)	454.15 ± 13.50 (747)	411.23 ± 14.74 (599)
SNF Yield	859.21 ± 17.83 (817)	922.16 ± 15.17 (985)	887.49 ± 15.49 (998)	868.68 ± 14.91 (964)	788.90 ± 34.18 (924)	741.12 ± 14.49 (900)	673.82 ± 14.37 (866)	605.28 ± 14.54 (813)	539.53 ± 15.44 (743)	491.90 ± 17.21 (595)

Figures in parenthesis represent the number of observations

Table 4: Least square means along with standard error for monthly average Test Day Fat %, SNF% and monthly average test day Fat Yield and SNF Yield under different test days

Monthly Test Day	Fat %	SNF%	Fat Yield	SNF Yield
Overall μ	7.84^{a}±0.01**	9.63±0.002	597.29^{e}±2.18**	730.63^{e}±2.50**
TD1	7.74^{a}±0.04**	9.62±0.006	673.07^{g}±7.01**	843.24^{h}±8.02**
TD2	7.58^{a}±0.04**	9.62 ±0.006	738.61^{j}±6.38**	913.20^{j}±7.32**
TD3	7.72^{a}±±0.04**	9.62 ±0.007	718.03^{i}±±6.34**	887.49^{i}±7.25**
TD4	7.84^{a}±0.04**	9.63 ±0.007	701.77^{h}±6.46**	866.29^{g}±7.38**
TD5	7.92^{a}±0.04**	9.63 ±0.006	647.44^{f}±6.59**	786.48^{f}±7.54**
TD6	8.01^{b}±0.04**	9.63 ±0.006	602.90^{e}±6.66**	729.71^{e}±7.64**
TD7	7.97^{b}±0.04**	9.63 ±0.006	549.17^{d}±6.78**	658.42^{d}±7.78**
TD8	7.90^{a}±0.04**	9.65 ±0.007	490.25^{c}±7.04**	601.50^{c}±8.04**
TD9	8.02^{b}±0.04**	9.63 ±0.007	438.77^{b}±7.35**	523.47^{b}±8.41**
TD10	7.69^{a}±0.05**	9.63 ±0.008	412.88^{a}±8.23**	490.75^{a}±9.39**

Similar superscripts indicate non-significant and dissimilar superscripts indicate significant difference among subclasses (P<0.01)

THI model 1(Thom, 1959) and categorizedheat stress into four classes with different range of THI under viz. normal (≤74), alert (74< THI <79), danger stress (79≤ THI <84) and emergency stress (THI ≥84) in livestock (LCI, 1970).The range of THI values which was obtained under THI model 2 in the present study varied from 51.94 in the month of January to 83.26 in the month of June. The range of THI values which was obtained under THI model 3 in the present study varied from 51.07 in the month of January to 81.48 in the month of July. By using THI model 4, THI values varied from 57.06 in the month of January to 82.90 in the month of June. The range of THI values which was obtained under THI model 5 varied from 62.01 in the month of January to 82.17 in the month of May. By using THI model 6, it has been observed that THI values varied from 54.24 in January to 82.63 in the month of July. The range of THI values which was obtained under THI model 7 varied from 54.12 in the month of January to 82.98 in the month of June.

The maximum monthly average THI values were observed in the month of June as 89.30, 83.26, 82.90 and 82.98 with THI model 1, 2, 4 and 7, respectively. For other THI models like 3 and 6, maximum monthly average THI values were found in the month of July as 81.48 and 82.63, respectively. The THI model 5 showed maximum monthly average THI value (82.17) in the month of May. The minimum monthly average THI values were seen in the

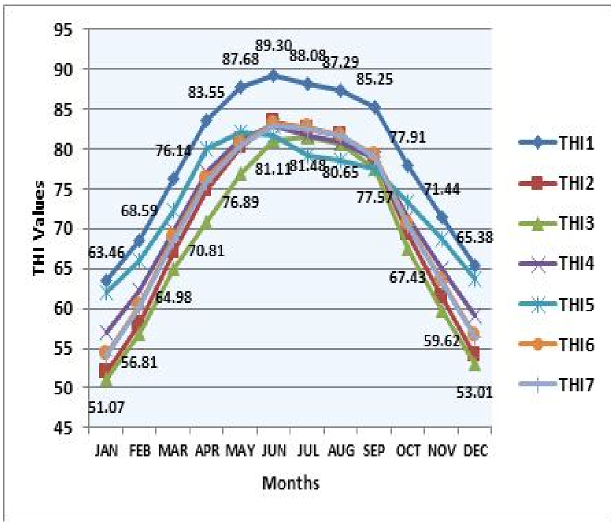

Figure 1: Monthly average Temperature Humidity Index values (THI values) under seven reported THI models (1-7) during March 1994-December 2013

month of January for all the THI models (1-7) as 63.46, 51.94, 51.07, 57.06, 62.01, 54.24and 54.12, respectively. Dash *et al.* (2013) also have reported a similar trend of monthly average THI at the subtropical climatic condition of Karnal.

Month wise average THI values with seven different THI models along with the corresponding monthly average fat and SNF % during twenty years from 1994-2013 are presented in Figure 2 and 3. Both monthly average fat% and SNF% started to decline during the month of April (fat % 7.86 in March and decreased to 7.81 in April and SNF %

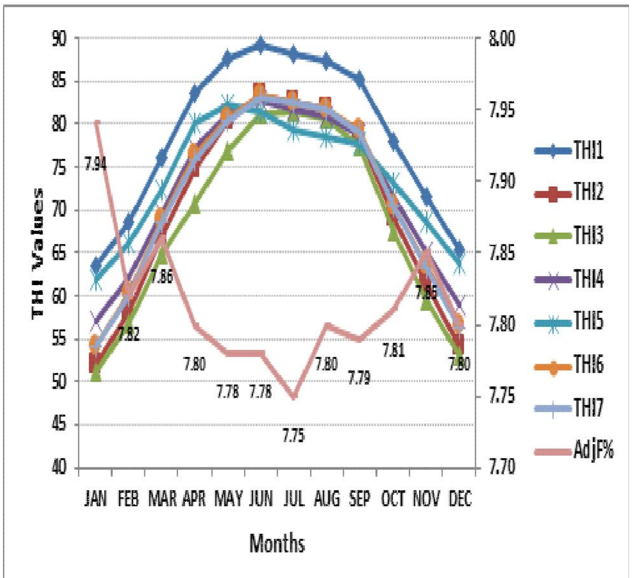

Figure 2: The trend of average monthly test day fat% in relation to Temperature Humidity Index values (THI values) under seven different THI models (1-7) during March 1994-December 2013

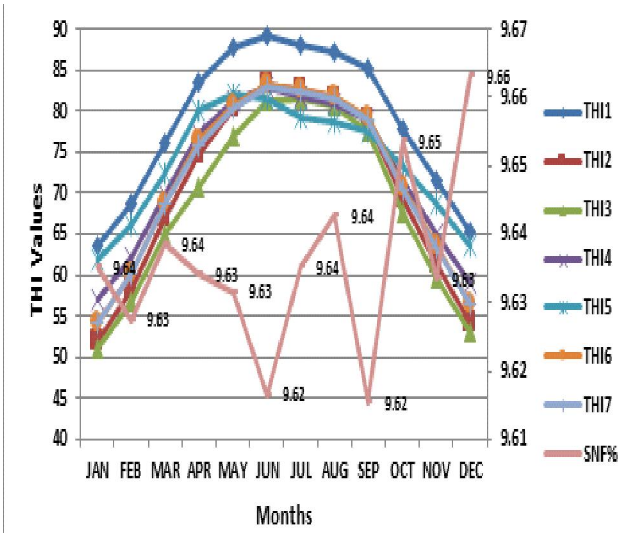

Figure 3: The trend of average monthly test day SNF% in relation to Temperature Humidity Index values (THI values) under seven different THI models (1-7) during March 1994-December 2013

was 9.64% in March and declined to 9.63% in April) and fat % remained declined up to July, showed a little increase in August and again declined in September while SNF% exhibited a fluctuating increasing and decreasing trend. Both monthly test day fat% and SNF% gradually started to increase from October month onwards (fat % 7.78 in September and rises to 7.81 in October and SNF % 9.61% in September to 9.65% in October). The lowest average monthly fat% of Murrah buffaloes was observed in the month of July (7.75%) while monthly average SNF % was lowest in the month of September (9.61%). The monthly average fat% was highest in the month of November (7.85%) and monthly average SNF % was found to be highest in the month December (9.66%). Pawar *et al.* (2013) has reported that average fat % of Murrah buffalo declined during summer season by 0.26% than rainy and winter season. However, no literature is available on the impact of THI on monthly test day fat % and SNF % of Murrah buffaloes.

Figure 4 depicted the trend of MTDFY in relation to THI across the twelve months. A declining trend was observed in monthly test day fat yield since April onwards till August and a gradual increase was observed from September onwards. The trend of MTDSNFY in relation to THI across the twelve months has also been shown in Figure 5. Monthly test day SNF yield followed a similar trend of remaining high till March, exhibited a declining trend from the month of April to July and was followed by a gradual increasing trend from August. No literature is available on the impact of THI on monthly test day fat yield and monthly test day SNF yield of Murrah buffaloes.

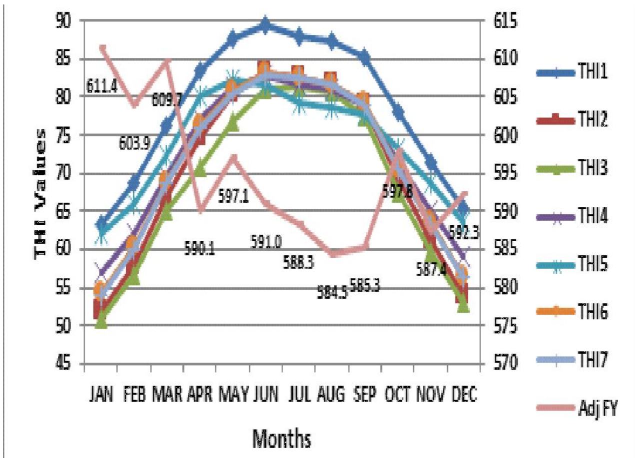

Figure 4: The trend of average monthly test day fat yield in relation to Temperature Humidity Index values (THI values) under seven different THI models (1-7) during March 1994-December 2013

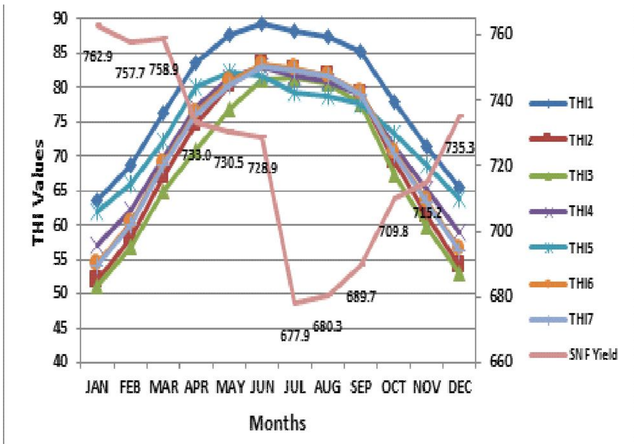

Figure 5: The trend of average monthly test day SNF yield in relation to Temperature Humidity Index values (THI values) under seven different THI models (1-7) during March 1994-December 2013

The coefficients of regression, coefficients of determination for MTDF% and MTDFY and THI under seven different THI models are presented in Table 5 and for MTDSNF% and MTDSNFY is presented in Table 6. A negative association was found between average MTDF%, MTDFY, MTDSNF% and MTDSNFY of Murrah buffaloes and monthly average THI values.

The decrease in MTDF% and MTDFY per each unit change in monthly average THI values and the rate of decline ranged between -0.0031 % to -0.005 % and -0.46 g to -0.68 g, respectively under seven different THI models. The THI model 5exhibited the maximum decline (-0.005 %) and THI model 2 showed the minimum decline (-0.0031 %) in MTDF% per unit increase in THI value. The THI model 5 showed the maximum decrease (-0.68 g) and THI model 2 indicated the minimum decrease (-0.46 g) in MTDFY per unit rise in THI value. This indicates THI model 5 as the best temperature humidity index model for assessing the impact of heat stress on monthly test day fat % and monthly test day fat yield of Murrah buffaloes.

Table 5: Rate of decline (b) in monthly test day fat % and monthly test day fat yield (g) due to heat stress under seven reported Temperature Humidity Indices (THI Models)

THI Models	MTDF%			MTDFY		
	a	b	R^2 (%)	a	b	R^2 (%)
1	8.11	-0.0038	53.53	638.73	-0.5572	33.18
2	8.03	-0.0031	53.67	627.31	-0.4643	34.37
3	8.03	-0.0032	53.33	628.15	-0.4857	35.70
4	8.09.	-0.0038	53.33	635.17	-0.5572	33.18
5	8.18	-0.0050	50.97	645.35	-0.6840	28.55
6	8.06	-0.0034	53.70	630.89	-0.5036	34.27
7	8.06	-0.0034	53.71	630.99	-0.5064	34.47

MTDF% = monthly test day fat%, MTDFY= monthly test day fat yield
a = Intercept, b = Regression Coefficient, R^2 = Coefficient of determination

Table 6: Rate of decline (b) in monthly test day SNF % and monthly test day SNF yield (g) due to heat stress under seven reported Temperature Humidity Indices(THI Models)

THI Models	MTDSNF%			MTDSNFY		
	a	b	R^2 (%)	a	b	R^2 (%)
1	9.68	-0.0006	18.55.	879.77.	-1.9883.	40.80.
2	9.67	-0.0005	18.53	842.60	-1.6978	44.38
3	9.67	-0.0005	18.31	848.83	-1.8332	49.11
4	9.68	-0.0008	18.55	867.04	-1.9883	40.80
5	9.69	-0.0005	17.89	889.09	-2.2471	29.75
6	9.67	-0.0005	18.39	853.77	-1.8247	43.46
7	9.67	-0.0005	18.38	854.61	-1.8247	44.02

MTDSNF% = monthly test day SNF%, MTDSNFY= monthly test day SNF yield a = Intercept, b = Regression Coefficient, R^2 = Coefficient of determination

The decrease in MTDSNF% and MTDSNFY for each unit change in monthly average THI values and the rate of decline ranged between -0.0005 % to -0.0008 % and -1.70 g to -2.25 g, respectively under seven different THI models. The THI model 5 indicated the maximum decline (-0.0008 %) and THI model 2 exhibited the minimum decline (-0.0005 %) in MTDF% per unit increase in THI value. The THI model 5 showed the maximum decline (-2.25 g) and THI model 2 reflected the minimum decline (-1.70 g) in MTDFY with per unit increase in THI value. This implies THI model 5 as the best temperature humidity index model for analyzing the effect of heat stress on monthly test day SNF % and monthly test day SNF yield of Murrah buffaloes.

CONCLUSION

The present study concluded that significant variability exists amongdifferent temperature humidity indices in their ability to measure heat stress affecting milk constituent traits of Murrah buffaloes. THI was found negatively associated with milk constituent traits viz; monthly test day fat% and SNF%, monthly test day fat yield and monthly test day SNF yield. The THI model [THI = $(0.55 \times T_{db} + 0.2 \times T_{dp}) \times 1.8 + 32 + 17.5$],developed by National Research Council (1971)was identified as the best THI model to assess the impact of heat stress on milk constituent traits of Murrah buffaloes after comparing seven reported THI models in a subtropical climatic conditions in Northern India indicating maximum decline in MTDF% (-0.005), MTDFY (-0.68 g), MTDSNF% (b= -0.0008) and MTDSNFY (-2.25 g) per unit rise in THI.

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