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Heat Stress in Dairy Cows: A Comprehensive Examination of Wellbeing, Milk Yield, Sexual Health

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Abstract

The welfare and productivity of cows can be negatively impacted by heat stress (HS), a significant issue in the dairy industry. Cows have limited evaporative cooling capacity, leading to increased respiration rates, reduced feed intake, decreased milk production, and impaired reproductive function. Strategies to reduce HS include providing cool water, air, shade and changing management practices. This study investigated 30 review papers on HS in dairy cows published between 2019 and 2023. This research examines the welfare of dairy cows, focusing on factors such as housing, food, and medical treatments. It explores the relationship between milk production and cow wellbeing and the potential implications for sustainable farming methods. The study also examines the impact of HS on milk production, reproductive health, and herd management. The Temperature Humidity Index (THI) categorizes HS severity, with higher values resulting in lower milk production and reproductive efficiency. The study emphasizes the importance of immediate cooling action to reduce financial losses in the dairy industry. Proactive measures are needed to strengthen dairy farming systems' resistance to climate change, ensuring the righteous optimization of cow health and productivity. The research advocates for a holistic approach to dairy farming that prioritizes cow health, milk production, and sexual health. Preventative measures, such as improving diet, housing, and disease control, are recommended.

Keywords: Temperature Humidity Index (THI), Heat Stress (HS), Cow's Health, Milk Production

INTRODUCTION

Over 1.3 billion people are employed in agriculture and animal husbandry, which accounts for 40% of Gross domestic product (GDP); the United Nations (UN) projects a sharp growth in the world population. The food sector is pressured to balance animal welfare, output, and the environment since the demand for livestock products is predicted to triple (1). With further rises of 0.3 to 4.8°C, the intergovernmental panel on climate change verified that the global temperature had increased by 1.5°C. Climate change will affect agricultural productivity, water quality, pasture availability, soil fertility, vectors, diseases, and parasites(2). When animals are subjected to bad weather, they gradually build up excess heat and show signs such as decreased feed intake, decreased nutrient utilization, and developing ruminal diseases. Reduced growth and production losses result from days to weeks of physiological and metabolic adaptation to HS(3). THI values greater than 68 cause HS in nursing animals, decreasing the overall and individual milk components produced. Generally speaking, dairy cattle have a faster metabolic turnover than beef cattle, and crossbreds' decreased genetic improvement makes them less resilient to HS. Higher milk production rates put nursing calves at risk for metabolic depletion, which increases their vulnerability to HS(4). In addition, milk production is predicted to decrease by 1.4 and 1.9 kg/day by the 2050s and 1980s, respectively, with economic losses estimated at 1.7 billion and 2.2 billion in the US (united states) alone, based on mathematical models that examine climate and milk production features. The dairy industry relies heavily on the total milk production and

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reproductive performance of herds, making comprehensive understanding of climate-production interactions crucial (5). Over time, our understanding of HS impacts animal production and well-being has grown substantially. Research on the consequences of climate change on economies and industrial systems was conducted in developed nations so more than in developing ones(6).The welfare of dairy cows is investigated in this study, with particular attention paid to housing, feeding, and medical care. Its goal is to examine the connection between cow welfare and milk output and any possible ramifications for environmentally friendly agricultural practices. Analysis of the dairy sector from various angles is very much needed. Table (1) represents the HS on dairy cows based on the THI.

Table (1). THI effects of HS in dairy cows (Source: https://www.e-jarb.org/journal/view.html?uid=2645&vmd=Full**)**

THI	HS categorization	Effects of HS
<72	none	Maximum efficiency in terms of production and reproduction
72-78	mild	Dairy cows look for shade, which causes their breathing to quicken and their blood vessels to dilate.
79-88	moderate	Both the rate of breathing and saliva production rise. Reduction in the quantity of feed and water utilized. Cattle have a decrease in their reproductive efficiency and an increase in body temperature.
89-98	severe	Respiration is rapidly rising and saliva production is high. Significantly less animal reproduction occurs.

HEALTH EFFECTS OF HS ON DAIRY COWS

HS impacts Dairy Cows' health through direct or indirect impacts on normal metabolism, physiology, hormones, and immune systems. Dairy cows' physical and emotional well-being depends on various factors, including adequate nourishment, cozy living quarters, and access to clean water. Immunizations, disease control, and preventive healthcare are crucial(7). A major measure of productivity, milk output is influenced by diet, heredity, and general health. The financial viability of dairy farming and the welfare of the animals are enhanced by tracking and optimizing milk output(8). Reproductive success depends on sexual health, and sustaining a viable dairy herd requires appropriate breeding management, which includes artificial insemination and reproductive health monitoring. Figure (1) shows the dairy cow's noticeable and unseen consequences.

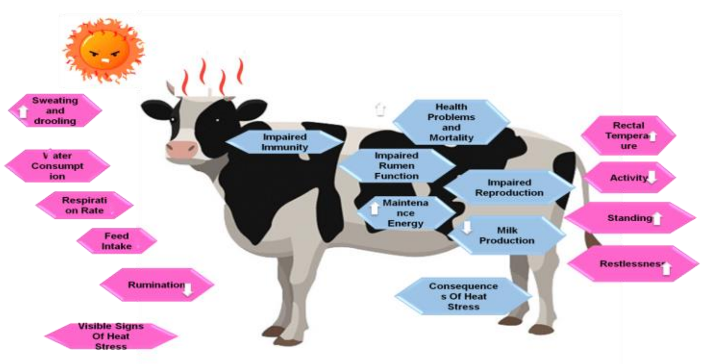

Figure (1). Visible and invisible effects of the dairy cow (“Source**:** https://www.researchgate.net/figure/Visible-signs-and-consequences-of-heat-stress-in-dairy-cows_fig2_343356698”)

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EXAMINING THE EFFECT ON WELFARE

Dairy cows are particularly vulnerable to HS because it impairs their capacity to control body temperature, which increases the likelihood of heat-related diseases and causes discomfort. In addition to its physiological impacts, HS alters behavior, interfering with daily routines, including eating, sleeping, and socializing. Heat-stressed cows show symptoms of distress, such as panting and fast breathing, which adds their general discomfort(9). Implementing techniques to reduce HS, such as providing sufficient shade, appropriate ventilation, and access to cold water sources, must address well-being and guarantee that the cows can sustain their ideal physical and behavioral health even in harsh weather circumstances(10). Figure (2) shows dairy cows' standing and resting behaviors during HS depending on the hour.

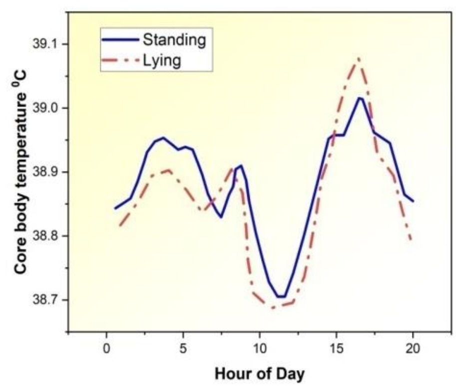

Figure (2). Dairy cows' standing and resting behavior ("Source: https://www.sciencedirect.com/science/article/pii/S0022030214007164")

Behavioral differences

Farm management determines the quality of living conditions for cows. Therefore, farmers must take action to reduce and mitigate detrimental stresses. Access to pasture improves the welfare of dairy cows by allowing for better grazing, longer lying and resting periods, and less aggressiveness. Cows kept in freestall barns sleep 12–14 hours a day, eat 3.5 hours, spend 2.5–3.5 hours outside the cage, socialize for 2-3 hours, and drink 30 minutes(11). However, their time allotment may change based on the surroundings and management structure. Cows on pasture sleep 8.3–9.8 hours a day, graze 8.3–9.0 hours a day, and sleep 9.7–11.3, respectively.Cows on pasture sleep 8.3–9.8 hours a day, graze 8.3–9.0 hours a day, and sleep 9.7–11.3, respectively. Cows in tie stalls sleep for 25% of the time they lie down 3–4 hours a day in little bursts of 3–5 minutes(12). Reductions in the ideal laying time of cows can harm their wellbeing and wellbeing. Table (2) and Figure (3) demonstrate the Dairy cows' changed actions under heat.

Table (2). Dairy cow's behavior changes in HS("Source:https://sciendo.com/article/10.2478/aoas-2020-0116")

Behaviors	Decrease (%)	Increase (%)
Lying Time	98	31
Shade seeking	2	95
Time to standing	10	90

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Feed Intake	96	20
Vocalization	60	30
Dry Matter Intake	80	22

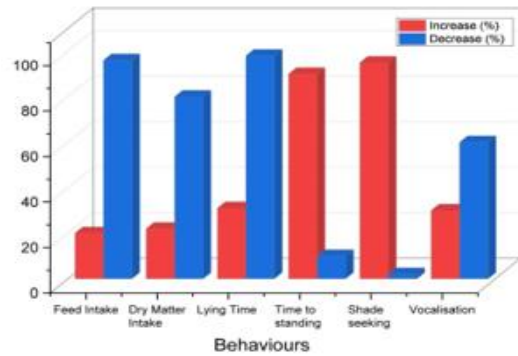

Figure (3). Behavior changes of dairy cows in HS("Source**:https://sciendo.com/article/10.2478/aoas-2020-0116")**

Feeding habits and drinking water

Cows in high-stress circumstances consume less feed; the most typical alterations are in dry matter intake, eating time, and ruminating time. An eight-year trial on two groups of Holstein Friesian cows did not support the idea that high-producing cows exhibit a higher decrease in feed intake. When HS is milder, the efficiency of turning DMI into milk rises, but it falls off quickly as HS gets more severe(13). After three weeks of heat, the DMI decrease is less, indicating that cows can acclimate. A dry period's thermal conditions are also important since HS reduces DMI by 0.7 kg/d.Any time during the dry season, cows exposed to HS had lower milk, protein, and lactose outputs during the next lactation. While data from behavioral monitoring indicates that water absorption rises during hot periods,Chilling might increase milk yield at the beginning of the dry season(14). Cattle under HS tend to plant more, drool more, and sweat more than usual, but they also tend to urinate and defecate less frequently. Figure (4) and (5) demonstrates the level of water intake and DMI in HS.

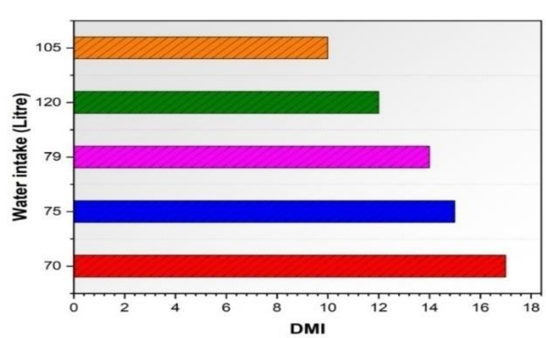

Figure (4). Behavior Differences in the quantity of water consumed("Source:
https://sciendo.com/article/10.2478/aoas-2020-0116")

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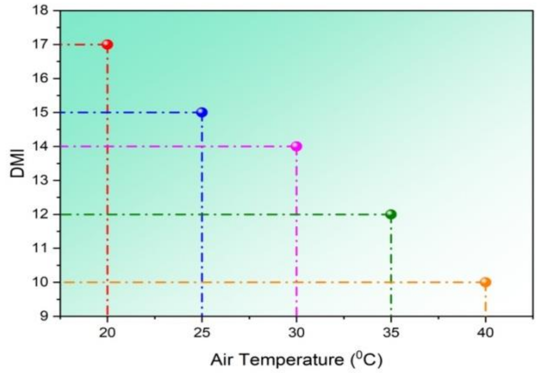

Figure (5). Behavior Differences in the quantity of DMI(“Source: https://sciendo.com/article/10.2478/aoas-2020-0116”)

EXAMINING THE EFFECT ON MILK YIELD

An examination of the variables affecting a dairy cow's productivity is necessary to determine the impact on milk output. The influence of several factors on the quantity and quality of milk produced is examined, including nutrition, health, environmental circumstances, and management techniques(15). Variations in feed intake, metabolism, and the cow's general health are taken into account since these factors might directly impact milk production. The well-being of the dairy herd and the effectiveness of the whole dairy business are ensured by the monitoring and evaluating of these elements (16), which enable the implementation of measures to improve milk output.

Reduced Milk Production and Substances in Diary

A decade of developments in nutrition, technology, biotechnology, and genetic development has resulted in 12% increase in milk output per cow in the United States. However, HS is becoming a major problem as dairy cows in the Southeast of the United States experience for over half of the year. This results in a loss of up to 2,072 kg of milk output per cow year(17). The summer months when somatic cell counts rise, which might more incidences of mastitis. For the whole US dairy industry, this decline in milk output results in an annual profit loss of 1.2 billion.Producers must recognize the signs of HS immediately and take appropriate cooling measures to reduce financial output losses(18). The stage of lactation significantly influences the degree of HS and the volume of milk loss. A drop in milk output can also result from seasonal calving since some farmers choose to calves their herds at different times of the year to avoid the summer when lactation peaks.

Components of diary

HS in dairy cows can affect milk composition, with some studies showing a decrease in total protein and fat yield. However, the effects on milk fat and protein percentages could be more consistent. HS-affected cows can have 9.7% less milk fat in their milk; milk protein and nonfat solids can decrease. Many authors have reported varied changes in the protein and fat composition as a result of HS, including an increase, decrease, or no change at all (19). Changes in milk fat percentage linked to HS are likewise uneven. Although the exact mechanisms causing the reduction in milk protein output due to HS are mostly unclear, they include several different biological systems.When compared to pair-fed thermo-neutral cows, heat-stressed cows had a 17% lower milk yield, a 4.1% lower milk protein, and a 23% lower 4% fat-corrected milk yield. Variability in study results can a sign that other

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factors, like nutrition, lactation stage, HS level, experimental model employed, refrigeration facilities, and duration of treatment, have an impact on the differences displayed (20). To validate the several theories on the reason for the changes in milk fat, more investigation is required and protein contents due to HS. Figure (6) explores the factors that influence DHI's SCC and test-day milk yield groups in the US.

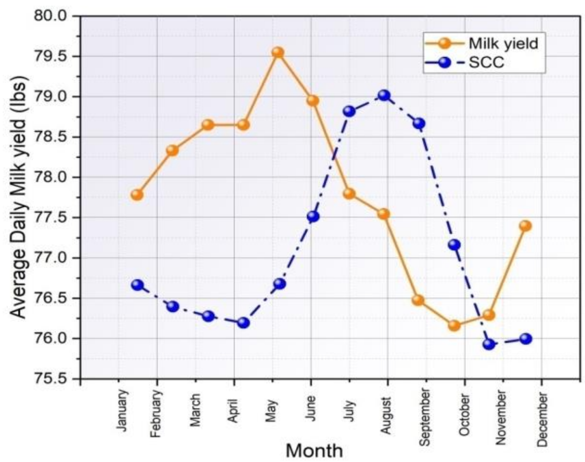

Figure (6). Determinants of SCC and test-day milk yield(“Source:https://www.sciencedirect.com/science/article/pii/S0022030220303829”)

Investigating the Impact on Sexual Health

The influence of HS on many elements of dairy cow reproduction is highlighted in this study. It was discovered that HS impacted anestrus, a condition that affects 18% of cows, especially in mild and moderate situations. Anestrus can be caused by breed, age, parity, and milk production. Estrus and calving rates showed seasonal changes, with breeding efficiency increasing in Can and June and dropping in the summer(21). The study also explores the effects of HS on Repeat Breeding Syndrome, finding an incidence of 14.1% in general and 21.5% under mild stress.The results, however not statistically significant, point to the necessity of farmer awareness, particularly in the context of intermediate HS conditions. With an overall abortion incidence of 4.3%, HS also affects the reproductive health of cows. This rate canbe impacted by breed, age, parity, and milk output. There was a documented incidence of dystocia, affected by HS conditions; elements that contributed to this were calf birth weight, cow age, gestation length, and environmental factors(22). The climate, particularly in the winter, was linked to greater dystocia rates because people were more alert and physically active then. The study's findings highlight the intricate interactions between HS and other variables affecting dairy cow reproductive success. In figure (7) and table (3) depicts the HS’s consequences include dystocia, abortion, anestrus, and the retained placenta.

Table (3). Effects of HS on anestrus, retained placenta, abortion, dystocia, and anestrus (“Source: https://www.e-jarb.org/journal/view.html?uid=2645&vmd=Full”)

Impact of HS	Total values
Anestrus	14.3

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Repeat Breeding	14.2
Abortion	405
Dystocia	18.9

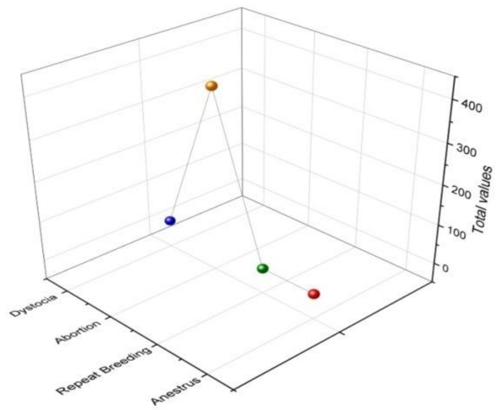

Figure (7). Impact of HS on dystocia, abortion, anestrus, retained placenta, and anestrus ("Source: https://www.e-jarb.org/journal/view.html?uid=2645&vmd=Full")

Reproductive challenges during HS

HS greatly impacts crop fertility, which can result in early embryonic demise, decreased follicular function, and lower estrus detection rates. Particularly affected are the ovarian follicle and the contained egg; on the day of estrus, an extra point on the temperature-humidity index results in a 0.1 mm reduction in follicle size. Additionally, HS causes damage to the cytoplasm, which alters the shape, function, and relative position of ooplasmic organelles, particularly mitochondria(23). These alterations are most noticeable in oocytes derived from Bostaurus. Nonetheless, Bosindicus oocytes maintain their developmental competence following an HS shock. The oocyte is harmed by carryover effects from summer HS to autumn fertility, which amplifies reproductive losses from seasonal HS.The term "carryover" describes two months of milder autumnal temperatures when fertility is below wintertime levels of reproductive activity. A heat-stressed follicle or egg will have a lower chance of successful fertilization and even less chance of developing into a healthy embryo if cows are artificially inseminated just before ovulation(24). Reducing the harmful effects of HS on the antral follicle carrying the oocyte can accomplished by cooling dry cows close to the end of gestation. When bulls are used for breeding, the negative effects of HS on fertility are amplified in production systems.

Effects of Reproductive Hormones on Heat Stress

Progestron and Estradiol

Progestrone and estradiol-17, hormones that control reproductive tract function, can be secreted in response to heat stress. Heat stress's impact on plasma progesterone concentration is debatable; some research indicates that it has no effect and delays luteolysis (25). Dairy cows experience extreme heat stress in the summer. Blood progesterone concentrations are up, lowered, or unaltered in other investigations. Unrestrained fluctuations in other variables influencing blood estrogen levels, such as the kind of heat stress and variations in dry matter consumption, might cause these discrepancies. Decreased levels of progesterone in plasma can affect fertility by causing faulty oocyte maturation, premature embryonic demise, and unsuccessful implantation. Pregnancy rates vary depending on whether endogenous progesterone is supplemented with exogenous progesterone post-insemination. However, in medium in size follicles generated by extreme heat, poor oestradiol synthesis by cells in granulose and high estrogen levels in the fluid inside the follicle can be associated with early atresia (26).Lower luteinizing hormone (LH) levels and a decrease in the dominant follicle of choice are consistent with this. According to recent investigations, heat stress can result in a decrease in peripheral estradiol-17 concentrations from day 4 through day eight and an increase from day 1 through day 4 of the estrous cycle. Exposure to chronic heat stress over an extended period is more likely than severe heat stress to lower the amount of estrogen in the fluid that surrounds the follicle.

Inhibin, luteinizing hormone (LH), and folicle-stimulating hormone (FSH)

Heat stress affects gonadotrophins and gonadotrophin-releasing hormone (LH) released by the anterior pituitary gland. Peripheral blood LH concentrations vary; varying studies show increased or unaltered levels. Under heat stress, cows' LH pulse frequency and amplitude both drop. Most evidence indicates that heat stress reduces LH levels, which reduces fertility and estradiol release (27). Decreasing amounts of plasma inhibin were observed in heat-stressed cows and buffaloes in India.Cattle that are under heat stress have higher FSH levels; this might be because their damaged follicles are producing less plasma inhibitor. However, heat-stressed cows had a decreased FSH response after receiving a GnRH mimic. Further investigation will be needed to ascertain the entire impact (28). Low LH concentrations might not be overcome by increased FSH, limiting the availability of androgen precursors to synthesize estradiol.

Corticostroids and gonadotrophins

The hypothalamo-pituitary-adrenal axis and sympathoadrenal system are triggered by heat stress, which stimulates the anterior pituitary gland'scorticotrophs. In reaction to heat stress, these corticotrophs generate peptides derived from pro-opiomelanocortin, such as melanocyte-stimulating hormone, endorphin, and ACTH. ACTH stimulates the adrenal glands' cortex to produce and secrete glucocorticoids, such as cortisol. Raised levels of adrenalin in calves during extreme temperatures can influence the lethal hormone (LH) since cortical has been associated with an inhibitory impact on the generation of LH by the anterior pituitary in cattle subspecies (29).Glucocorticoids can inhibit gonadotrophin secretion by sheep, pigs, and dairy cows. Nevertheless, a decrease in gonadotrophin synthesis is not always associated with a rise in glucocorticoid release, particularly in acute stress. Chronic stress situations make reproduction more likely, and various species can show variable levels of glucocorticoid suppression of the release of LH and FSH (30).

Androstenedion

The heat stress can reduce androstenedione production in cal cells but not estradiol-17 synthesis. The reason for this drop is unknown, and no signs of alterations in mRNA content are associated with heat exposure. Nevertheless, given the marked decrease in LH-stimulated androstenedione production, LH receptor activity canimpact by exposure to heat. In the fluid inside of the predominant follicle, Heat exhaustion elevated testosterone and lowered estrogen-17 concentrations from day 3 to day 5 during the period.

DISCUSSION

The study looks into how HS affects dairy cows.Focusing on their welfare, milk yield, and sexual health. It uses the THI to categorize the severity of HS, revealing distinct effects at different THI levels. The study emphasizes the health effects of HS on dairy cows' metabolism, physiology, hormones, and immune systems, which are linked to factors like nutrition, living conditions, and access to clean water. Immunizations, disease control, and preventive healthcare are crucial for maintaining optimal cow health. The correlation between cow health and milk output is explored, emphasizing the need for tracking and optimizing milk production to enhance both the financial viability of dairy farming and the welfare of the animals. Behavioral changes induced by HS reveal the vulnerability of dairy cows to this stressor, with disruptions in daily routines and visible signs of distress. Strategies to mitigate HS include providing shade, proper ventilation, and access to cold water. The study also discusses the impact of HS on feeding habits and water intake, revealing alterations in dry matter intake and eating time during high-stress circumstances. The study underscores the importance of timely cooling measures and potential acclimation of cows to HS, providing insights into strategies for maintaining milk efficiency during challenging periods. The study also examines the effects of HS on milk yield, revealing a substantial reduction in production and changes in milk composition. Inconsistencies in research findings prompt further exploration into the mechanisms underlying these changes. The study concludes with an investigation into the profound effects of HS on sexual health, detailing its impact on anestrus, breeding efficiency, and reproductive challenges. The intricate interactions between HS and other variables affecting reproductive success highlight the need for farmer awareness and proactive interventions.

CONCLUSION

In summary, the effects of HS on dairy cows are complex and affect their overall health, milk production, and sexual health. The observed alterations in behavior and physiology amid high temperatures provide serious problems for the animals' general well-being. Due to decreased feed intake and changes in milk composition, HS hurts milk production and necessitates careful management techniques to minimize financial losses.In addition, HS's effects on hormones and reproductive function highlight how critical it is to address sexual health issues in dairy herds. Maintaining the health and output of dairy cows in the face of harsh weather requires a comprehensive strategy that considers dietary changes, environmental changes, and medical procedures. To mitigate the negative impacts of HS on dairy cattle, a thorough investigation of these interrelated factors is necessary.Future research on heat stress in dairy cows should focus on improving the health of the animals, maximizing milk production, and addressing any possible effects on sexual health to create resilient and sustainable dairy farming methods.

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