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TECHNOLOGICAL AND CLIMATE FACTORS AFFECTING MILK QUALITY OF DAIRY CATTLE

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One of the most vulnerable spheres of human activity to environmental threats is agricultural production, which, on the one hand, is a source of significant emissions of greenhouse gases which is one of the causes of global warming, and, on the other hand, is the most dependent on its consequences. Ukraine has high positions in the world in many sectors of agricultural production. However, environmental threats are able to cause the transformation of the majority of the climatic and agricultural zones of Ukraine and make adjustments to the development of the agricultural sector of production. The consequences of climate change significantly affect agriculture, which is largely dependent on weather and climate conditions, and, accordingly, the country's food security. The overview of the latest research on the establishment of the main technological and climatic factors affecting the quality of milk was carried out. It has been established that most researchers emphasize such natural factors as breed, seasonal changes of the year, temperature and humidity, age of the cow, stage of lactation and interval between lactations, state of health of the animal and technological factors such as housing conditions, milking technology, fodder and feeding rations, veterinary care. In different countries, cows react differently to heat stress, animals in countries with a hot arid climate with temperatures that exceed the upper critical index for a long time suffer the most. It has been proven that an increase in temperature above the critical temperature leads to oxidative stress of the body, a decrease in the content of dry matter, fat and protein in milk and an increase in somatic cells and microbial contamination of milk. Some researchers associate the predisposition or resistance to heat stress with a genetic component, others with a violation of the conditions of keeping and feeding animals. Thus, the development of further strategic programs to reduce the negative impact of climatic and technological conditions on the production and quality of milk should include breeding programs for creating populations of thermotolerant animals, adaptive technologies that reduce stress, feeding systems with the inclusion of innovative feed products that guarantee a reduction in greenhouse emissions, animal health and food safety.

Key words: dairy cattle, heat stress, technology, milk productivity, milk quality

ТЕХНОЛОГІЧНІ ТА КЛІМАТИЧНІ ЧИННИКИ, ЩО ВПЛИВАЮТЬ НА ЯКІСТЬ МОЛОКА ХУДОБИ МОЛОЧНИХ ПОРІД

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Однією з найбільш вразливих до екологічних загроз сфер людської діяльності є сільськогосподарське виробництво, яке з одного боку є джерелом значних



викидів парникових газів – однієї з причин глобального потепління, а з іншого – найбільш залежне від його наслідків. Україна за багатьма секторами аграрного виробництва сільськогосподарської продукції має високі позиції в світі. Однак екологічні загрози здатні спричинити трансформацію переважної частини кліматичних і сільськогосподарських зон України та внести свої корективи в розвиток аграрного сектору виробництва. Наслідки зміни клімату суттєво впливають на сільське господарство, яке значною мірою залежить від погодних та кліматичних умов, та, відповідно, на продовольчу безпеку країни. Проведено огляд останніх досліджень з встановлення основних технологічних та кліматичних чинників впливу на якість молока. Встановлено, що більшість дослідників наголошують на таких природних чинниках, як порода, сезонні зміни року, температура та вологість повітря, вік корови, стадія лактації та інтервал між лактаціями, стан здоров'я тварини і технологічних чинниках - умови утримання, технологія доїння, корми і раціони годівлі, ветеринарне обслуговування. В різних країнах корови по-різному реагують на тепловий стрес, найбільше страждають тварини у країнах із спекотним посушливим кліматом із температурою, що тривалий час перевищує верхній критичний показник. Доведено, що підвищення температури понад критичної, призводить до окислативного стресу організму, зменшення вмісту сухої речовини, жиру і білка у молоці та збільшення соматичних клітин і мікробного забруднення молока. Схильність або протидію тепловому стресу деякі дослідники пов'язують із генетичною складовою, інші – із порушенням умов утримання і годівлі тварин. Таким чином, розробка подальших стратегічних програм зменшення негативного впливу кліматичних і технологічних умов на виробництво і якість молока мають включати селекційні програми зі створення популяцій термотолерантних тварин, адаптивних технологій, що нівелюють стрес, систем годівлі з включенням інноваційних кормових засобів, що гарантують зменшення парникових викидів, здоров'я тварин і безпеку продуктів харчування.

Ключові слова: молочна худоба, тепловий стрес, технологія, молочна продуктивність, якість молока

Introduction. Global warming is one of the biggest threats caused by human activities as a result of excessive use of fossil fuels as an energy resource (Al-Ghussain, 2019). As global warming increases, ecosystems, plant and animal biodiversity, and food security are threatened (Gauly M. & Ammer S., 2020). It is already widely recognized that the direct and indirect effects of global warming, combined with an increase in the frequency of extreme weather events, are a serious problem for livestock production even in temperate zones such as Central Europe. Global warming causes heat stress, which is an important problem for the dairy industry in many regions of the world. It arises from the inability of the animal's body to distribute the heat load from the metabolism of the body and the surrounding environment. As a result, body temperature rises, breathing and pulse speed up, sweating increases, and shortness of breath appears.

In a thermal environment in which the animal's heat production exceeds heat output, the body stores an increasing amount of heat, which leads to an increase in body temperature. When body temperature rises significantly, a host of homeothermic phenomena are activated, including increased heat loss through respiration and skin evaporation. However, when high temperatures and solar radiation reduce the animal's ability to radiate body heat, feed intake, metabolism, body weight, and milk production decrease, helping to alleviate the thermal imbalance. Although tissue substrates are mobilized, energy metabolism, growth and lactation are reduced (Silpa, 2021). Das R. et al.



(2016) note that dairy cattle are more sensitive to heat stress than meat cattle. This is especially true for highly productive animals, because they generate more metabolic heat.

Modern producers of dairy products divide the influencing factors into natural (breed, period of the year, age of the cow, stage of lactation and the interval between lactations, state of health of the animal) and technological (housing conditions, milking technology, fodder and feeding rations, veterinary care).

The purpose of our work is a review of modern scientific works considering this topic.

Research materials and methods. A systematic review of literature sources was performed by monitoring publications in the databases Scopus, Web of Sciences, Google Scholar, etc., published in Ukrainian and English over the past five years in accordance with the inclusion criteria. The systematization of published data was carried out with the aim of accumulating modern scientific knowledge regarding the factors affecting the quality of dairy products for the further construction of our own methodological basis for research in this direction in domestic conditions, taking into account international experience.

Research results. In 1987, Johnson described a model of the main ecosystem factors affecting a cow's ability to produce milk, grow and reproduce: meteorological (temperature, length of day) and non-meteorological (forage quantity and quality, disease). Environmental temperature and stress signal the hypothalamus and central nervous system to alter feed intake, hormonal functions, and heat production and/or loss, resulting in reduced milk production and fertility.

Quiédeville S. (2022) studied the economic indicators of the dairy sector of the European Union and established the main factors of negative impact: heat stress, which directly affects the reduction of milk productivity, heat and drought, which affect the quantity and quality of fodder for dairy cows.

Scientists are particularly concerned with the impact of climate change on the production of livestock products in a country with an arid climate. Thus, studies of the quality of milk of Holstein cows in the northeastern regions of Iran Toghdy A. et al. (2022) proved that the productivity of livestock is affected by various factors due to the complex interaction between the animal and the environment. These researchers consider the temperature and humidity of the environment to be the main factors influencing the quality of milk. They connect their conclusions with the fact that the temperature increased from 6.2 °C to 31.3 °C, which led to a significant decrease in the content of milk protein by 4.09% and fat by 5.75% in milk. Depending on the increase in ambient temperature, the content of nonfat dry matter (SNF) decreased by 1.31% and the content of somatic cells by 16.8%. On the other hand, as the ambient temperature increased, the total content of microorganisms in milk increased by 13.7%.

The increase in air humidity from 54% to 82% caused a significant increase in the content of milk protein (by 4.84%), fat (by 4.84%), defatted dry matter (by 1.06%) and somatic cells (by 10.2 %) in milk, on the other hand, the content of microorganisms decreased by 16.3%. The researchers confirm the results of their studies with correlations between the periods of the year, temperature and air humidity, and the content of milk components and somatic cells in it. The highest percentage of milk fat was recorded by them in January-March, the lowest in May-June. At the same time, milk fat did not change significantly during January-February, sharply decreased in April and remained low until August, increased by 1.24% in September and did not change significantly from then until the end of the year. The mass fraction of protein was the highest in March, the lowest in June. The percentage of mass fraction of dry matter in milk was



the highest in January-March, the lowest in August. The number of somatic cells in milk was the highest in March and the lowest in September-December. The maximum level of total microbial insemination was recorded in May-June, the lowest – in September.

Pacheco-Pappenheim S. et al. (2021) relate the fatty acid and triacylglycerol composition of cow's milk to seasonal changes. In their research, they indicate significant changes in the fatty acid composition of milk with increased intake of C18:3 *cis*-9,12,15 with grass in the spring and summer. The triacylglycerol profile, in turn, depended on the fatty acid composition of milk. Thus, low- and medium-molecular groups of the triacylglycerol profile increased in winter and decreased in summer, while high-molecular groups increased in summer and decreased in winter.

Ayemele A. G. (2021) proved that heat causes oxidative stress in the body, as a result of which the content of reactive oxygen species in cells increases. A significantly higher level of stress indices of catalase, SOD, GSH reductase and malondialdehyde was established in lactating cows in summer. Increased milk production during this period leads to oxidative tissue damage due to the induction of heat stress.

Picinin L. C. A. et al. (2019) established a correlation between climatic factors and physicochemical properties of raw milk, as well as the total volume of milk produced in the conditions of dairy farms in Brazil. The increase in precipitation, average daily temperature and relative humidity had a negative effect on the quality of milk and increased its bacterial contamination. Benavides R. M. et al. (2022) are sure that the most important factors affecting the production and quality of milk, although, in their opinion, solar radiation and wind speed also deserve attention as influencing factors.

In India, dairy cattle experience significant heat stress, because the temperature of the environment in summer exceeds 45 °C, which is 18 °C higher than the upper critical temperature (David B. et al., 2021). At high temperatures, animals spend a lot of feed energy to speed up breathing and sweating, and therefore, in the summer, milk production is reduced by half.

In the conditions of Korea, Eunjeong J. et al. (2023) made a large-scale analysis of the impact of climate change and heat stress on the milk production of Holstein cows and recognized critical environmental parameters on cow productivity and milk quality. Scientists emphasize the importance of implementing appropriate feeding management strategies that take into account climatic factors to ensure optimal performance and stability of Holstein cows in changing environmental conditions.

In Pakistan, Rahman M.A. et al. (2019) identified critical risk factors threatening the dairy production system due to climate change. The most influential of them are the lack of genetic studies and research on the assessment of feed safety, laboratories for disease detection, water shortages, and innovations in the processing of milk and dairy products.

Magan J. B. et al. (2021) in the conditions of Scotland proved that even at too low environmental temperature there was a negative impact on milk production. At the same time, cows that calved for the first time suffered the most. The researchers suggest taking into account the factor of low environmental temperature in the conditions of climate change when implementing the technological strategy of dairy farming.

Experimenting on Holstein cows, Tančin V. et al. (2020) proved the effect on milk quality indicators of the season of the year, hotel activity, number and stage of lactation, and the content of somatic cells.

Ataallahi M. et al. (2023) correlated cortisol concentration in pasteurized and sterilized dairy products with temperature and humidity index during milk production in northeastern South Korea. In their experiments, cortisol levels fluctuated in samples



produced during the summer and autumn months of the year, and were the highest in July (211.9 ± 95.1 pg/ml) and August (173.5 ± 63.8 pg/ml). Researchers suggest that monitoring cortisol residues in dairy products can serve as an alternative indicator of heat stress in dairy cattle. Other South Korean scientists Lee D. et al. (2023), after examining 1.5 million experimental data, established a negative effect of heat stress on productivity and milk quality of Holstein cows.

In the work, Feliciano R. J. et al. (2020) indicated that climate change affects the microbial safety of dairy products. In conditions of heat stress, susceptibility of lactating cows to microbial contamination increases, accordingly, microbial contamination of milk increases. The researchers suggest the development of models to quantify microbial contamination to assess risk mitigation strategies, a key step in prioritizing a climate-resilient dairy industry. The same researchers (Feliciano R. J. et al., 2023) studied milk quality indicators (content of mass fractions of fat and protein) in different weather conditions throughout the year and established seasonal patterns. However, other authors Magan J. B. et al. (2021), Hayes E. et al. (2023) associate seasonal changes in milk quality primarily with the cow's diet. Correa-Calderón A. et al. (2022) add that no less than 40% of the decrease in milk productivity is associated with a decrease in the consumption of dry matter of feed, the rest is associated with a direct effect on the general metabolism and cellular heat resistance. The decrease in milk synthesis is associated with insufficient consumption of dry matter (Gao S. T. et al., 2019). They associate this process with biological changes in the mammary gland. Based on their experiments, it can be assumed that heat stress reduces the transcription of genes related to metabolism and increases the concentration of genes related to inflammation in mammary gland tissues, due to which milk protein synthesis decreases.

Marai I. F. & Habeen A. A. M. (2010) note that industrial and domestic animals are more prone to heat stress losses than indigenous ones. In this direction, studies on determining the endurance of cows of different genotypes to heat stress were conducted by Voytenko S. L. et al. (2020), who proved that under the natural and ecological conditions of the Poltava region, cows with different Holstein bloodlines, as well as female offsprings of different breeders, reacted differently to stress factors.

Researchers from the USA Sigdel A. et al. (2019) prove a negative genetic relationship between cow productivity and resistance to heat stress, and believe that selection for productive traits without taking into account thermotolerance will lead to greater dependence on heat stress.

Piddubna L. et al. (2021) found a significant level of influence of the genetic component on the quality of milk of cows of the Ukrainian black and white dairy breed. Therefore, the content of mass fractions of fat and protein depended on the origin of the cow's sire by 11.4; 31.0 and 31.5%, respectively, while linear belonging affected the indicated indicators with half the level.

Silpa M. V. et al. (2021) also see overcoming the impact of heat stress on the animal body in the activation of genomic selection, which is based on already identified biomarkers that regulate heat stress and milk productivity, and also contribute to the discovery of additional characteristics related to adaptation, production and reduced emission of methane. That is, it is the task of the genetics is to obtain a well-adapted thermotolerant animal capable of producing under different climatic conditions and releasing less methane per unit of used feed. In this context, Cassandro M. (2020) believes that understanding the adaptive properties of livestock is a key factor in counteracting the effects of global climate change. The tool for this understanding is the identification of genes that form adaptive phenotypes. Therefore, the importance of using technolo-



gies that increase the efficiency of land and fodder use and mitigate the negative impact of animal husbandry on biodiversity, ecosystems and global warming is understood.

To prevent the negative effects of heat stress on dairy cows, researchers suggest more detailed management of feeding and installation of cooling systems on farms. Thus, Avendaño-Reyes L. et al. (2021) proved that in conditions of high heat stress, additional cooling at night made it possible to lower the body surface temperature of Holstein and Jersey cows, slightly reduce the content of triiodothyronine and increase the content of thyroxine, and increase the amount and quality of milk. Tao S. et al. (2020) also emphasize that the most effective way to reduce the negative impact of heat stress on the animal body is to reduce the temperature through shading and evaporative cooling.

Ukrainian scientists (Sediuk, I. et al., 2023; Zolotarov A.P. et al., 2023) studied the possibilities of reducing the influence of high ambient temperature on milk productivity of cows using different approaches to the organization of feeding technology. It has been proven that the introduction of 1.5 kg of a protein feed additive with protected protein (TEP-mix) into the diet of high-yielding cows helps to increase the productivity of experimental cows (in terms of base milk) by 15.7% (4.3 kg). Modernization of the feeding ration of high-yielding cows by increasing the content of undegradable protein in the rumen to the norm during temperature stress contributed to better adaptation of animals in terms of productivity and quality indicators of milk: an increase in the mass fraction of fat by 0.67% and the mass fraction of protein by 0.26%, with content of somatic cells $285.06 \pm 81.0 \dots 409.3 \pm 134.3$ thousand/cm³.

Min L. et al. (2021) claim that feeding strategies with the inclusion and dosage variations of dietary fats, dietary fibers, dietary microbial additives, minerals, vitamins, buffer solutions of metal ions, plant extracts, etc., are capable of mitigating the negative effects of heat stress in dairy cows, increasing production of milk and content of protein and fat in milk.

Razzaghi A. et al. (2023) are confident that in dairy cows exposed to stressors: social (housing conditions, regrouping, feed delivery), physiological (beginning of lactation and calving), or physical (heat or cold stress), body reactions include changes in energy balance and distribution of nutrients. The ability of an animal to synthesize milk fat depends largely on the availability of substrates for lipid synthesis from the diet, ruminal fermentation, or adipose tissue reserves, all of which can be altered under conditions of stress. Indeed, milk fat concentration is particularly sensitive to changes in diet and environment, where a wide range of nutritional and technological factors influence milk fat yield.

Gerun I. et al. (2021) established that the quality and safety of milk directly depends on the technology of its production. With the use of the latest technology of milk production, with 2,000 cows kept indoors without tethering, the number of somatic cells and total insemination of milk did not exceed 221.1 thousand/cm³ and 70.8 thousand CFU/cm³, which corresponds to the "extra" grade. Moreover, the incidence of mastitis in cows did not exceed 6.4%. Milking of cows was carried out on the "Parallel" milking plant of the DeLaval company. The effectiveness of the use of "Parallel" MM in relation to the quality and technological properties of milk is proven by Lutsenko M. et al. (2021). In their opinion, the better quality of milk is due to the fact that the "Parallel" milking machine provides a higher intensity of milk yield in the first minute of milking (compared to the "Carousel" milking machine).

Researchers published interesting facts about dairy cows that were kept on pastures in the conditions of the Amazon region of Brazil (Vieira R. K. R., 2022). According to their data, an increased content of somatic cells was observed in the milk of cows



that grazed on irrigated pastures. These animals were 5.03 times more likely to develop mastitis than those grazed on non-irrigated pastures.

Gunn K. M. et al. (2019) studied the cost-effectiveness of four heat stress reduction strategies at minimal cost (tent, shading), moderate (forced ventilation), high (ventilation and condensation), and intensive (indoor air conditioning) and found that intensive technologies allowed for an increase in annual milk production. The studies were carried out under conditions of increasing heat stress, the annual milk losses were the highest in the western, southwestern, southern and southeastern regions of the USA. Therefore, in these regions, increasingly intensive technologies for reducing temperature stress using air cooling are needed.

Borshch O.O. (2021) studied the dynamics of the productivity and quality of milk of cows in the central part of the Forest Steppe of Ukraine under different technological options for keeping and proved that under the conditions of an increase in the average annual temperature, the use of continental-scaled spatial composite structures for housing dairy cattle reduces the effect of temperature stress on the animal body.

In our research, we have become convinced that it is probably desirable to add to further scientific research a Swiss mathematical model that helps to identify the general thermal effects in the production of dairy products and, at the same time, on empirically visible veterinary costs and feed purchases at the farm level (Bucheli J., 2022). However, the temperature regimes for different regions should be taken into account, because animals from the northern countries have time to recover from the heat stress they receive in the summer.

Discussion. Stating the review of modern research and forecasts of well-known scientists regarding the influence of technological and climatic factors that affect the quality of cow milk, it should be noted that climate change will continue to affect domestic animal husbandry, and therefore the development of potential strategies for mitigating this negative impact is of particular importance. It is necessary to pay attention, first of all, to the adaptation of safety management programs for the production of animal husbandry products to climate change forecasts.

EU regulations currently set high requirements for the quality of milk and its processing products. It is known that the quality of milk depends on genetic and technological factors, but in the conditions of environmental changes, it is important to take into account the factors of the influence of the surrounding environment, to follow the forecasts of changes in order to improve technologies for the comfort of dairy cattle. In this regard, it is necessary to adapt all current programs for managing the safety of production of animal husbandry products. Local and regional heat stress reduction strategies for dairy cattle should be adjusted according to climate projections for different temperature zones to mitigate potential losses of dairy production due to heat stress. The decrease in the body temperature of animals during the heat promotes their consumption of more feed, and the introduction of special feed elements into the diet reduces the release of electrolytes from the body through the skin. Thus, the development of mineral supplements for regulating the acid-alkaline balance of the animal body is needed. No less important is the search for genes associated with thermotolerance, namely, markers for breeding programs to increase the adaptive properties of animals.

According to the climate forecasts of different regions of Ukraine, it is necessary to adjust local and regional strategies for reducing the impact of negative factors on dairy cattle in order to mitigate potential losses of dairy production. The climatic zones of Ukraine are quite diverse, due to their geographical location, they often belong to the zones of risky agriculture: arid steppes, mountain and forest areas with increased precipitation, the Carpathians and Crimean Mountains, the Black Sea and Azov coasts. That is



why, for different climatic conditions, well-adapted breeds of animals were once created. Therefore, in different climatic regions of Ukraine, research is needed on the adaptation of animal husbandry under the influence of climate changes, as well as in the search for ways to prevent them: breeding, technological, physiological, veterinary. Particular attention is paid to the development of stress-free and adaptive animal husbandry technologies taking into account actual and possible environmental changes, the spread of ecological and organic production technologies for animal husbandry, as well as the creation of anti-stress systems and feeding rations using technologies of targeted nitrogen release, regulation of stability and the content of rumen microflora in ruminants, the development and use of preparations and probiotics that are anti-stress products of synergistic action, vitagens, immunomodulators, organic acids, mineral compounds. In the conditions of climate change, the least vulnerable to environmental risks will be livestock enterprises that use modern technologies for keeping and feeding animals.

Conclusions. The lives of people all over the world depend on the quality of food, among the most important of which are milk and dairy products. Obtaining high-quality milk depends on successful dairy farming, which, in turn, depends on many natural and unnatural factors. Environmental factors, such as temperature, humidity, wind speed, and radiation directly affect the production of dairy products, and scientists consider thermal stress to be the most influencing factor. Researchers from different countries have proven that climate change causes not only a decrease in the quantity of dairy products, but also its quality. It is possible to reduce the impact of thermal stress by selecting animals with a thermotolerant genotype, adjusting the feeding system with the inclusion of innovative substances that reduce oxidative stress, and technological means of protecting animals from critical temperatures.

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