Effect of Heat Stress on Milk Production and Composition in Murrah Buffaloes

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Abstract: Temperature humidity index (THI) is widely used to assess the effect of temperature and relative humidity on performance in animals. In summer the THI was between 74 – 89 with average value of 81.18. in winter months THI ranged between 49 -70 with the average of 60. The results showed a significant effect of heat stress on daily milk yield and milk composition. In the present study the daily milk yield decreases from 4.46 to 3.65kg, heat stress reduced milk yield by 18.2%. There was a significant effect of heat stress on milk composition. Heat stress significantly reduced milk fat content from 8.3% during the winter to 7.19% during the summer. Milk protein percentage significantly decreased as a result of summer heat stress (3.08 vs.2.9 %, respectively for the winter and summer). In the present study the SNF decreases from 9.08 to 9.05 %, heat stress reduced SNF % as the THI value went from ≤ 74 to ≥ 83 in summer. Results showed that milk production is a function of THI. The negative slope of regression line indicates that milk production fat%, protein% and SNF% decreases as THI increases. This regression indicates that in general for each point increase in THI value. There was decrease in milk yield of 0.028kg per buffalo per day. Heat stress environments have been associated with depression in milk fat%, protein% and SNF%. There was decrease in milk fat of 0.046% per buffalo per day. There was also decrease in milk protein of 0.00014 % per buffalo per day. The decrease in milk SNF of 0.0047 % per buffalo per day.

Keywords: Temperature Humidity Index, Heat stress, Buffalo, Milk production.

INTRODUCTION

India is home to great biodiversity of buffalo germplasm, including the world famous Murrah buffaloes- renowned for high milk production potential. The country is host to both river and swamp types of buffaloes. The world buffalo population is estimated to be approximately 177.247 million spread in around 42 countries of which 171 million (97%) of them are found in Asia, while approximately 5.38 million (3%) are found in rest of the world (FAO, 2008). India has 98.7 millions and they number to approximately 55.7 percent of the total world buffalo population. During the last 10 years world buffalo population increased by approximately 18 million showing annual increase of about 1.13% which is mainly due to the increase in Asian countries. The percent increase in India was about 1.0% as compared to 1.09% in Asia and 2.58% in rest of the world. India is the highest producer of buffalo milk in the world producing 56 million tones of milk [1]. India produces 104 million tones milk out of 622.3 million tons per annum presently produced in the world. Thus contribution of India is 14.2 percent of total milk production of the world. The average milk production potential of buffaloes in India is approximately 1400 kg. as compared to 900 kg. in cattle including crossbreds.

Milk production is a net result of interaction of genetic potential coupled with environmental effects. The relationship between the animal and its environment determines the degree to which animal remains in thermal equilibrium with its environment [2]. The thermal environment has a strong influence on farm animals with air temperature having primary effect, but altered by wind, precipitation, humidity and radiation. The thermal environment is a major factor that negatively affects milk production of dairy animals, especially in animals of high genetic merit. Increase in physiological reactions at high temperatures will elevate heat loads of animals resulting into a decline in productivity of meat, wool, milk and draught power [3]. As the genetic relationship between production and heat tolerance is negative, continued selection for production results in decrease in heat tolerance [4]. Dairy buffaloes in many regions are subject to high ambient temperatures (Ta), relative humidity (RH) and solar radiation for prolonged periods while at stress.

The Temperature-Humidity Index (THI) is widely used in hot areas all over the world to assess the impact of heat stress on dairy animals [5] and to correlate productivity and animal discomfort. THI would more precisely describe the effect of the environment on the buffalo's ability to dissipate heat. Research on THI as an indicator of heat stress and its effects on milk production of buffaloes managed under the Indian temperate climatic conditions are limited. The objective of this study was to measure the effects of heat stress

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on milk production and composition and to examine the relationship between THI and milk yield in confined lactating buffaloes in a temperate climate in Ludhiana, Punjab.

MATERIALS AND METHODS

Experimental Animals

The Murrah buffaloes are being maintained at the Dairy Farm, GADVASU, Ludhiana under the "Network project on buffalo breeding". Buffaloes in milk both in summer (June- September) and winter (November – February) seasons in the year 2008-09 i.e. those that calved in the months of June'09 and July'09 were considered in the study. The animals were reared under normal management and feeding practices. The milk production and its composition records were collected from the production records being maintained at the Dairy Farm. The buffaloes were milked twice a day and milk yield of the individual cows was recorded at each milking on all test days. A weekly composite sample from the two milking was analyzed for protein and fat. Milk yield and milk fat percentage was used to calculate 4% fat-corrected milk (FCM).

Temperature Recording

Daily maximum and minimum temperatures and Relative Humidity (RH) were recorded at Department of Meteorology, Punjab Agricultural University (PAU), Ludhiana. Daily THI values were determined for the experimental period using the equation, THI = 1.8 × Ta – (1 – RH) × (Ta – 14.3) + 32, as described by Kibler [6] where Ta is the average ambient temperature in ^{o}C and RH is the average relative humidity.

Statistical Method

Least squares analysis [7] on raw data to find out the significance of lactation number and stage of lactation on milk yield and milk composition was done. Factors when found significant were corrected and the corrected values of milk yield, fat, protein and SNF percentage were regressed on THI (JMP 5.0)

The statistical model was:

$$y_{ijkl} = \mu + s_i + l_j + p_k + e_{ijkl}$$

Where, y_{ijkl} – Daily milk yield/fat percent/protein percent/SNF percent of l^{th} animal in i^{th} season, j^{th} lactation number and in k^{th} stage of lactation; s_i – effect of i^{th} season (i= 1 and 2); l_j – effect of j^{th} lactation number; p_k – effect of k^{th} stage of lactation; e_{ijkl} – random error NID (0, $б_e^2$). The stage of lactation was classified as, first stage: 1-100 days of milking; second stage: 101-200 days of milking and third stage: 201 days of milking and more.

RESULTS AND DISCUSSION

Environmental Conditions During the Experimental Periods

The optimal zone (thermoneutral zone) for livestock production is a range of temperatures and other environmental conditions for which the animal does not need to significantly alter behaviour or physiological functions to maintain a relatively constant core body temperature. As environmental conditions result in core body temperature approaching and/or moving outside normal diurnal boundaries, the animal must begin to conserve or dissipate heat to maintain homeostasis. This is accomplished through shifts in short-term and long-term behavioral, physiological and metabolic thermoregulatory processes [3]. The onset of thermal challenge often results in decline in physical activity and an associated decline in eating and grazing activity (for ruminants and herbivorous). Hormonal changes, triggered by environmental stress, result in shifts in cardiac output, blood flow to extremities and passage rate of digesta. Adverse environmental stress can elicit a panting or shivering response, which increases maintenance requirements of the animal and contributes to decrease in productivity.

A sudden change in temperature, either a rise in maximum temperature (T max), during summer i.e. heat wave or a fall in minimum temperature (T min) during winter i.e. cold wave; causes a decline in milk yield. Both increase in T max (more than 4 ^{o}C above normal) during summer and decline in T min (less than 3 ^{o}C than normal) during winter negatively impact milk production of crossbred cattle and buffaloes [3]. In this study the winter period was characterized by mean maximum and minimum Ta and RH of 23.07 and 9.19 ^{o}C and 96.36 and 51.54 %, respectively. In contrast, the summer period was characterized by heat stress conditions; mean maximum Ta and maximum RH were 33.03 and 25.19 ^{o}C; 89.61 and 68.19%, respectively. Mean maximum and minimum Temperature (Ta) and Relative Humidity (RH) by the experimental period are shown in Table **1**.

Temperature Humidity Index (THI) describes the effect of environment on animal's ability to dissipate

Table 1: Variation Between Summer and Winter in Temperature, Relative Humidity (RH), THI and Average Daily Milk Yield

Parameters	Period (Mean ± SE)	
	Summer	Winter
Temperature, minimum (°C)	25.19 ± 2.5	9.19 ± 3.09
Temperature, maximum (°C)	33.03 ± 2.58	23.07 ± 4.16
Average temperature (°C)	29.08 ± 2.1	16.16 ± 3.16
RH, minimum (%)	68.19 ± 13.38	51.54 ± 15.31
RH, maximum (%)	89.61 ± 5.9	96.36 ± 4.88
RH, average (%)	78.98 ± 7.79	73.96 ± 8.42
Average daily THI	81.18 ± 3.13	60.44 ± 4.8
Average daily milk yield (kg)	7.6 ± 1.74	7.92 ± 1.8

heat. Milk production in buffalo decreases when THI exceeds the critical comfort level of 72 [8]. In the present study average THI exceeded the critical comfort level (Table **1**) during test days (100%) in summer indicating that cows were exposed to heat stress during the summer trial. The presence of summer heat stress was depicted by the THI values varying between 89 and 70 from June to September. Average daily Ta, RH and THI were 16.16 and 29.08 ^{o}C; 73.96 and 78.98%; and 60.44 and 81.18 for the winter and summer periods, respectively. Day to day THI variations across each period is given in Figure **1**. Variation between days, within a period, was low as indicated by the standard deviation for each period (Table **1**).

The Effect of Heat Stress on Milk Production and Milk Composition

Least squares analysis of adjusted data of milk yield and fat % for lactation number and stage of lactation taking season as independent variable indicated that season significantly affected ($P \leq 0.01$) milk yield and fat %. The reduction in daily milk yield is a consistent response to heat stress in lactating dairy cows [9, 10]. The daily milk yield decreased from 4.46 to 3.65kg by 18.2% as the THI increased from ≤ 74 to ≥ 83 in summer. This confirmed the reported findings by Johnson *et al.* [11] which indicated that milk yield declines when THI exceeds 72. The 4 per cent drop in milk production was similar to decline noted by Mallonee *et al.* [12] and Du Preez [13].

Milk fat% decreased from 8.3 per cent during the winter to 7.19 per cent during the summer (Figure **1**). Heat stress environments have been associated with depressions in milk fat percentage [14]. However, no significant decrease in fat percentage for cows under heat stress was observed in other studies [15, 16].

Further, in the present study no significant effect ($P \geq 0.05$) on milk protein and SNF percentages was

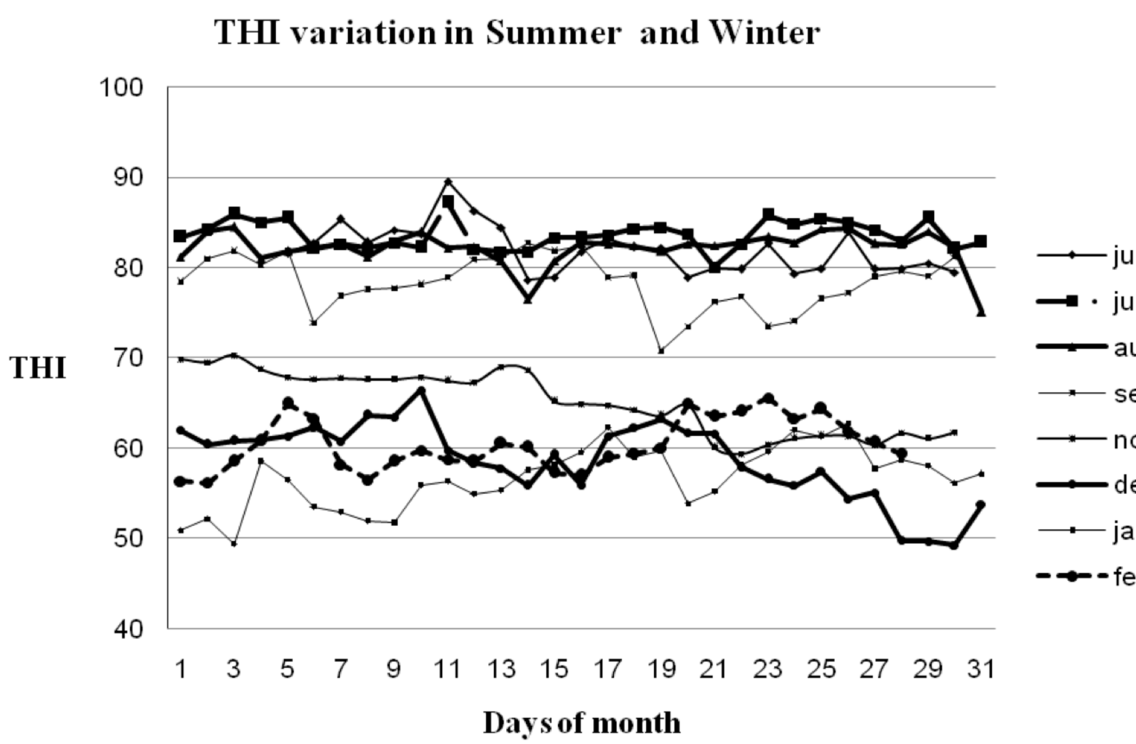

Figure 1: Day to day variation in Temerature humidity Index (THI) in Summer and Winter months.

observed as a result of summer heat stress (3.08 vs.2.9 per cent protein and 9.08 vs 9.05 per cent SNF, respectively, for the winter and summer). Our results were in line to those reported by Rodriguez *et al.* [14] and Knapp and Grummer [15] where a decreased milk protein with increased THI was observed. Studies have shown that the SNF content in June and July are rather consistently lower than in other months of the year [17].

THI-Milk Production and Milk Composition Relationship

The milk production, fat percentage, protein percentage and SNF percentage as a function of THI had a negative slope which is best expressed by the equations: Milk yield (kg per buffalo per day) = 6.167 - 0.028 THI (R^2=0.238); Milk fat (% per buffalo per day)= 11.018- 0.047 THI (R^2=0.28); Milk protein (% per buffalo per day) = 3.061-0.00014 THI (R^2= 0.053); and The milk SNF (% per buffalo per day) = 9.464 - 0.0048 THI (R^2=0.009).

These regressions indicate that in general for each point increase in THI value, there was a decrease, in milk yield of 0.028kg; in milk fat of 0.047 per cent; in milk protein of 0.00014; and in milk SNF of 0.0048 per cent per buffalo per day. The regressions of milk yield on THI and milk fat percentage on THI were significant ($P \leq 0.05$) with an R^2 of 0.172 and R^2 of 0.292, respectively. However, the regression of milk protein percentage on THI and milk SNF percentage on THI were not significant ($P \geq 0.05$) with an R^2 of 0.00011 and 0.037, respectively. The drop in milk yield in present study is lower than 0.32 and 0.26 kg per cow per day reported by Ingraham *et al.* [18] and Johnson [19] for each point increase in THI values.

CONCLUSION

Summer heat stress significantly decreased MY and milk fat, protein and SNF in lactating Murrah buffaloes. The regression equation obtained under the conditions indicates that milk yield and fat % drops by 0.028 kg and 0.047% per buffalo per day for each point increase in the value of THI above 72. Management strategies are needed to minimize heat stress and attain optimal animal productivity.

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REFERENCES

[1] FAO. Food and Agriculture Organization. Rome Italy. STAT database 2008; www.fao.org.

[2] Finch VA. An assessment of the energy budget of Boran cattle. J Therm Biol 1976; 1: 143-48. http://dx.doi.org/10.1016/0306-4565(76)90004-8

[3] Upadhyay RC, Singh SV, Ashutosh A. Impact of climate change on livestock souvenir of XXXVI. Dairy Industry Conference BHU, Varanasi 2008; 68-73.

[4] Misztal I. Model to study genetic component of heat stress in dairy cattle using national data. J Dairy Sci 1999; 82: 32. (Abstr).

[5] Ravagnolo O, Misztal I, Hoogenboom G. Genetic component of heat stress in dairy cattle development of heat index function. J Dairy Sci 2000; 83: 2120-25.

[6] Kibler HH. Environmental physiology and shelter engineering. LXVII. Thermal effects of various temperature-humidity combinations on Holstein cattle as measured by eight physiological responses. Res Bull Missouri Agri Exp Station 1964; 862.

[7] Harvey WR. Least square analysis of data with unequal subclass numbers. ARS. H-4, U.S. Department Agriculture USA 1975.

[8] Johnson HD. Environmental management of cattle to minimize the stress of climate changes. Intl J Biomet 1980; 24: 65-78.

[9] Beede DK, Coller RJ. Potential nutritional strategies for intensively managed cattle during thermal stress. J Anim Sci 1986; 62: 543-54.

[10] Mohamed ME, Johnson HD. Effect of growth hormone on milk yields and related physiological functions of Holstein cows exposed to heat stress. J Dairy Sci 1985; 68: 1123-33. http://dx.doi.org/10.3168/jds.S0022-0302(85)80938-3

[11] Johnson HD, Ragsdale AC, Berry IL, Shanklin MD. Temperature-humidity effects including influence of acclimation in fed and water consumption of Holstein cattle. University of Missouri, Research Bulletin 1963; 846.

[12] Mallonee PG, Beede DK, Coller RJ, Wilcox CJ. Production and physiological responses of dairy cows to varying dietary potassium during heat stress. J Dairy Sci 1985; 68: 1479-87. http://dx.doi.org/10.3168/jds.S0022-0302(85)80986-3

[13] Du Preez JH, Giesecke WH, Hattingh PJ. Heat stress in dairy cattle andother livestock under Southern African conditions. I. Temperature- humidity index mean values during the four main seasons, Onderstepoort. J Vet Res 1990; 57: 77-86.

[14] Rodriguez LW, Mekonnen G, Wilcox CJ, Martin FG, Krienk WA. Effects of relative humidity, maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield. J Dairy Sci 1985; 68: 973-8. http://dx.doi.org/10.3168/jds.S0022-0302(85)80917-6

[15] Knapp DM, Grummer RR. Response of lactating dairy cows to fat supplementation during heat stress. J Dairy Sci 1991; 74: 2573-79. http://dx.doi.org/10.3168/jds.S0022-0302(91)78435-X

[16] Roman-Ponce H, Thatcher WW, Buffington DD, Wilcox CJ, Van Horn HH. Physiological and production responses of dairy cattle to shade structure in a subtropical environment. J Dairy Sci 1977; 60: 424-30. http://dx.doi.org/10.3168/jds.S0022-0302(77)83882-4

[17] Griffith TW, Featherstone J. Variations in the solids-not-fat content of milk.Investigations into the nature of the solids-

not-fat problems in the East Midlands. J Dairy Res 1957; 24: 1527-32.

[18] Ingraham RH, Stanley RW, Wagner WC. Seasonal effect of the tropical climate on shaded and non shaded cows as measured by rectal temperature, adrenal cortex hormones, thyroid hormone and milk production. Am J Vet Res 1979; 40: 1792-7.

[19] Johnson HD. Physiological responses and productivity of cattle, In: Yousef MK, Ed. Stress physiology in livestock. Basic Princ 1985; 1: 4-19.

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