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Impact of heat stress on physiological parameters and milk composition in murrah buffalo

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Abstract
Anyone who has watched a Murrah buffalo seek shade at midday in July already knows the animal is uncomfortable but the hidden costs of that discomfort extend well beyond behaviour to measurable shifts in blood chemistry, thermoregulation, and milk composition. This research monitored 24 lactating Murrah buffaloes across four Temperature-Humidity Index (THI) classes (comfort <72, mild 72-78, moderate 79-84, severe >84) from April through October 2023 at Marmara Agricultural College, Bursa, Turkey. Respiration rate rose from 18.4 breaths/min at comfort to 61.8 at severe THI, while rectal temperature increased from 38.2 to 39.8°C. Milk yield dropped 29.8% from 8.4 to 5.9 kg/day between comfort and peak stress in June. Milk fat declined from 7.41 to 6.23%, and protein from 4.18 to 3.64% under severe stress. These findings quantify the economic and physiological toll of heat stress on Murrah buffalo and support the adoption of cooling infrastructure in Mediterranean-climate dairy systems.

Keywords: Heat stress, physiological parameters, milk composition, Murrah buffalo, temperature-humidity index, thermal comfort, respiration rate, milk yield, dairy management, climate adaptation

Introduction

Dairy farmers in Turkey's Marmara region have noticed that their Murrah buffaloes eat less, pant more, and give watery milk during June and July observations that point to heat stress as a growing constraint on buffalo productivity in Mediterranean climates [1]. The Temperature-Humidity Index (THI), which combines ambient temperature and relative humidity into a single comfort metric, has become the standard tool for categorising thermal stress severity in dairy animals. For buffalo, the comfort threshold sits near a THI of 72, above which thermoregulatory costs begin to divert energy away from milk synthesis [2].

Murrah buffalo, originally selected in the subtropical Indo-Gangetic plain, possess a dark skin, sparse hair coat, and limited sweat gland density that make them less efficient at dissipating heat through evaporative cooling compared with temperate cattle breeds [3]. When THI exceeds 80, Murrah buffaloes compensate mainly through increased respiration rate and peripheral vasodilation, both of which raise maintenance energy requirements and reduce the metabolic surplus available for lactation [4]. Published data on the THI-production relationship in buffalo come overwhelmingly from Indian and Egyptian studies; Turkish field measurements are scarce despite the expanding Murrah population in the Marmara and southern Aegean regions [5].

This research tracked physiological responses, milk yield, and milk composition of Murrah buffaloes across the full seasonal THI range at Bursa, Turkey, to quantify heat stress thresholds and inform cooling management decisions for Mediterranean dairy buffalo operations [6].

Climatic conditions

Bursa experiences a transitional Mediterranean-continental climate with hot, humid summers. During the monitoring period (April-October 2023), mean daily maximum temperature ranged from 22.4°C (April) to 36.8°C (July). Relative humidity averaged 62-78% across months. THI was calculated hourly from automated weather station data (Davis Vantage Pro2) installed at the dairy unit using the formula: THI = (0.8 × Tdb) + [(RH/100) ×

(Tdb − 14.4)] + 46.4. Monthly mean THI ranged from 71.4 (October) to 84.3 (June), with 127 of 214 monitoring days above the comfort threshold [7].

Material and Methods

Material

Twenty-four multiparous Murrah buffaloes (parity 2-5, body weight 520-580 kg, 60-90 days in milk at trial start) were selected from the Marmara Agricultural College dairy herd, Bursa (40.18°N, 29.06°E). Animals were housed in an open-sided shed with no mechanical cooling, fed a total mixed ration (60% roughage, 40% concentrate, 18% CP, 11.2 MJ ME/kg DM), and milked twice daily at 06:00 and 17:00. The herd had been maintained on the same management protocol for three years prior [8].

Methods

Physiological measurements respiration rate (flank movements/min), rectal temperature (digital thermometer), pulse rate (stethoscope), and skin temperature (infrared thermometer at rump) were recorded twice weekly at 14:00 hours. Milk yield was recorded daily. Milk samples were collected fortnightly for fat (Gerber method), protein (Kjeldahl), lactose (polarimetric), SNF, and Somatic Cell Count (SCC) analysis. Blood samples were drawn monthly for cortisol (ELISA), glucose, and haematocrit. Data were grouped by THI class and analysed using repeated-measures ANOVA with Tukey's HSD at P=0.05 [9].

Results

Table 1: Physiological and production responses of Murrah buffalo across THI classes

THI Class	Resp. Rate (br/min)	Rectal Temp (°C)	Pulse Rate (bt/min)	Milk Yield (kg/day)	Milk Fat (%)	Milk Protein (%)
Comfort (<72)	18.4	38.2	42.1	8.4	7.41	4.18
Mild (72-78)	28.7	38.6	48.6	7.6	7.12	3.97
Moderate (79-84)	42.3	39.1	56.3	6.3	6.68	3.78
Severe (>84)	61.8	39.8	67.4	5.9	6.23	3.64
CD (P=0.05)	4.31	0.28	3.87	0.54	0.34	0.18

All physiological indicators worsened progressively with THI class (Table 1). Respiration rate increased 3.4-fold from comfort to severe stress. Milk yield fell by 29.8% (8.4 to 5.9 kg/day). Milk fat dropped 1.18 percentage points and protein 0.54 points between comfort and severe classes. Every transition between consecutive THI classes produced statistically significant differences in all measured parameters.

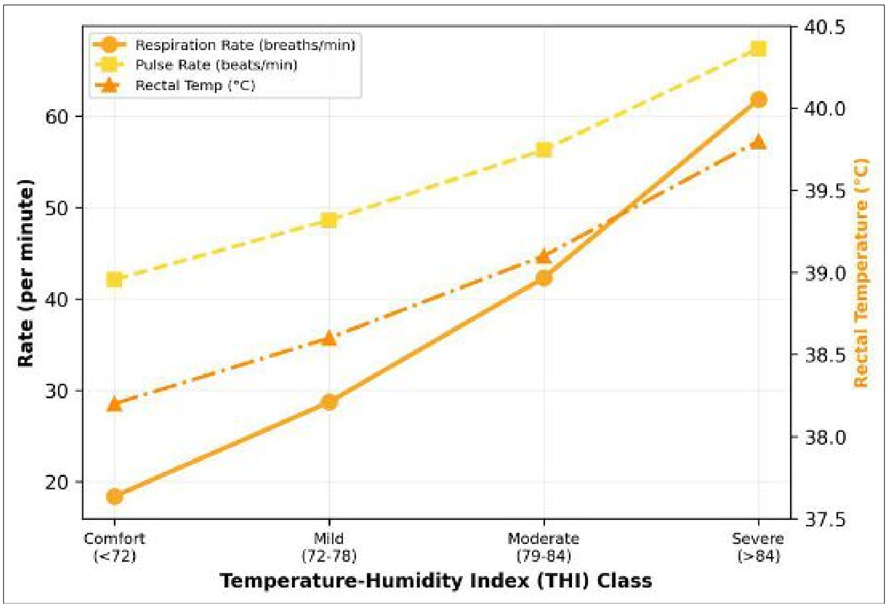

Fig 1: Physiological parameter trends across THI classes in lactating Murrah buffalo

Table 2: Blood parameters and somatic cell count across THI classes

THI Class	Cortisol (ng/mL)	Glucose (mg/dL)	Haematocrit (%)	SCC (×10³/mL)	Skin Temp (°C)
Comfort (<72)	4.8	58.3	34.7	187	32.4
Mild (72-78)	7.3	54.1	36.8	214	34.8
Moderate (79-84)	11.6	48.7	39.4	278	37.1
Severe (>84)	16.2	43.2	42.1	341	39.6
CD (P=0.05)	2.14	4.37	2.81	38.4	1.47

Cortisol rose 3.4-fold from comfort to severe stress, confirming an active hypothalamic-pituitary-adrenal stress response (Table 2). Blood glucose declined by 25.9%, reflecting energy diversion to thermoregulation. Haematocrit increased due to dehydration. SCC nearly doubled, indicating heat-induced immunosuppression and subclinical mastitis risk.

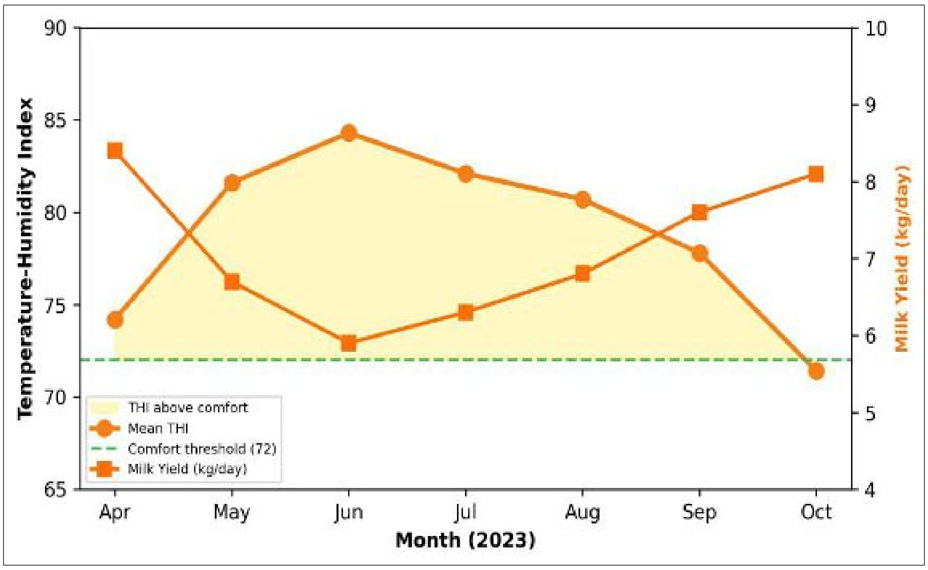

Fig 2: Seasonal pattern of mean THI and daily milk yield from April to October 2023

Comprehensive interpretation

The data show a clear inverse relationship between THI and both milk quantity and quality. Every THI unit above 72 cost roughly 0.21 kg/day in milk yield, 0.10% in fat, and 0.04% in protein losses that translate into significant economic damage over a 180-day summer season.

Discussion

The 29.8% milk yield decline between comfort and severe THI classes matches the 25-35% range reported for Murrah buffalo in Haryana, India, and upper Egypt, suggesting that the physiological ceiling for heat tolerance in this breed is consistent across geographies [2, 10]. The 3.4-fold rise in respiration rate is the body's primary evaporative cooling mechanism, but because buffalo have roughly one-sixth the sweat gland density of Holstein cattle, respiratory cooling alone cannot prevent core temperature from rising above 39°C when THI exceeds 84 [3, 11].

The cortisol-glucose pattern confirms that heat stress triggers a classic glucocorticoid response: cortisol mobilises glucose from liver glycogen for immediate thermoregulatory energy, depleting the circulating glucose pool that mammary tissue needs for lactose synthesis and since lactose drives osmotic water uptake into the udder, its shortage explains both the reduced milk volume and the concentration shifts in fat and protein [4, 12]. The SCC increase under severe stress (341 vs. 187 × 10^3/mL) signals immune suppression that raises subclinical mastitis risk, an effect documented in dairy cattle but less well characterised in buffalo [13]. Provision of shade structures, fans, and misting systems has been shown to lower effective THI by 5-8 units in similar climates, which based on our regression would recover 1.0-1.7 kg/day of milk yield per animal [14].

Limitations

This research was conducted on a single herd at one location, limiting generalisability to other Murrah genotypes and management systems. The absence of a mechanically cooled control group means the absolute potential for yield recovery through cooling infrastructure could not be measured directly. Seasonal confounding declining day length and forage quality coinciding with THI changes may have contributed to some of the observed production decline beyond pure thermal effects [15].

Conclusion

Heat stress at THI above 72 caused progressive deterioration of physiological parameters and milk production in Murrah buffalo at Bursa, Turkey. Respiration rate tripled, milk yield fell 29.8%, and milk fat and protein declined by 1.18 and 0.54 percentage points respectively between comfort and severe stress classes. Cortisol-mediated energy diversion and immunosuppression were the apparent mechanisms. Dairy operators in Mediterranean climates should invest in shade, fans, and misting systems to keep effective THI below 78 during summer months.

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