Chapter 5

HEAT STRESS IN DAIRY CATTLE

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INTRODUCTION

Livestock products are an important component of global food security, as they provide 17 % of the world's kilocalories consumption and 33 % of protein consumption[1]. Genetic selection combined with improved feeding and housing systems for dairy cows has led to an increase in milk yield of more than 400 % over the last century. A cow producing 45 kg of milk per day needs 4 times the total energy it needs to survive. An elite cow producing 90 kg of milk per day needs 7 times more total energy than she needs for the body, the rest goes to ensure productivity. Consequently, feed energy efficiency is much higher for an elite cow than for a cow 100 years ago. As animal productivity increases, the need for a large number of lactating cows to produce milk per capita disappears and the net income per cow increases[2].

Global warming on the planet is causing great concern about providing food for the ever-growing population of the Earth. These impacts are mainly driven by rising temperatures, atmospheric carbon dioxide (CO_2) concentrations, precipitation, and a combination of these factors.

It's not just that animals overheat, but their productivity and reproduction levels decrease. There is also a huge problem of growing forage crops, equipping irrigated pastures with canopies from solar radiation, and balancing animal diets from local feed resources. Absolutely all species of wildlife inhabiting a given ecosystem undergo adaptation to climate change. A huge number of species are on the verge of extinction, leaving a given location or

[1] Rosegrant, M. W.; Fernandez, M.; Sinha, A.; Alder, J.; Ahammad, H.; de Fraiture, Charlotte; Eickhour, B.; Fonseca, J.; Huang, J.; Koyama, O.; Omezzine, A. M.; Pingali, P.; Ramirez, R.; Ringler, C.; Robinson, S.; Thornton, P.; van Vuuren, D.; Yana-Shapiro, H. Looking into the future for agriculture and AKST. IN: McIntyre, B. D.; Herren, H. R.; Wakhungu, J.; Watson, R. T. (Eds.). International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD): Agriculture at a Crossroads, global report. Washington, DC, USA: 2009. Island Press. pp.307–376.

[2] VandeHaar, M. J., & St-Pierre, N. Major advances in nutrition: Relevance to the sustainability of the dairy industry. *Journal of dairy science*, 2006. 89 (4), 1280–1291.

appearing, migrating through the optimal temperature environment for the species.

The animal world, like the plant world, is very sensitive to environmental temperature. You can often find migration of certain species of wild animals associated with seasonal temperature changes. The shift in traditional migration routes of wild animals due to climate change has a significant impact on the biological security of entire regions[3].

Temperature influences most critical livestock production factors such as water availability, product production, livestock reproduction and health. Feed quantity and quality are affected by a combination of rising temperatures, CO_2 emissions and fluctuations in precipitation. The increase in livestock diseases is mainly influenced by rising temperatures and fluctuations in precipitation. It is believed that a 2 °C increase in temperature will have a negative impact on pastures and livestock production in arid and semi-arid regions and a positive impact in humid temperate regions[4].

1. Impact of climate change on the agroecosystem and dairy farming

Today, climate remains the most important factor influencing the productivity of farm animals. However, in countries with developed industrial livestock farming, indoor microclimate control systems have long been used. The use of a free-range system or technology that involves grazing animals is extremely sensitive to climate change. The use of complete isolation of productive animals significantly reduces, or makes impossible, the direct influence of variable factors (feed quality; temperature changes, thermal migration of species; the emergence of new pathogenic and quarantine species; etc.), however, the question arises of the economic feasibility and vulnerability of such production.

Livestock farming technologies in different ecosystems are absolutely dependent on the climatic conditions of the region and are determined by economic feasibility. Livestock production in hot semi-arid environments is mostly extensive. The productive potential of animals in these ecosystems is mainly determined by current climatic conditions. Livestock grazing in hot semi-arid zones faces large variations in the quantity and quality of suitable

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[3] Carlson, C. J., Albery, G. F., Merow, C., Trisos C. H., Zipfel C. M., Eskew E. A., Olival K. J., Ross N., Bansal S. Climate change increases cross-species viral transmission risk. *Nature*. 2022. 607. P. 555–562. https://doi.org/10.1038/s41586-022-04788-w

[4] Melissa Rojas-Downing M., Pouyan Nejadhashemi A., Timothy Harrigan, Sean A. Woznicki, Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*. 2017. Vol. 16. P. 145–163. URL: https://doi.org/10.1016/j.crm.2017.02.001

pasture, feed and drinking water available. Animals often have to travel long distances in search of these limited resources during the hot summer months[5].

In addition to the additional temperature load on the body, a productive animal during the extensive production of animal husbandry products receives a number of other influencing factors related to its nutrition, motor activity, reproduction and rearing of young. Therefore, all these factors are indivisible and have a complex effect not only on the body as a whole, but also on the intensity of food production.

2. Thermal homeostasis and its regulation

The increase in global temperature (by approximately 1.2 °C) decreased by an hour, during which the great horned thinness is lost in thermal comfort zones. The deep core temperature for European lactating cows, which should be thermoneutral, ranges from – 0.5 °C to 20 °C[6], that is, the vologicity of the temperature is obvious from 40 % to 60 %[7, 8].

The environmental temperature above which an organism must increase evaporative heat loss to maintain heat balance is called the upper critical temperature (UCT). The skin and its derivatives or additional structures, which are called the integumentary system, provide a physical barrier and antimicrobial protection, include thermo- and immunoregulation, excretion, secretion, pigmentation, sensation and movement of the animal, and also ensure the effective entry and release of heat from an organism[9].

The body temperature of warm-blooded animals is regulated by the central nervous system, which, by maintaining a balance between the formation of endogenous heat, external heating and the release of heat into the environment, ensures a constant body temperature[10]. The oxidation of

[5] Sejian V., Bhatta R., Gaughan J., Dunshea F., & Lacetera, N. Review: Adaptation of animals to heat stress. *Animal*. 2018. 12 (S2). S. 431-S444. doi:10.1017/S1751731118001945

[6] West, J. W. Effects of heat-stress on production in dairy cattle. *Journal of dairy science*. 2003. 86 (6). 2131–2144.

[7] Manzoor, A., Maqbool, I., Ganaie, Z. A., Afzal, I., Khan, H. M., & Zaffe, B. Mitigating winter vagaries in dairy animals: A review. Int. J. Vet. Sci. Anim. Husbandry. 2019. 4 (1), 01–05

[8] Frigeri, Karen Dal' Magro, Kariane Donatti Kachinski, Nédia de Castilhos Ghisi, Matheus Deniz, Flávio Alves Damasceno, Matteo Barbari, Piotr Herbut, and Frederico Márcio Corrêa Vieira. "Effects of Heat Stress in Dairy Cows

[9] Visha, P., Das, P. K., Mukherjee, J., Banerjee, D. (2023). Special Senses. In: Das, P. K., Sejian, V., Mukherjee, J., Banerjee, D. (eds) Textbook of Veterinary Physiology. Springer, Singapore. https://doi.org/10.1007/978-981-19-9410-4_12..

[10] Lim, Chin Leong. Fundamental Concepts of Human Thermoregulation and Adaptation to Heat: A Review in the Context of Global Warming. *International Journal of Environmental Research and Public Health.* 2020. no. 21: 7795. https://doi.org/10.3390/ijerph17217795.

metabolites in mitochondria provides mammals with a huge amount of energy, which is divided into chemical (metabolism) and thermal (homeothermy)[11].

Thermoregulation is carried out with the help of physiological, morphological and behavioral mechanisms. Body temperature regulates the speed of chemical reactions in the organism, and an increase in temperature accelerates them, and a decrease in temperature slows them down[12].

Heat dissipation in the environment by cattle occurs through a number of physiological mechanisms: conduction, convection, radiation; evaporation[13]. Radiation is the transfer of energy in the form of electromagnetic waves. Convection is the transfer of heat due to the volumetric movement of molecules in fluids (liquids and gases, not solids). Heat transfer by convection depends on the temperature of the surface of the animal, the temperature of the liquid in contact with the surface of the animal, the area of the contact surface and the speed of air movement. Conduction is the movement of energy through solid matter (from hot to cold) and occurs as a result of collisions and the transfer of energy from more energetic to less energetic molecules. Conduction occurs in rigid bodies, liquids and gases. Evaporation is the movement of molecules from the surface of a liquid into the air as the molecules change from the liquid phase to the gas phase. The phase change requires energy, which is taken from the evaporating surface, thereby cooling it[14].

Highly productive dairy cow must dissipate the additional heat generated by increased anabolic processes, making them less able to maintain body temperature and more susceptible to heat stress[15, 16].

In highly productive dairy cows, the return of heat shock is reduced by 9.0–13.5 % due to increased emissions, by 20–25 % due to evaporation and by 67.5 % due to conduction and convection.

Rectally measuring the core temperature of cattle is one of the main ways to determine the animal's health, but requires the animal to be contained and

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[11] Andrea Kurz. Physiology of Thermoregulation, Best Practice & Research Clinical Anaesthesiology. Vol. 22. Is. 4, 2008. P. 627–644. URL: https://doi.org/10.1016/j.bpa.2008.06.004.П.

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[16] Polsky, L., & von Keyserlingk, M. A. Invited review: Effects of heat stress on dairy cattle welfare. *Journal of dairy science*. 2017. 100 (11), 8645–8657.

must be performed manually. New methods for determining temperature measurements are being developed, one of which is subcutaneous temperature sensors[17]; internal recorders that arev swallowed by animals[18], or skin sensors with different clamps are also used.

Loss of thermal energy through evaporation is the only mechanism for reducing an animal's core temperature when the ambient temperature is higher than body temperature[19] .

Typically, in the thermal comfort zone, physiological thermoregulatory mechanisms ensure the maintenance of homeostasis[20] and optimal levels of performance. However, as cow productivity increases and endogenous heat production increases, it is necessary to ensure efficient heat transfer, thus ensuring their welfare. In general, the concept of animal welfare is greatly underestimated, and not only considering the zone of their thermal comfort. Ensuring the well-being of animals makes it impossible to manifest heat stress with its classic symptoms. Although, in our opinion, global warming causes corresponding physiological changes in productive animals as well, by selecting them for sensitivity to heat stress and the ability to ensure the maximum level of productivity in adverse conditions. Different behavioral types of cattle should also be taken into account[21].

Thermal homeostasis can be will described as:

$$HG - HL = \triangle Tbody \times cp \times m^{22},$$

where HG = heat input (from metabolism, activity and environment),

HL = heat loss (to the environment), $\triangle$Tbody – is a change in body temperature,

cp – specific heat capacity of the body (3,47 кДж кг −1 °K −1), m – body weight (kg).

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[17] Breukers, T. Assessing surgically implanted temperature sensors to measure body temperature in dairy calves during individual-and group period (Master's thesis, Eesti Maaülikool). Tartu 2022. 54.

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The relationship between heat input and loss can also be expressed in the form of a heat balance equation:

$$HS = M \pm HCD \pm HCV \pm HRAD - HER - HES,$$

where HS – this is pure heat stored in the body,

M – metabolic heat production, HCD – heat Transfer by Conduction,

HCV – heat transfer by convection,

HRAD – heat transfer by radiation,

HER – is the loss of heat through evaporation in the respiratory tract,

HES – is the loss of heat due to evaporation due to sweating.

3. Heat stress of dairy cows

Cattle are very sensitive to high temperatures, especially dairy cows. One danger is heat stress. It should also be taken into account that the modern high-yielding dairy cow generates a significant amount of metabolic heat due to the increased need for nutrients and active fermentation in the rumen (the largest section of the 4-chamber stomach of ruminants) and high milk productivity. Essentially, she has a super-intense metabolism that far exceeds normal levels. Vulnerability of livestock to heat stress varies by species, genetic potential, life stage, management or production system and feeding features[23].

Thermostability was defined as a cellular adaptation caused by a single sublethal exposure to heat, allowing the organism to survive the subsequent impact of lethal heat stress[24]. This definition of heat resistance was based on the protective effects of heat shock proteins on cellular structures from lethal heat stress after a single exposure to sublethal heat stress, the so-called heat shock response[25].

Adaptations to the livestock production process include switching to more heat-resistant breeds and providing shade, ventilation and cooling. Production losses from heat stress are estimated at $39.94 billion per year until the end of the century[26].

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If we talk about a general biological definition, then according to modern concepts, thermal stress (hot or cold) is an adaptive reaction that triggers adaptive mechanisms that depend on genetic and epigenetic modifications, physiological plasticity, as well as behavioral and social factors[27].

Heat stress in cows is a condition of the body that occurs under the influence of keeping animals in an environment whose temperature exceeds the upper limit of the optimum. Ambient temperature and humidity, wind speed, solar radiation and access to water determine the amount of heat stress cows experience. Lactating dairy cows exhibit various mechanisms of adaptation to excessive temperatures, which partly alleviate the thermal balance between heat input and output, but also account for reduced performance. Reduced milk production is the most recognized effect of heat stress on dairy cows and results in significant economic losses for dairy producers[28].

Veterinary doctors have long ago learned to diagnose heat stress in cows based on external signs: animals breathe loudly with an outstretched neck and an open mouth; feed consumption decreases (10–25 %); many saliva are produced – traces of saliva on the face; sweat is released on the sides and back; the amount of urine decreases, urine becomes more concentrated; milk yield and fat content decrease; the number of cases of manifestations of "sexual excitement (in female animals)" is falling, its detection is becoming more difficult; animals reduce physical activity to reduce heat production.

Dairy cattle are very sensitive to heat stress. Although heat reduction through shade, fans, and water is widely used in the dairy industry, economic losses due to decreased milk production due to heat stress in lactation dairy cows are still estimated at more than $1.2 billion [29].

Basically, animal adaptation involves the animal's morphological, behavioral and genetic ability to change. They can arise over generations due to slow modifications as animals adapt to environmental challenges. The adaptation process can be expanded to include: morphological, behavioral, physiological, neuroendocrine, blood chemistry, combined metabolic, molecular and cellular responses to promote survival in a particular environment[30].

[27] Micheline de Sousa Zanotti Stagliorio Coelho, Mariana Matera Veras, Paulo Hilario Nascimento Saldiva, Chapter 3 - The biologic mechanism for heat exposure and human health, Editor(s): Yuming Guo, Shanshan Li, Heat Exposure and Human Health in the Context of Climate Change, Elsevier, 2023. P. 37–67. URL: https://doi.org/10.1016/B978-0-12-819080-7.00001-X.

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Ukrainian breeds of cattle, which have been cultivated in the steppes of Ukraine for centuries, are usually genetically resistant to climate change due to their physiological characteristics, but their level of productivity is somewhat lower. A high level of milk productivity also implies a high level of feed consumption, a large body weight and, in particular, the mammary gland, which cannot be said about native breeds, which are more adapted to temperature changes, water shortages, and a limited amount of pasture. Ensuring food security requires making trade-offs between productivity levels, livestock reproduction and animal welfare in the face of climate change. However, in any case, this path must be provided by breeders, relying on biochemical and physiological markers of sensitivity to heat stress.

Traditionally, it has been thought that decreased productivity (for example, milk production and muscle growth) under heat stress is a consequence of reduced nutrient intake (that is, the classic biological response common to all animals during environmentally induced hyperthermia). The heat stress response markedly alters the postabsorptive metabolism of carbohydrates, lipids, and proteins independent of reduced feed intake due to coordinated changes in metabolite supply and utilization by multiple tissues[31].

The literature describes seasonal fluctuations in animal productivity due to temperature changes, however, these are adaptation mechanisms produced during the evolution of the species and they do not differ significantly depending on the breed of productive animals. However, with climate change, other mechanisms may be triggered, with a pronounced negative character [32,33,34,35,36] .

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Cattle body temperature has a clear circadian rhythm with a minimum in the morning and a maximum in the afternoon. Body temperature is also influenced by physiological condition, breed and performance level [37]. Cows that are milked twice a day have higher body temperatures in the morning and evening than cows that are milked once a day [38]. Older cows are much more sensitive than young cows, and not all animals react to it anyway.

Ambient temperature and relative humidity data were used to calculate THI according to the equation given by Kendall and Webster[39]:

$$THI = (1{,}8 \times AT + 32) – [(0{,}55 – 0{,}0055 \times RH) \times (1{,}8 \times AT – 26)]$$

For the convenience of farmers, entire tables with THI were developed, from which the farmer could determine the level of threat of heat stress in dairy cows, having only indicators of ambient temperature and relative humidity[40].

Table 1

Impact of heat stress on dairy cattle[41]

THI	Stress level	Comments
< 72	None	
72–79	Mild	Dairy cows will adjust by seeking shade, increasing respiration rate and dilation of the blood vessels. The effect on milk production will be minimal.
80–89	Moderate	Both saliva production and respiration rate will increase. Feed intake may be depressed and water consumption will increase. There will be an increase in body temperature. Milk production and reproduction will be decreased.
90–98	Severe	Cows will become very uncomfortable due to high body temperature, rapid respiration (panting) and excessive saliva production. Milk production and reproduction will be markedly decreased.
> 98	Danger	Potential cow deaths can occur.

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Although the THI is a useful tool for assessing the threat of heat stress to a cow, an animal's individual response to excess heat is the best indicator of its degree of heat stress. And here in the first place come breed features, age, level of productivity, motor activity and behavior of the animal, features of higher nervous activity.

Selection of dairy cows for productivity is focused on producing milk, but such animals are very often unable to maintain a high level of productivity during heat stress. By helping cows dissipate excess heat, we maintain their health, reproductive capacity, and productivity. A well-thought-out and timely implementation of a strategy to combat heat stress will not only help protect the farm from financial losses, but will also ensure continuous milk production throughout the year. There are three strategies for minimizing the effects of heat stress used in dairy farming: technological changes in the conditions of keeping cows; genetic monitoring of the herd aimed at obtaining heat-tolerant animals; optimization of cow feeding[42,43.].

However, it is not so simple, decades of research using genetically defined populations have demonstrated that the use of conventional crossbreeding approaches to improve thermal stress tolerance in the dairy industry has consistently resulted in lower milk yields in the F_1 generation, as measured by body weight gain in beef animals[44].

During pregnancy, the cow's mammary gland undergoes significant changes aimed at ensuring cell renewal through apoptosis[45] and the initiation of lactation in the postpartum period, which correlates with milk production in subsequent lactation[46].

One possible explanation for the detrimental effects of heat stress on lactation is disruption of mammary gland cell turnover between lactations[47].

Cows whose dry period occurred in the summer months had lower milk yields during the next lactation compared to cows during the winter dry

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[43] Stojnov, Martin, et al. Influence of Heat Stress on Some Physiological, Productive and Reproductive Indicators in Dairy Cows--A Review. *Veterinarija ir Zootechnika*, 2022, 80.2.

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period. After calving, animals with summer overheating were more likely to have retained membranes and have a higher incidence of mastitis and respiratory problems[48]. Studies conducted on Holstein dairy cows have shown a strong relationship between exposure to heat stress during late pregnancy and early lactation and animal performance, disease risk, reproduction and calf survival in the first 90 days postpartum[49].

Moderate heat stress is manifested by an increase in the motor activity of cows, aimed at searching for shaded places or conditions that will contribute to an increase in heat transfer from the animal's body, but at the same time the level of productivity will remain at a basic level. However, with regard to the physiology of the blood, some changes may already be noted. Along with a significant increase in the frequency of respiratory movements and heart rate, there is a tendency to increase the number of red blood cells, the hematocrit value and a decrease in the content of hemoglobin and individual white blood cells[50].

In cows exposed to heat stress, significantly altered rumen digestion was observed to decrease rumen pH and acetate concentrations and increase lactate concentrations[51].

The average dairy cow in the US experiences 96 days of heat stress during the year if it is not cooled. The most productive dairy breeds, mainly used all over the world, were bred in a temperate climate and are most effective at temperatures from 5 to 15 °C. When the temperature exceeds 25 °C, especially with high relative humidity, a sharp decrease in milk production can occur. As a result, 25 °C is usually onsidered the upper critical temperature for dairy cows during lactation[52].

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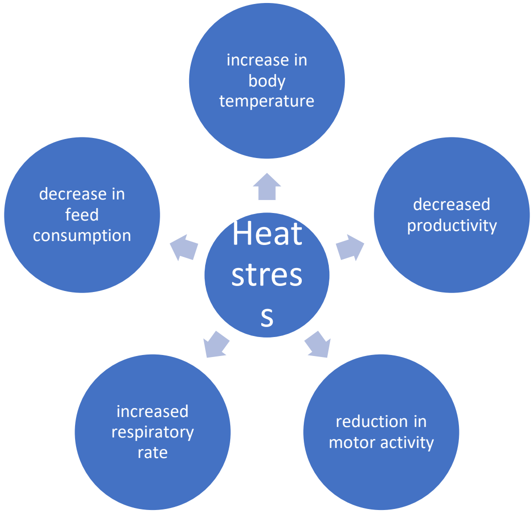

Fig. 1. Physiological parameters of heat stress control

Elevated temperature causes a stress response, characterized by activation of the hypothalamic-pituitary-adrenal axis and subsequent secretion of cortisol[53].

During moderate heat stress, just above the upper critical temperature, cattle will regulate heat transfer by altering radiative, conductive, convective and evaporative heat transfer. They do this primarily by increasing blood flow to the skin, which increases the delivery of metabolic heat produced by the internal organs to the periphery, where it is lost to the environment by convection, radiation, and evaporation of s weat from the skin or fluid from the upper respiratory tract. When the ambient temperature exceeds the surface temperature of the skin (approximately 36 °C), heat will flow from the warmer air to the cooler skin, adding warmth to the body. At this point, to maintain heat balance, evaporative cooling must increase to accommodate the additional heat load, as these cattle are now entirely dependent on evaporative cooling to dissipate heat. Similarly, the influence of solar radiation increases radiative heat and helps explain why shade can improve livestock welfare even when the air temperature in the shade is the same as outside it [5]. During moderate heat stress, just above the upper critical temperature, cattle will regulate heat transfer by altering radiative, conductive, convective and

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evaporative heat transfer. They do this primarily by increasing blood flow to the skin, which increases the delivery of metabolic heat produced by the internal organs to the periphery, where it is lost to the environment by convection, radiation, and evaporation of sweat from the skin or fluid from the upper respiratory tract. When the ambient temperature exceeds the surface temperature of the skin (approximately 36 °C), heat will flow from the warmer air to the cooler skin, adding warmth to the body. At this point, to maintain heat balance, evaporative cooling must increase to accommodate the additional heat load, as these cattle are now entirely dependent on evaporative cooling to dissipate heat. Similarly, the influence of solar radiation increases radiative heat and helps explain why shade can improve livestock welfare even when the air temperature in the shade is the same as outside it[54].

Recent research suggests that physiological heart rate parameters are a good marker of stress response in dairy cows[55].

In all mammals, the first molecular reaction against heat stress is the synthesis of heat shock proteins (HSP). These proteins play a protective role in cells, protecting cell integrity, immune response, apoptosis and promoting post-translational folding and transport of proteins through cell membranes[56,57,58].

At the biochemical level, adaptation is regulated due to changes in gene expression: include 1) activation of heat shock transcription factor 1 (HSF1); 2) increased expression of heat shock proteins (HSP) and decreased expression and synthesis of other proteins; 3) increased oxidation of glucose and amino acids and decreased metabolism of fatty acids; 4) activation of the stress response of the endocrine system; 5) activation of the immune system through extracellular secretion of HSP. If stress continues, these changes in gene expression lead to an altered physiological state called “acclimation”, a process largely controlled by the endocrine system[59].

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Fig. 2. Physiological mechanisms of thermal adaptation of cows

Heat stress increases gastrointestinal permeability in cattle, and feeding supplemental organic acids and pure botanicals partially restores lactation efficiency by increasing feed dry matter intake and improving the intestinal barrier, hence increasing milk yield and nitrogen efficiency[60].

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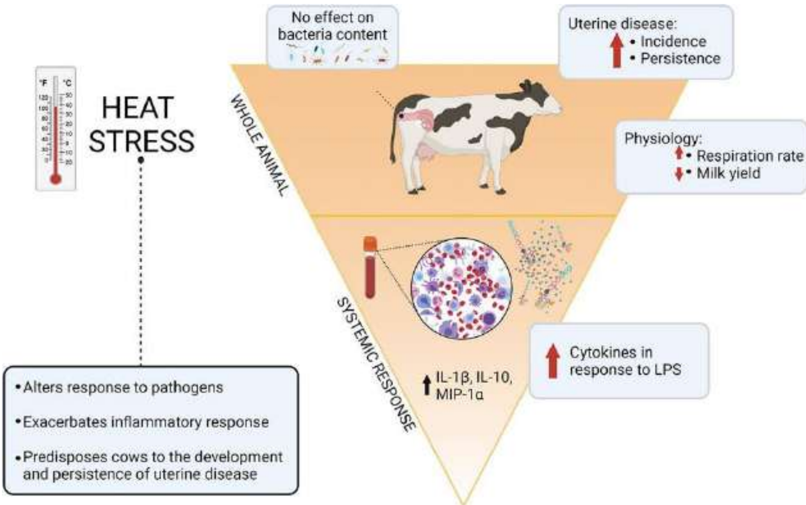

Fig. 3. The influence of heat stress on the sensitivity of cows to postpartum inflammatory processes[61]

As shown in Figure 1, antepartum heat stress during late pregnancy has a transient effect on postpartum innate immunity, which may contribute to an increase in the frequency of uterine diseases observed in cows exposed to antepartum heat stress[62].

It should be noted that the initial stages of heat stress affected physiological adaptation, avoidance of excessive heat, increased thermal output and decreased thermogenesis, but there comes a period when the physiological and biochemical mechanisms of adaptation proceed to the appearance of morphological changes in cells. Exposure of cells to elevated temperature causes a number of abnormalities in their functioning, including a general inhibition of protein synthesis, defects in protein structure and function, morphological changes due to cytoskeletal rearrangements, shifts in metabolism, changes in the dynamics and fluidity of the cell membrane, and

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decreased cell proliferation. These abnormalities cause significant changes in gene transcription and protein synthesis, known as the response[63].

In humans, the diagnosis of heatstroke is based on increased core body temperature, multi-organ involvement and dysfunction (such as hypotension, acute myocardial infarction, liver failure, and renal failure), and predominant central nervous system dysfunction causing delirium, seizures, or coma[64,65].

Hyperthermia induces HSP72 mRNA expression in brain regions involved in central blood pressure control [66].

There is a causal relationship between overexpression of HSP72 in many vital organs, including the heart and brain, and protection against hyperthermia, circulatory shock, and cerebral ischemic injury in this in vivo model of heat stroke.

Thus, HSP72 expression appears to be critical for the development of thermotolerance and protection against heat stress-associated cell damage[67].

To implement effective cooling methods, it is necessary to understand the physiological changes caused by heat. Such methods include providing dairy cows with plenty of drinking water at all times, providing shade and ventilation, and using water absorbers and air movement (that is fans) to help cows dissipate heat.

Under heat stress, cows dissipate heat through respiration and sweating, increasing water intake by up to 50 %. If the water supply is insufficient during heat stress, cows divert water normally used for milk synthesis to physiological processes associated with heat dissipation. In addition to practical methods for alleviating heat stress, clean and fresh drinking water should be available to cows at all times. Additional temporary water sources may be needed to improve water access to minimize the negative effects of heat on dairy cattle[68].

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During 3 consecutive heat waves 2010–2012 in Southern Ontario, a one-unit increase in the HSI resulted in a 3 % (1.03-fold) increase in the mortality rate, and a typical increase associated with a heat wave increased the mortality rate by 27 % relative to the control period. Farm mortality rates increase by 8 % (1.08 times) eastward across the region (approximately 400 km)[69].

Dairy cow mortality is a concern from both a financial and animal welfare perspective, but the quantitative relationship between the magnitude of heat stress and mortality risk is difficult to assess because the effects of heat stress are typically hidden among high natural and management sources of variation, as well as a number of associated factors such as stage of lactation, breed and age of the animal.

The basic annual mortality rate for adult dairy cattle in Italy is 2 % of cattle [70].

CONCLUSIONS

The climate of the agroecosystem is a decisive factor that determines the possibility of using animal husbandry technologies that ensure the production of marketable milk. Technological adaptation of dairy production is not keeping pace with global climate changes. In dairy cows, even in relatively safe areas of industrial animal husbandry, signs of heat stress, reduced productivity and reproduction of livestock are increasingly being registered, the fertility of traditional fodder crops for this area is decreasing, and the botanical composition of pastures is changing. The most common way to determine the threat of heat stress for animals is to use the temperature-humidity index (THI). However, sensitivity to heat stress depends not only on the value of THI, but also on the level of milk production of the cow, because during the digestion of nutrients in the forestomach and catabolic reactions, a huge amount of heat is released, which requires removal from the body. Moreover, the higher the level of productivity, the more the animal needs nutrients, which are metabolized into the synthesis of milk components with the release of a large amount of heat. Therefore, heat stress in highly productive cows can have the most severe consequences for the animal. There is an urgent need to monitor the physiological parameters of dairy cows for the increase in THI. Otherwise, even with a moderate course of heat stress in lactating cows, long-term consequences can be observed for quite a long time,

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both on the reproductive ability, resistance and productivity, and on the viability of the resulting offspring.

SUMMARY

The climate of the agroecosystem is a decisive factor determining the possibility of using livestock technologies that ensure the production of marketable milk. Technological adaptation of dairy production does not keep pace with global climate change. Dairy cows, even in relatively safe zones of industrial livestock farming, are increasingly showing signs of heat stress, a decrease in productivity and reproduction of livestock, the fertility of traditional forage crops for a given zone is decreasing, and the botanical composition of pastures is changing. The most common method for determining the threat of heat stress for animals is the use of the temperature-humidity index (THI). However, sensitivity to heat stress depends not only on the value of THI, but also on the level of milk production of the cow, because during the digestion of nutrients in the forestomach and catabolic reactions, a huge amount of heat is released, which requires removal from the body. Moreover, the higher the level of productivity, the more the animal needs nutrients, which are metabolized into the synthesis of milk components with the release of a large amount of heat. Therefore, heat stress in highly productive cows can have the most severe consequences for the animal. There is an urgent need to monitor the physiological parameters of dairy cows for the increase in THI. Otherwise, even with a moderate course of heat stress in lactating cows, long-term consequences can be observed for quite a long time, both on the reproductive ability, resistance and productivity, and on the viability of the resulting offspring.

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