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Comparative evaluation of dietary supplementation with turmeric, aloe vera, moringa and shatavari for mitigation of heat stress and improvement of production parameters in lactating Murrah buffaloes

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Abstract

Heat stress is a major constraint to buffalo production in tropical and subtropical regions, particularly in high-yielding river buffaloes such as Murrah-graded buffaloes. Owing to their dark skin, sparse sweat glands, thick epidermis, and high metabolic heat production associated with lactation, these animals possess limited thermoregulatory capacity and are therefore highly susceptible to thermal stress. Exposure to elevated ambient temperature and humidity results in reduced feed intake, altered physiological and metabolic functions, increased oxidative stress, compromised immune responses, and significant declines in milk yield and milk quality. Consequently, effective nutritional interventions are required to alleviate the adverse effects of heat stress and sustain productive performance. The present study was undertaken to evaluate the efficacy of selected herbal supplements as natural dietary additives for mitigating heat stress and improving milk production, milk composition, and overall physiological resilience in lactating Murrah-graded buffaloes under varying thermal conditions.

Fifty second-parity Murrah graded buffaloes, producing on an average 8.2 kg milk/day, 8.3% milk fat, and 10.5% solids-not-fat (SNF) during non-heat stress season, were selected during the summer season and randomly allocated into five groups (n = 10 per group). Group I served as the control and was maintained under ambient environmental conditions without herbal supplementation. Groups II, III, IV, and V received dietary supplementation of turmeric (*Curcuma longa*), aloe vera (*Aloe barbadensis*), shatavari (*Asparagus racemosus*), and moringa (*Moringa oleifera*), respectively. Productive responses associated with heat stress were monitored throughout the experimental period of 31 days.

Herbal supplementation significantly improved thermal adaptability and production performance compared with the control group. Moringa supplementation exhibited the highest efficacy, effectively eliminating detectable signs of heat stress and restoring production parameters to normal ranges. Buffaloes receiving moringa recorded the greatest improvement in milk yield and milk composition, followed by Shatavari, aloe vera, and turmeric. Improvements were reflected through enhanced milk fat and SNF percentages, indicating better nutrient utilization and metabolic stability under thermal stress conditions. The control group showed persistent manifestations of heat stress and comparatively lower productive performance.

The findings suggest that herbal feed additives can serve as sustainable, economical, and farmer-friendly strategies for heat stress mitigation in buffaloes, with *Moringa oleifera* emerging as the most promising phyto-genic intervention for maintaining productivity and milk quality under hot environmental conditions.

Keywords: Heat stress, Murrah graded buffalo, *Moringa oleifera*, shatavari, aloe vera, turmeric, milk yield, milk composition, phyto-genic feed additives

Introduction

Buffaloes contribute significantly to the dairy economy of many tropical and subtropical countries, particularly India, which possesses the largest buffalo population in the world (Darji, *et al.*, 2024) [4]. Buffalo milk is highly valued due to its higher fat, protein, and total solids content (Chen *et al.*, 2024) [14]. However, buffaloes are highly susceptible to heat stress because of their dark skin colour, sparse hair coat, lower density of sweat glands, and limited capacity for evaporative cooling (Jasinski *et al.*, 2023) [17]. Under conditions of elevated ambient temperature and humidity, buffaloes experience considerable physiological stress, leading to reduced feed intake, impaired metabolic functions, compromised immune responses, and decreased milk production (Rashid *et al.*, 2024) [16].

Heat stress has emerged as a major challenge to sustainable buffalo production owing to climate change and the increasing frequency of heat waves (Sejian *et al.*, 2018) [18]. When the Temperature-Humidity Index (THI) exceeds the comfort threshold, buffaloes exhibit increased rectal temperature, respiration rate, pulse rate, and oxidative stress (Polsky & Keyserlingk 2017) [28]. These physiological alterations disrupt endocrine and metabolic homeostasis, resulting in reduced nutrient utilization and productivity. Economic losses associated with heat stress include decreased milk yield, fat and SNF% and reduced overall farm profitability (Gujar *et al.*, 2023) [19].

Conventional approaches to alleviate heat stress, such as cooling systems, fans, sprinklers, foggers, and wallowing facilities, are often expensive and difficult to implement for smallholder farmers (Das *et al.*, 2016) [23]. Consequently, there is growing interest in natural and cost-effective nutritional interventions that can enhance the resilience of dairy animals to thermal stress (Wang *et al.*, 2024) [33]. Medicinal plants and herbal feed additives have gained considerable attention due to their antioxidant, anti-inflammatory, adaptogenic, immunomodulatory, and metabolic regulatory properties (Biswas *et al.*, 2024) [22].

Turmeric (*Curcuma longa*) is widely recognized for its bioactive compound curcumin, which possesses potent antioxidant and anti-inflammatory activities (Kunnumakkara *et al.*, 2017) [27]. Curcumin has been reported to scavenge free radicals, reduce lipid peroxidation, improve immune function, and protect tissues from oxidative damage induced by environmental stressors. Supplementation of turmeric may therefore help maintain physiological stability and improve productivity in heat-stressed buffaloes (Biswas *et al.*, 2024) [22].

Shatavari (*Asparagus racemosus*) is an important medicinal herb in traditional Indian medicine and is considered a natural adaptogen (Sharma *et al.*, 2021) [31]. It contains steroidal saponins, flavonoids, and polyphenolic compounds that enhance stress tolerance, improve immune competence, and support endocrine balance (Alok *et al.*, 2013) [21]. Previous studies have demonstrated that shatavari supplementation can improve feed utilization, health status, and productive performance in livestock exposed to environmental stress (Chawla *et al.*, 2022).

Aloe vera (*Aloe barbadensis* Miller) is rich in vitamins, minerals, polysaccharides, amino acids, and antioxidant compounds (Surjushe *et al.*, 2008) [32]. The plant exhibits anti-inflammatory, immunomodulatory, and antimicrobial properties (Sahu *et al.*, 2013) [29]. Aloe vera supplementation has been reported to improve digestive efficiency, enhance nutrient absorption, and reduce physiological stress responses (Surjushe *et al.*, 2008) [32]. Its antioxidant activity may help mitigate cellular damage caused by excessive heat exposure (Choi & Chung 2021) [20].

Moringa (*Moringa oleifera*) is often referred to as a "miracle tree" due to its exceptional nutritional and medicinal value (Sebola, *et al.*, 2019) [30]. The leaves are rich in proteins, essential amino acids, vitamins, minerals, and natural antioxidants such as flavonoids and phenolic compounds (Falowo *et al.*, 2018) [25]. Moringa supplementation has been associated with improved feed intake, enhanced immune function, better antioxidant status, and increased milk production in dairy animals (Khan & Wang 2024). Its ability to counteract oxidative stress makes

it a promising dietary intervention for animals subjected to high environmental temperatures (Falowo *et al.*, 2018) [25].

Although individual studies have reported beneficial effects of these herbal supplements in livestock, information regarding their comparative efficacy in alleviating heat stress in buffaloes remains limited. Therefore, the present study was undertaken to evaluate the effects of dietary supplementation with turmeric, Shatavari, aloe vera, and moringa on productive performance of heat-stressed buffaloes. It was hypothesized that supplementation with these medicinal herbs would improve thermotolerance, reduce stress-induced physiological alterations, and enhance productive performance during periods of elevated environmental temperature.

Materials and Methods

Study area, context and Design

The present study was conducted in Hardoi district, Uttar Pradesh, India. The district is located in the central Gangetic plains and is characterized by a subtropical monsoon climate with hot summers and a humid rainy season. During the summer months (May-June), ambient temperatures frequently range between 40°C and 46°C, accompanied by intense solar radiation and occasional heat waves, resulting in substantial thermal stress in livestock. Relative humidity remains moderate during early summer and increases progressively with the approach of the monsoon. Consequently, the Temperature-Humidity Index (THI) often exceeds the critical threshold for dairy buffaloes, indicating severe heat stress conditions (GOI 2025) [26].

A total of 50 healthy lactating Murrah graded buffaloes in their second parity were selected for the study. All experimental animals were clinically healthy and maintained under similar managemental conditions. At the commencement of the experiment during non-heat stress conditions, the buffaloes produced an average milk yield of 8.2 kg/day, with mean milk fat and solid-not-fat (SNF) contents of 8.3% and 10.5%, respectively.

Throughout the experimental period, all animals were provided with a uniform basal ration formulated to meet their maintenance and production requirements. The concentrate mixture consisted of maize/barley/wheat (35 parts), mustard cake or groundnut cake (25 parts), wheat bran (35 parts), mineral mixture (2 parts), common salt (1 part), and dicalcium phosphate (DCP) or limestone powder (2 parts). In addition to the concentrate mixture, animals had free access to clean drinking water and were managed according to standard dairy husbandry practices.

A total of 50 lactating Murrah graded buffaloes were randomly allocated into five experimental groups comprising 10 animals each. Group I served as the control and was maintained under ambient environmental conditions without any herbal supplementation. Animals in Group II, Group III, Group IV, and Group V received dietary supplementation of turmeric (*Curcuma longa*), aloe vera (*Aloe barbadensis*), shatavari (*Asparagus racemosus*), and moringa (*Moringa oleifera*), respectively under ambient environmental conditions. The experiment was conducted for a period of 31 consecutive days during the peak summer season (may 2026), and productive responses associated with heat stress were monitored throughout the study.

Ambient temperature (°C) and relative humidity (%) were recorded three times daily, in the morning, afternoon, and evening, using a calibrated digital thermo-hygrometer. The

Temperature-Humidity Index (THI) was calculated for each observation using the following equation:

$$\text{THI} = (1.8T + 32) - [(0.55 - 0.0055\text{RH}) \times (1.8T - 26)]$$

where T represents ambient temperature (°C) and RH denotes relative humidity (%).

The daily THI value was obtained by averaging the morning, afternoon, and evening THI measurements. Subsequently, the mean THI for the experimental period was calculated from the daily THI values and used as an indicator of the degree of thermal stress experienced by the animals.

Sample collection

Milk yield was recorded individually for each buffalo on a daily basis throughout the 31-day experimental period. Animals were milked twice daily (morning and evening), and the average daily milk yield was calculated as the mean

of the morning and evening milk yields. Group-wise average milk yield was subsequently determined by averaging the daily milk production data of the ten buffaloes within each treatment group over the entire study period.

Milk composition analysis was performed at weekly intervals. Representative pooled milk samples, comprising proportional aliquots from the morning and evening milkings, were collected from each animal and analysed for milk fat and solid-not-fat (SNF) percentages using a calibrated electronic milk analyser. Weekly values obtained for each animal were averaged to derive treatment-wise mean fat and SNF percentages for the experimental period. These parameters were used to evaluate the effects of herbal supplementation on milk production and composition in lactating Murrah graded buffaloes subjected to severe heat stress conditions.

Herbal additive preparation and administration

Herb	Preparation of herbal Powder	Dose rate
Turmeric (<i>Curcuma longa</i>)	Clean rhizomes were sliced, shade-dried for 7-10 days, grinded into fine powder. Mixed with basal ration	75 gm powder/day/animal
Shatavari (<i>Asparagus racemosus</i>)	Roots were washed thoroughly, sliced into small pieces, shade-dried, grinded into powder. Mixed with basal ration.	125 gm powder/day/animal
Moringa (<i>Moringa oleifera</i>)	Mature leaves were collected, shade-dried to preserve nutrients, grinded into leaf powder. Mixed with basal ration.	200 gm leaf powder/day/animal
Aloe vera (<i>Aloe barbadensis</i>)	Fresh leaves, were harvested and spines and outer rind, was removed gel was collected, dried at 50-60°C in hot air oven and then grinded into powder. Mixed with basal ration.	125 gm powder/day/animal

All the herbs were fed for 31 consecutive days.

Statistical analysis

Two-way ANOVA was applied to evaluate the effects of herbal supplementation on milk yield, fat percentage, and SNF percentage in heat-stressed buffaloes. The analysis tested the main effects of treatment (herbal supplements) and heat stress category, as well as their interaction, on each response variable. Results were interpreted to determine whether supplementation significantly influenced production and milk composition traits under heat stress conditions. Significance was declared at $P < 0.05$, and highly significant effects were considered at $P < 0.01$ and $P < 0.0001$, as appropriate.

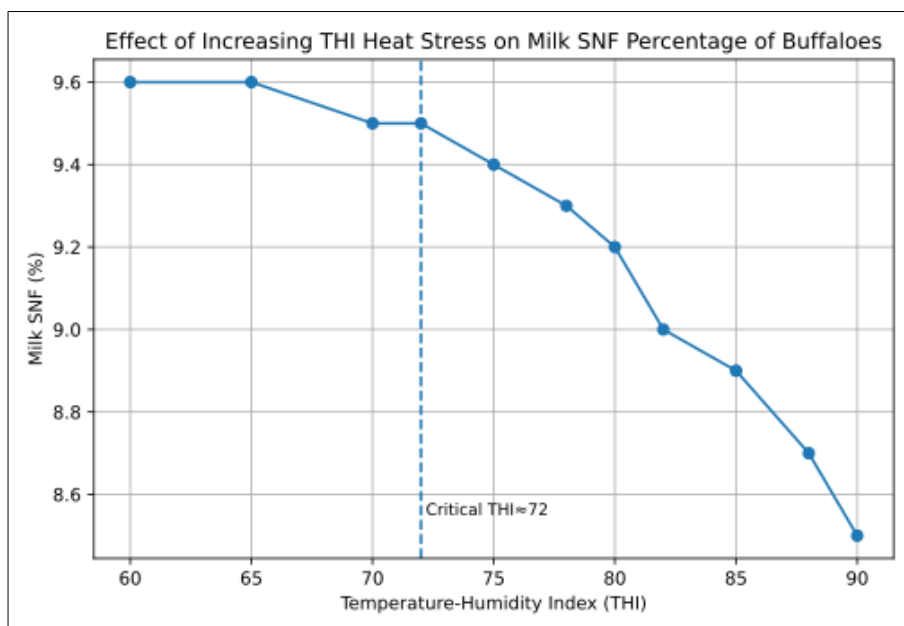
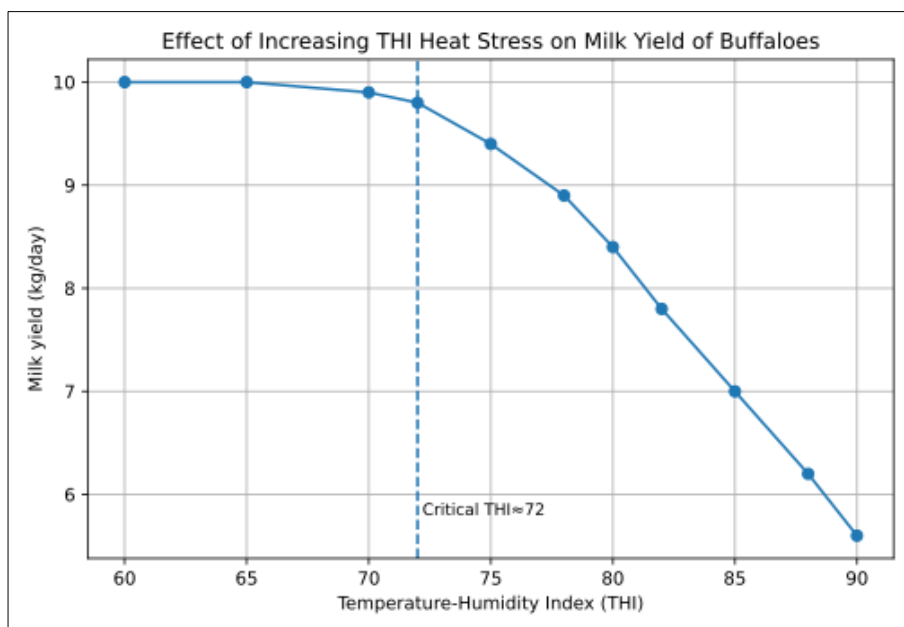
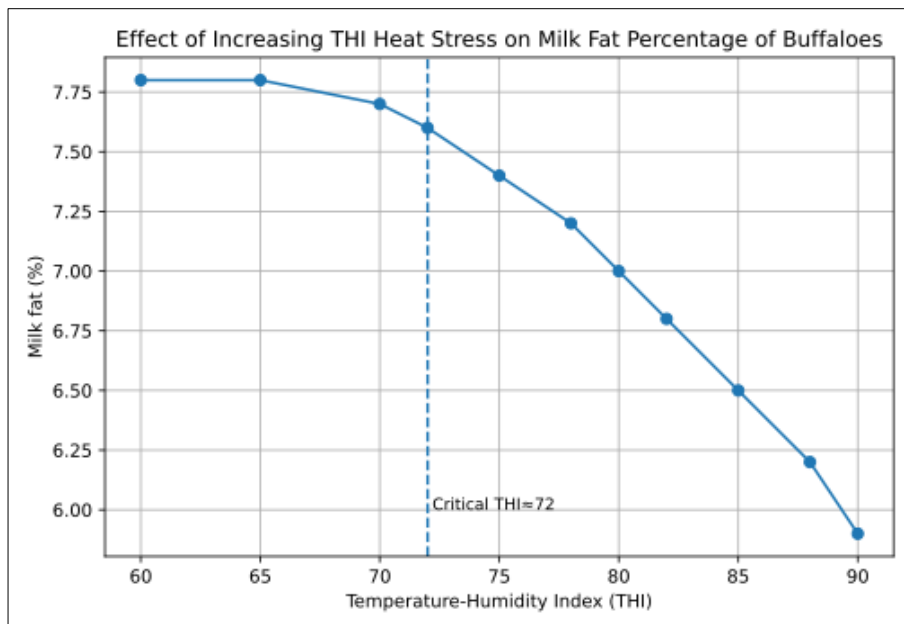
Results and Discussion

The average Temperature-Humidity Index (THI) recorded during the month of May in Hardoi district, Uttar Pradesh,

was categorized into four levels, namely low, moderate, high, and severe (Dash *et al.*, 2021) [24].

THI Range	Category
≤ 75	Low
75.1-80	Moderate
80.1-85	High
> 85	Severe

These environmental conditions exposed the experimental Murrah graded buffaloes to varying degrees of heat stress, which adversely affected milk yield and milk composition. Effect of increasing Temperature-Humidity Index (THI) on milk yield, milk fat percentage, and solids-not-fat (SNF) percentage in lactating Murrah-graded buffaloes. Increasing THI is associated with progressive declines in milk yield and milk quality traits, indicating the adverse impact of heat stress on productive performance.



To evaluate the potential ameliorative effects of herbal feed additives under different THI conditions, dietary supplementation with Turmeric (*Curcuma longa*), Aloe vera (*Aloe barbadensis*), Shatavari (*Asparagus racemosus*), and Moringa (*Moringa oleifera*) was administered and compared with an un-supplemented control group.

The effects of treatment, THI level, and their interaction on milk yield, milk fat percentage, and solids-not-fat (SNF) percentage were analysed using a two-way analysis of variance (ANOVA). The statistical model assessed the main effects of dietary treatment and THI category, as well as the interaction between these factors. The results obtained from the analysis are presented below.

Table 1: Effect of herbal supplementation on milk fat percentage

Treatment	Milk fat (%) (Mean $\pm$ SE)
Control	6.86 $\pm$ 0.10
Aloe vera	7.51 $\pm$ 0.07
Turmeric	7.51 $\pm$ 0.07
Shatavari	7.93 $\pm$ 0.04
Moringa	8.11 $\pm$ 0.05

Milk fat percentage was significantly influenced by both herbal supplementation and THI category. Two-way ANOVA showed a highly significant effect of treatment ($P < 0.0001$) and THI category ($P < 0.0001$), whereas the treatment $\times$ THI interaction was non-significant ($P > 0.05$). Among the treatments, Moringa supplementation resulted in the highest fat percentage (8.11 $\pm$ 0.05%), followed by Shatavari (7.93 $\pm$ 0.04%), Turmeric (7.51 $\pm$ 0.07%) and Aloe vera (7.51 $\pm$ 0.07%), while the Control group recorded the lowest value (6.86 $\pm$ 0.10%). Fat percentage decreased progressively with increasing THI, with the highest values observed under low THI conditions (7.94 $\pm$ 0.13%) and the lowest under severe THI conditions (7.35 $\pm$ 0.11%).

The present findings are consistent with previous reports indicating that phytochemical supplementation enhances milk fat percentage in dairy cattle and buffaloes. Supplementation with *Moringa oleifera* has been associated with improved rumen fermentation efficiency and increased acetate availability, thereby supporting higher milk fat synthesis in crossbred cows and buffaloes (Dong *et al.*, 2019) [3]. Similarly, improvements in milk composition following *Asparagus racemosus* (Shatavari) supplementation have been reported in dairy animals, where enhanced lactogenic activity and metabolic modulation were observed (Kumar *et al.*, 2011; Muwal *et al.*, 2020) [5, 1].

The significant decline in milk fat percentage with increasing THI is strongly supported by heat stress physiology studies demonstrating that elevated THI reduces dry matter intake, alters rumen volatile fatty acid profiles, and decreases acetate production, ultimately suppressing de novo fatty acid synthesis in the mammary gland (Liu *et al.*, 2017) [2]. Recent large-scale analyses further confirm that heat stress can reduce milk yield and alter milk composition in dairy systems globally, particularly in tropical regions (Rashid *et al.*, 2024) [16].

The non-significant treatment $\times$ THI interaction observed in the present study suggests that herbal supplementation improved baseline metabolic efficiency but did not differentially modify milk fat responses under varying thermal stress conditions. It may be due to selection of short period of 31 days.

Table 2: Effect of herbal supplementation on milk yield

Treatment	Milk yield (kg/day) Mean $\pm$ SE
Control	6.48 $\pm$ 0.11
Aloe vera	7.39 $\pm$ 0.06
Turmeric	7.52 $\pm$ 0.06
Shatavari	7.93 $\pm$ 0.04
Moringa	8.11 $\pm$ 0.05

Two-way ANOVA revealed significant effects of treatment ($P < 0.0001$) and THI category ($P < 0.0001$) on milk yield. However, the interaction between treatment and THI category was not significant ($P > 0.05$). Moringa supplementation resulted in the highest milk yield (8.11 $\pm$ 0.05 kg/day), followed by Shatavari (7.93 $\pm$ 0.04 kg/day), Turmeric (7.52 $\pm$ 0.06 kg/day) and Aloe vera (7.39 $\pm$ 0.06 kg/day), whereas the Control group recorded the lowest yield (6.48 $\pm$ 0.11 kg/day). Milk yield decreased significantly as THI increased, indicating the adverse effects of heat stress. Herbal supplementation effectively ameliorated the decline in milk production associated with elevated THI.

Our findings align with well-established evidence that increasing THI depresses milk yield due to reduced feed intake and altered endocrine responses. Similar reductions in production under heat stress were reported by West (2003) [10] and by Dikmen & Hansen (2009) [8], who observed significant declines in milk yield with rising THI in dairy cattle. (Bouraoui *et al.*, 2002 & Chen *et al.*, 2024) [7, 14] also demonstrated a negative linear relationship between THI and milk production.

The ameliorative effect of herbal supplementation is partially supported by studies reporting improved lactation performance with phytochemical additives. Moringa-based supplementation has been associated with enhanced nutrient utilization and milk yield improvement in ruminants (Fahey, 2005; Taiwo & Aye 2013) [9, 6]. However, evidence for herbs such as Shatavari and Aloe vera remains limited and species-dependent, indicating variability across studies. Overall, the present results are consistent with literature confirming heat stress impairment and potential benefits of phytochemical interventions.

Table 3: Effect of herbal supplementation on milk SNF percentage

Treatment	SNF (%) Mean $\pm$ SE
Control	8.86 $\pm$ 0.07
Turmeric	9.09 $\pm$ 0.09
Aloe vera	9.46 $\pm$ 0.05
Shatavari	9.53 $\pm$ 0.05
Moringa	9.53 $\pm$ 0.06

Two-way ANOVA revealed significant effects of treatment ($P < 0.0001$) and THI category ($P < 0.0001$) on milk SNF percentage. However, the interaction between treatment and THI category was non-significant ($P > 0.05$). The highest SNF values were observed in the Moringa (9.53 $\pm$ 0.06%) and Shatavari (9.53 $\pm$ 0.05%) groups, followed by Aloe vera (9.46 $\pm$ 0.05%), Turmeric (9.09 $\pm$ 0.09%), and the Control group (8.86 $\pm$ 0.07%). SNF percentage declined significantly with increasing THI, with the lowest values recorded under severe heat stress conditions. Herbal supplementation effectively ameliorated the adverse effects of heat stress on milk quality, as reflected by improved SNF percentages across all THI categories.

Similar improvements in milk solids-not-fat have been reported with *Moringa oleifera* supplementation, attributed to its rich profile of antioxidants, vitamins, and bioavailable minerals that enhance rumen fermentation and nutrient utilization (Kholif *et al.*, 2015) ^[13]. Likewise, Shatavari (*Asparagus racemosus*) has been associated with improved metabolic efficiency and lactational performance due to its phytoestrogenic and adaptogenic properties (Singh *et al.*, 2023) ^[15].

The positive response observed with Aloe vera supplementation aligns with findings suggesting its bioactive compounds improve gut health and nutrient absorption, indirectly supporting milk solids synthesis (Barman *et al.*, 2017). Similarly, the moderate improvement observed with Turmeric (*Curcuma longa*) may be attributed to curcumin-mediated antioxidant and anti-inflammatory effects, which mitigate oxidative stress induced by elevated THI (Akbarian *et al.*, 2016) ^[11].

The decline in SNF percentage with increasing THI is in agreement with the established literature indicating that heat stress reduces feed intake, alters endocrine regulation, and impairs mammary nutrient uptake, ultimately lowering milk solids (Chen *et al.*, 2024) ^[14]. However, the ability of herbal supplementation to maintain higher SNF levels across THI categories suggests a buffering effect against heat-induced metabolic disturbances.

Overall, these results reinforce the hypothesis that phytogenic feed additives enhance thermotolerance and sustain milk quality in heat-stressed buffaloes.

Parameter	THI Effect	Treatment Effect	Interaction
Milk yield	Significant	Significant	Non-significant
Fat%	Significant	Significant	Non-significant
SNF%	Significant	Significant	Non-significant

Source of Variation	Milk Yield	Fat (%)	SNF (%)
Treatment	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
THI Category	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Treatment $\times$ THI	NS ($P > 0.05$)	NS ($P > 0.05$)	NS ($P > 0.05$)

References

1. Muwal H, Rai DC, Bhateshwar V, Meena JP, Lal D. Effect of Shatavari root powder (*Asparagus racemosus*) supplementation on milk composition of Sahiwal crossbred cows. Journal of Animal Research. 2020;10(3):411-415.

2. Liu Z, Ezernieks V, Wang J, Arachchillage NW, Garner JB, Wales WJ, *et al.* Heat stress in dairy cattle alters lipid composition of milk. Scientific Reports. 2017;7(1):961.

3. Dong L, Zhang T, Diao Q. Effect of dietary supplementation of *Moringa oleifera* on the production performance and fecal methanogenic community of lactating dairy cows. Animals. 2019;9(5):262.

4. Darji M, Gupta JP, Brahmkshtri BP, Saha S, Mohapatra SK, Chaudhari J, *et al.* Estimation of the threshold for heat stress and genetic features for milk yield in Mehsana buffaloes in India. Journal of Thermal Biology. 2024;123:103931.

5. Kumar S, Mehla RK, Gupta AK, Sharma V, Meena RK, Dandi RL, *et al.* Effect of herbal feed supplement Shatavari (*Asparagus racemosus*) on milk production and composition in crossbred cows. Indian Journal of Animal Sciences. 2011;81(4):420.

6. Taiwo MK, Aye PA. Growth Performance and Economic Analysis of West African Dwarf Goats fed *Moringa oleifera* and Cotton Seed Cake as Protein Supplements to *Panicum maximum*. American Journal of Food and Nutrition. 2013;3(2):58-63.

7. Bouraoui R, Lahmar M, Majdoub A, Djemali MN, Belyea R. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research. 2002;51(6):479-491.

8. Dikmen S, Hansen PJ. Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? Journal of Dairy Science. 2009;92(1):109-116.

9. Fahey JW. *Moringa oleifera*: a review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. Trees for Life Journal. 2005;1(5):1-15.

10. West JW. Effects of heat-stress on production in dairy cattle. Journal of Dairy Science. 2003;86(6):2131-2144.

11. Akbarian A, Michiels J, Degroote J, Majdeddin M, Golian A, De Smet S. Association between heat stress and oxidative stress in poultry; mitochondrial dysfunction and dietary interventions with phytochemicals. Journal of Animal Science and Biotechnology. 2016;7(1):37.

12. Bernabucci U, Lacetera N, Baumgard LH, Rhoads RP, Ronchi B, Nardone A. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal. 2010;4(7):1167-1183.

13. Kholif AE, Gouda GA, Morsy TA, Salem AZM, López S, Kholif AM. *Moringa oleifera* leaf meal as a protein source in lactating goat's diets: feed intake, digestibility, ruminal fermentation, milk yield and composition, and its fatty acids profile. Small Ruminant Research. 2015;129:129-137.

14. Chen L, Thorup VM, Kudahl AB, Østergaard S. Effects of heat stress on feed intake, milk yield, milk composition, and feed efficiency in dairy cows: A meta-analysis. Journal of Dairy Science. 2024;107(5):3207-3218.

15. Singh N, Garg M, Prajapati P, Singh PK, Chopra R, Kumari A, *et al.* Adaptogenic property of *Asparagus racemosus*: Future trends and prospects. Heliyon. 2023;9(4):e14857.

16. Rashid M, Aboshady HM, Agamy R, Archimede H. Milk production and composition in warm-climate regions: a systematic review and meta-analysis. Tropical Animal Health and Production. 2024;56(8):382.

17. Petrocchi Jasinski F, Evangelista C, Basiricò L, Bernabucci U. Responses of dairy Buffalo to heat stress conditions and mitigation strategies: a review. Animals. 2023;13(7):1260.

18. Sejian V, Bhatta R, Gaughan JB, Dunshea FR, Lacetera N. Adaptation of animals to heat stress. Animal. 2018;12(s2):s431-s444.

19. Gujar G, Tiwari M, Yadav N. Heat stress adaptation in cows-Physiological responses and underlying molecular mechanisms. Journal of Thermal Biology. 2023;118:103740.

20. Choi S, Chung MH. A review on the relationship between *Aloe vera* components and their biologic

- effects. *Seminars in Integrative Medicine*. 2003;1(1):53-62.
21. Alok S, Jain SK, Verma A, Kumar M, Mahor A, Sabharwal M. Plant profile, phytochemistry and pharmacology of *Asparagus racemosus* (Shatavari): A review. *Asian Pacific Journal of Tropical Disease*. 2013;3(3):242-251.
22. Biswas S, Ahn JM, Kim IH. Assessing the potential of phytogetic feed additives: A comprehensive review on their effectiveness as a potent dietary enhancement for nonruminant in swine and poultry. *Journal of Animal Physiology and Animal Nutrition*. 2024;108(3):711-723.
23. Das R, Sailo L, Verma N, Bharti P, Saikia J, Imtiwati, *et al*. Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World*. 2016;9(3):260-268.
24. Dash SK, Chakravarty AK, Singh A, Upadhyay A, Singh M, Yousuf S. Delineation of temperature-humidity index (THI) as indicator of heat stress in riverine buffaloes (*Bubalus bubalis*) of a sub-tropical Indian region. *Cell Stress and Chaperones*. 2021;26(4):657-669.
25. Falowo AB, Mukumbo FE, Idamokoro EM, Lorenzo JM, Afolayan AJ, Muchenje V. Multi-functional application of *Moringa oleifera* Lam. in nutrition and animal food products: A review. *Food Research International*. 2018;106:317-334.
26. Government of India. About District Hardoi. District Administration Hardoi, Uttar Pradesh; 2025.
27. Kunnumakkara AB, Bordoloi D, Padmavathi G, Monisha J, Roy NK, Prasad S, *et al*. Curcumin, the golden nutraceutical: Multitargeting for multiple chronic diseases. *British Journal of Pharmacology*. 2017;174(11):1325-1348.
28. Polsky L, Von Keyserlingk MA. Invited review: Effects of heat stress on dairy cattle welfare. *Journal of Dairy Science*. 2017;100(11):8645-8657.
29. Sahu PK, Giri DD, Singh R, Pandey P, Gupta S, Shrivastava AK, *et al*. Therapeutic and medicinal uses of *Aloe vera*: A review. *Pharmacology & Pharmacy*. 2013;4(8):599-610.
30. Sebola NA, Mlambo V, Mokoboki HK. Chemical characterisation of *Moringa oleifera* (MO) leaves and the apparent digestibility of MO leaf meal-based diets offered to three chicken strains. *Agroforestry Systems*. 2019;93(1):149-160.
31. Sharma H, Parihar G, Verma P. Adaptogenic and immunomodulatory role of medicinal plants used in Ayurveda: A review. *Journal of Herbal Medicine*. 2021;28:100443.
32. Surjushe A, Vasani R, Saple D. *Aloe vera*: a short review. *Indian Journal of Dermatology*. 2008;53(4):163-166.
33. Wang J, Deng L, Chen M, Che Y, Li L, Zhu L, *et al*. Phytogenic feed additives as natural antibiotic alternatives in animal health and production: A review of the literature of the last decade. *Animal Nutrition*. 2024;17:244-264.