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ORGANIZATION OF CATTLE PRODUCTION IN CONDITIONS OF CLIMATE CHANGE

Ljiljana Samolovac[1], Dragan Nikšić[1], Dušica Ostojić Andrić[1], Vladimir Živković[1], Dragan Stanojević[2], Vlada Pantelić[1], Nenad Mićić[1]

[1]Institute for Animal Husbandry, Belgrade – Zemun
[2]University of Belgrade, Faculty of Agriculture, Belgrade-Zemun
Corresponding author: Ljiljana Samolovac, ljiljanasamolovac@gmail.com
Invited paper

Abstract: The greenhouse effect has led to a changed precipitation regime, an increase in the average temperature, the occurrence of extreme meteorological events (droughts and floods) and the like. All this harms the yield and quality of feed, the incidence of mycotoxins in food, reduced productivity of animals, the incidence of new and non-specific pathogens, the development of diseases, etc. According to the FAO and the World Bank, the countries most affected by climate change are the countries of Central Europe and the Mediterranean. The population of people living in rural areas and engaged in agriculture will be particularly at risk. With difficult working and living conditions and reduced incomes, there will be an increased migration of the population to the cities. The simultaneous decline in agricultural production and increased food demand will lead to a food supply crisis (FAO predicts that by 2050 the global population will increase to 9.6 billion people, resulting in a demand for 70% more food than in 2013).Cattle production is affected by the climate in different ways, directly and indirectly. Livestock condition, production level, reproductive performance, morbidity and mortality are correlated with climatic conditions. The most pronounced negative impact on the health and welfare of animals is a phenomenon called heat stress. Exposure to microclimatic conditions characterized by a combination of high temperature and air humidity overcomes the ability of animals to maintain normal thermoregulation and constant body temperature, leading to an increase in body temperature that exceeds physiological limits. In addition to the direct effects of heat stress on the productivity, reproduction and health status of animals, global warming also affects animals indirectly through reduced soil fertility, water availability, crop yields, quality of plant nutrients and the circulation of pathogenic agents. Finding a solution to mitigate and prevent the consequences of unfavourable climatic and microclimatic conditions is a challenge for the entire scientific and professional community, but also for every cattle breeder. Solutions can be biological and technological. Biological ones refer to the animals themselves (breed selection,

selection for functional traits, selection for adaptability to heat stress, use of genomic selection, artificial insemination programs, herd size). Technological solutions relate to how animals are kept (free system, in outlets with canopies, use of grazing), facilities (new materials and technical solutions in the construction of facilities, use of insulating materials, regulation of microclimate conditions in facilities - ventilation and air humidity), nutrition and feeding (feeding method, feeding time, use of new types of feed, continuous water supply, etc.).The goal of agricultural production is to ensure food security in the face of climate change, and it is one of the most demanding tasks facing humanity.

Key words: greenhouse effect, climate change, cattle production

Introduction

Eradicating hunger, securing food supply and improving nutrition are important goals of sustainable development. At the same time, climate change, which negatively affects agriculture and food security, makes this task difficult. That is why the international community has been making efforts for many years to prevent climate change and its negative impact by adopting a series of legal acts, to which the Republic of Serbia is a signatory. The Intergovernmental Panel on Climate Change was created in 1988 at the request of the United Nations, the World Meteorological Organization and the UN Environment Program to assess the risk of climate change caused by human activity. The UN Framework Convention on Climate Change was adopted in 1992. It was followed by the Kyoto Protocol in 2007, the Paris Agreement in 2015, and the Glasgow Agreement in 2021.

And yet, according to the FAO report, between 691 and 783 million people have faced hunger in 2022, an increase of 122 million people compared to 2019. At the same time, more than 3.1 billion people worldwide cannot provide healthy nutrition, according to a joint report of the Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD), the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), the World Meteorological Organisation (WMO) and World Food Program (WFP). It was estimated that more than 250 million people in 2023 were exposed to acute food shortages. Of these, almost 57 million people in 12 countries found themselves in this unfavourable situation solely due to extreme climatic phenomena (droughts, floods, tornadoes, tropical storms, etc.). Compared to 2021, the increase in the number of people at risk is multiple (23.5 million people in 8 countries were affected by extreme conditions). By 2030, according to the

International Fund for Agricultural Development (IFAD), 670 million people will face acute hunger. Populations living in rural areas and engaged in agriculture are particularly affected. And such, according to FAO data, makeup almost half of the world's population. About 1.23 billion people were employed in 2019 in agri-food systems (857 million people in primary agricultural production and 375 million in food processing and distribution systems). Three times more, or almost half of the world's population, live in households whose source of financial income is related to agricultural production.

The results of the increase in global temperature are irregular precipitation, floods, tornadoes and storms, melting of glaciers, which is a threat to biodiversity. Estimates are that an increase in global average surface air temperature between 1.8^0C and 4.0^0C by 2100 will lead to the extinction of approximately 20 to 30% of plant and animal species, with severe consequences for food security in developing countries.

Climate change affects all branches of agricultural production, both crop and livestock production, given that they are closely related (*Hatfield et al., 2018*). The trend of continuous warming with the appearance of changed intensity and the seasonal nature of precipitation increases the sensitivity of agricultural systems, thereby endangering food production (*Gornall et al., 2019*).

In crop production, stagnation of grain yield is observed, as well as great yield variability. In addition, the nutritional and technological quality of the obtained products decreases. Diseases and pests further reduce the yield (*Fróna et al., 2021*). At the same time, due to desertification and soil degradation, the areas suitable for growing crops are also decreasing (*Arora, 2019*).

Livestock, and primarily, cattle production, are affected directly and indirectly by adverse climatic conditions (*Hempel et al., 2019, Angel et al., 2018, Nardone et al., 2010*). Directly, changed climatic conditions cause heat stress in animals, affecting growth reduction, reduction of milk and meat production, the occurrence of diseases, disruption of the reproductive cycle, etc. All of the above are indicated by the results of numerous studies (*Mićić et al., 2022, Samolovac et al., 2022, Samolovac et al., 2020, Samolovac et al., 2019, Beskorovajni et al., 2015, Beskorovajni et al., 2012, Nardone et al., 2010, Dickman and Hansen, 2009, Chase, 2000*).The indirect impact is reflected in the water and food deficiencies. An increase in air temperature requires higher consumption of water on the one hand and leads to a decrease in the amount of available water on the other. Lack of water affects the yields of plant crops that are used for food, both for animals and for humans. In addition to obtaining a smaller amount of food, its quality is significantly diminished. The reason for this is the changed chemical composition, digestibility and nutritional value of nutrients of plant origin.

The fact that agricultural production, especially cattle breeding, harms climate change through the emission of greenhouse gases (primarily methane and carbon dioxide) cannot be ignored. Nevertheless, the emphasis in this paper is on cattle production and its survival in the conditions of climate change due to its importance in supplying food to a large part of the human population. Therefore, it is necessary to create cattle breeding development programs through which all the advantages of modern technologies in the selection and rearing of cattle would be used. They must enable, on the one hand, the survival of cattle breeding in the conditions of climate change, and on the other hand, reduce to a minimum the emission of greenhouse gases whose sources are related to cattle breeding (enteric processes of ruminants, production and manipulation of manure, production of animal feed, processing and transport, etc.).

Impact of climate change on cattle production

Climate change has far-reaching consequences for all branches of agricultural production. Cattle production is one of the areas most susceptible to the negative consequences of climate change. It is estimated that livestock losses due to heat stress will be 40 billion dollars per year by the end of the 21st century, which is about 10% of the total value of milk and meat production in 2005. Exposure of animals to extreme temperatures can disrupt their capacity for high productivity despite their genetic potential. Economic losses due to the reduced production capacity of animals caused by heat stress exceed losses associated with livestock mortality by 5 to 10 times. Each year, environmental heat stress alone costs the dairy industry over $900 million and the meat industry over $300 million (*Hatfield et al., 2020*).

Heat stress caused by climate change negatively affects the production and welfare state of cattle directly and indirectly (*Angel et al., 2018*). Directly: reduced food intake, reduced growth, reduced milk production, disorders in reproduction, the occurrence of various diseases, increased mortality, reduced ability to adapt. The most reliable indicator of the occurrence or risk of occurrence of heat stress is the THI index, the ratio of temperature and air humidity. A THI of 72 is the threshold for the occurrence of stress in dairy cattle (*Beskorovajni et al., 2015; Beskorovajni et al., 2012*), and it has this value at a temperature of 24 ^{0}C and 66% air humidity. In Serbia, it is most pronounced in the period June-August, although the risk of heat stress exists from April to October.

According to *Dikman and Hansen (2009),* heat stress is the sum of all environmental influences acting on the animal, which causes an increase in its body temperature, causing a physiological response. Environmental factors that contribute to heat stress are high temperature, high humidity and radiant energy (sunlight). Heat stress can be simply defined as the point at which the cow cannot release an adequate amount of heat and maintain body heat balance (*Chase, 2000*). An increase in temperature and moisture content in the air impairs production (individual growth, yield and quality of meat and milk) and reproductive performance of animals, metabolic and health status and immune response (*Nardone et al., 2010)*.

The intensity of the impact of climate change on animal health depends on several factors: genotype, specific and non-specific resistance of animals to diseases, cultivation area, as well as pathogen characteristics. Symptoms of heat stress can range from mild changes in metabolism and milk production to potential cow mortality. The severity of heat stress depends on numerous factors such as temperature and humidity, duration of exposure to heat stress, ventilation and airflow, degree of night cooling, keeping of animals, availability of water, etc. (*Chakrabarti et al., 2022; Samolovac et al., 2020*). Some factors that affect the severity of heat stress depend on the animal itself: breed, body size, body weight, level of milk production, intake of dry matter before heat stress, colour and density of hair. Black-coated cows absorb more radiation than light-coated cows and face more heat stress. A high-yielding cow will be more affected by heat stress than a low-yielding or dry cow (*Kumar et al., 2018; Collier et al., 2015; Chase, 2000*). As stated by *Chakrabarti et al. (2022),* at ambient temperatures above 23^{0}C and 80% air humidity cows show heat-induced depression such as lower feed intake and lower productivity. At high relative humidity, normal evaporation decreases and prevents heat loss through breathing and sweating. Also, direct solar radiation increases the body temperature of animals and causes heat stress. Due to the action of stress factors, there are disturbances in the normal biological function of the organism and energy that should be used for growth or reproduction is consumed.

High-yielding animals are more sensitive than low-yielding animals. Also, animals reared in an intensive production system due to limited ability to move, inability to cool down adequately, exposure to heat radiation from surfaces in housing facilities, feeding on high-energy nutrients, etc. In such production systems, it is necessary to ensure optimal microclimatic conditions in the facilities. (*Samolovac, 2019; Samolovac et al., 2016*). Dairy cows with THI $\geq$ 72 react with reduced intake and poorer feed conversion. This leads to a decrease in milk yield, a lower percentage of milk fat and protein, poor condition and body weight, an increase in the number of somatic cells in milk, etc. (*Mićić et al., 2022; Beskorovajni et al., 2015; Lambertz et al., 2014; Beskorovajni et al., 2012*).

The effect of heat stress on reproduction is great. In females, heat stress leads to lower fertility due to shortened estrus duration, frequent occurrence of anestrus, poorer ovulation and embryonic death. In males, it causes disruption of spermatogenesis, poorer sperm quality, a decrease in testicular volume, decrease in the amount of fertile semen. Altogether it leads to a reduction in the conception rate by 10-20%. Heat stress in the last 50 days of pregnancy endangers udder development and reduces colostrum and milk production due to altered placental hormone production and reduced dry matter intake. Negative effects of heat stress have been identified from 42 days before to 40 days after insemination (*Jordan, 2003*). Increased temperature and air humidity affect the reduced expression of estrus. Plasma progesterone levels may increase or decrease depending on whether the heat stress is acute or chronic, as well as the metabolic state of the animal. All changes in hormone secretion reduce the activity of follicles and change the ovulatory mechanism, which leads to a decrease in the quality of oocytes and embryos. It also affects the change in the environment in the uterus and reduces the possibility of embryo implantation. Appetite and dry matter intake are reduced due to heat stress, which prolongs the postpartum period of negative energy balance and increases the duration of the service period, especially in highly productive dairy cows *(De Rensis and Scaramuzzi, 2003; Jordan, 2003)*.

The indirect impact of heat stress on animals is manifested through a reduced yield and poorer quality of food, lack of water, the presence of mycotoxins in food, and the appearance of pathogenic agents and pests. Agriculture is the single largest global consumer of water, with a share of 69%. Global warming is causing problems in the quantity and quality of available water. An increase in temperature leads to increased water consumption per head and hectare of arable land. With water shortages, there is increased competition between livestock, crops and non-agricultural water use, further exacerbating the problem. Water deficiency with high air temperature leads to premature ageing of plant tissue and lignification, which contributes to a lower quality of plant nutrients (lower digestibility and chemical composition of plants). Pasture systems are particularly at risk because higher temperatures and less precipitation reduce plant mass yields and increase soil degradation. Also, frequent droughts and extremely high temperatures lead to the dominance of more resistant plant species with lower nutritional value (weeds and lower-quality species). Climate change at the global level leads to seasonal variations and the occurrence of extreme climatic events, even in areas for which they are not typical. This is why climate zones change. High temperatures and changes in the precipitation regime promote the development and spread of pathogens, the modification of microorganisms, the emergence of new diseases, and increase the susceptibility of livestock to diseases, leading to increased morbidity and mortality of animals. The number of disease-carrying vectors (rodents, insects) is also increasing. The immune system has the greatest impact on the quality of health, but the problem is that heat stress has an immunosuppressive effect.

Nevertheless, it is encouraging that over time, animals have developed, to varying degrees, different adaptation mechanisms that include morphological, behavioural, physiological, neuroendocrine, biochemical and cellular responses that enable their survival in a given environment (*Angel et al., 2018; Summer et al., 2018*).

Response to climate change

The consequences of unfavourable climatic conditions can be mitigated in different ways. Some mechanisms are related to the animals themselves (adaptability, genetic diversity of breeds, raising animals to obtain different types of products) and to the organization of production that depends on the breeder (herd size, mobility, balance between productivity and welfare of the herd, technological equipment). These mechanisms can be used individually or in combination, depending on the goal of production, means, intensity of climate change action, environment, etc. (*Nozieres et al., 2011*). Some of the most important measures to mitigate climate change in cattle breeding include biological adaptation and technological optimization of cattle production (*Samolovac et al., 2022*).

Biological adaptation refers to animals and includes several processes, such as:

- selection of genotypes for heat tolerance, resistance to diseases and more efficient food utilization,
- use of genomic selection,
- use in the breeding of individuals whose offspring are resistant to heat stress (heat stress tolerance),
- introduction of new breeds tolerant to high temperatures and air humidity and
- breeding of domestic breeds adapted to the conditions characteristic of a specific breeding area.

Some of the effects of climate change are rising temperatures, water shortages, and rising grain prices due to increased demand for human and animal feed. Consequently, future dairy systems must rely more on grazing instead of using cereals in the diet of cows, so as not to represent "competition" with human nutrition. It is also very important to carry out selection in the herd in the direction of the efficiency of food utilization. However, the efficiency of selection in cattle breeding is reduced by a long generation interval. This requires the development of new selection methods to select superior heads suitable for future production systems. One solution is to find different genetic markers that can be used to detect cows resistant to heat stress, which would efficiently utilize poorer quality feed with high milk yield (*Hayes et al., 2009*). Identification of such animals presents a challenge to scientists due to the complexity of the response to heat stress and the negative correlation between heat tolerance and productivity. The development of new technologies provides an opportunity to solve this problem. After finding highly productive individuals resistant to the negative impact of climatic factors, the information obtained about their genome should be used for comparison with the genome of individuals sensitive to heat stress to identify the polymorphism of certain genes and perform selection in that direction. Various physiological indicators, such as rectal temperature, breathing frequency and salivation, can be used to genetically identify animals with more efficient adaptation mechanisms to the presence of heat stress. However, heritability for these physiological traits is low. That is why it is necessary to develop methods for evaluating the reproductive value of the head, which will include indicators for improving heat tolerance in dairy cattle.

Negative genetic relationships observed between heat tolerance and other economically important traits should be included in the selection indices to enable the selection of cattle that have resistance to heat stress while simultaneously maintaining or increasing productivity *(Luo et al., 2021).*

Thanks to the application of intensive selection and modern technological methods (artificial insemination, embryo transfer, genomic selection, etc.), enormous progress has been made in livestock production in the past few decades. The level of milk production has increased many times while the number of cows has decreased. However, it also has its drawbacks. Genetic diversity has been reduced, with negative consequences for health, longevity, fertility and resistance of animals to unfavourable conditions of keeping. In the future, dairy cattle breeders should place greater emphasis on traits related to animal welfare, health, longevity, environmental efficiency (e.g. methane emissions and feed utilization efficiency) and overall resilience. To achieve the set goal, it is necessary to define criteria (traits) that (a) represent the biological mechanisms underlying the corresponding phenotypes, (b) are hereditary and (c) can be measured in a large number of animals in the early period of life. Also, it is necessary to preserve and use the gene pool of domestic breeds whose resistance and ability to adapt should be integrated into modern breeding goals. This would avoid further losses of genetic diversity in the populations of modern breeds of cattle and the reduction of production potential while improving the health and welfare of the animals *(Brito et al., 2021*).

One of the methods of biological adaptation refers to the reproduction of animals. Techniques that have been investigated to reduce the negative effects of heat stress on reproduction include embryo transfer, ovulation induction and a combination of different procedures. (*Jordan, 2003; Rensis and Scaramuzzi, 2003).*

Breeding strategies for heat-tolerant heads depend on the production system. Systems that can provide sufficient resources for high productivity with the use of high technology and farm equipment will benefit more from the cultivation of highly selected noble breeds. In contrast, production systems with scarce resources in terms of housing and nutritional conditions will benefit more from crossbreeding with domestic breeds (*Carabaño et al., 2019*).

Technological optimization implies corrections in the method and time of feeding:

- Increasing the share of energy in the diet, because animals that are exposed to heat stress use part of their energy to maintain homeostasis;
- Avoiding feeding animals during the warmer part of the day;
- Increasing the quality of nutrients used in nutrition;
- Use of additives, such as probiotics and supplements that increase resistance to heat stress;
- Provision of sufficient quantities of fresh water;
- Control of temperature and air humidity in buildings
- Ventilation, cooling and airflowin buildings;
- Use of THI control applications;
- Thermal insulation of roofs;
- Natural shading of buildings, provision of ranges and canopies on ranges;
- Direct cooling of animals (dew or pouring water);
- Avoiding relocation, unnecessary movement or transport of animals;
- Control of insects (primarily flies) and
- Screening for the emergence and spread of new animal diseases.

The use of new materials and technical solutions that are now used in a certain form in construction and that would be adapted to the principles of building facilities for housing animals and enable a more effective fight against the consequences of heat stress in cattle. These are various technical solutions related to the shape and position of the barn, new insulation materials, such as cold materials or cross-laminated wood, as well as polyurethane insulation or shading systems, etc.

Grazing cattle on grasslands and natural pastures of satisfactory quality has significant advantages, which are reflected in a reduction of feeding costs, diminished risk of nutritional deficits and infectious diseases, i.e. increasing general resistance due to the possibility of movement, being in the fresh air and exposure to the sun. In principle, the quality of food largely depends on the way it is produced and preserved. In addition to ensuring the quality of feed used in cattle nutrition, great attention must be paid to the optimization of meals concerning the specific needs of animals in nutrients according to breed, sex, head category and stage of the production cycle.

Adaptation of the diet involves changes in the time and frequency of feeding (cooler time of day, more feedings per day), adequate feed, enough space for all the cows to eat together, plenty of cold water and adequate airflow. Increasing the number of feedings per day has two advantages. First, the food is fresher, which encourages consumption and reduces the number of insects that come into the food. Second, cows are curious by nature, so they will be stimulated to come and get food more often. Feeding time is also important. Increasing the amount of food available during the cooler part of the day, early in the morning or late in the evening, maybe another alternative. During hot days, the cow will eat mostly at night and after milking (*Kumar et al., 2018*).

In milk production, the occurrence of heat stress leads to huge economic losses every year. To better manage the heat regime in dairy cows, its early detection must be improved to apply certain cooling measures in time. With the development of sensor and wireless transmission technologies, body surface temperature and breathing rate can be automatically measured via portable devices. This will enable rapid, automatic regulation of microclimatic conditions in facilities and areas for housing animals using different methods of cooling animals (*Shu et al., 2021*).

Cattle production is directly affected by climate change, as it uses resources whose seasonality and capacity depend on climatic conditions. Farmers are responding to the negative impact of climate change by applying different adaptation strategies. The choice of strategy depends on many factors. The main factors that, according to research, influence the choice of adaptation strategy of farmers are experience, herd size, membership in agricultural organizations and associations, level of education and climate zone (*Idrissou et al., 2020*).

Conclusion

If it is necessary to react to unfavourable conditions when they are present, it is usually too late and the damage has already been done. In order to avoid such a situation, it is necessary to define long-term strategies to minimize the risk of climate change.

Improving the genetic potential for higher milk production per head can lead to an increase in total milk production without increasing the total number of heads. The necessity of improving milk production and increasing the efficiency and competitiveness of milk producers was also recognized by the Government of the Republic of Serbia with the adoption of the Action Plan for the implementation of the Government Program 2023 - 2026, the adoption of the Agriculture and Rural Development Strategy (2014-2024), as well as the IPARD (Instrument for Pre-Accession Assistance in Rural Development) projects.

The measures that should enable the achievement of the planned goals in the field of work of breeding organizations are the application of modern technologies in the assessment of the breeding value of animals, including resistance to heat stress (genomic selection, determination of genetic polymorphism, etc.), selection and breeding of animals with the best breeding values, both for production and functional traits (application of artificial insemination, embryo transfer), education of breeders, up-to-date forwarding of information about breeding animals (bull catalogue, public presentation, publications, online accessible information, etc.), sale of breeding animals, provision of a sufficient number of doses of semens of suitable bulls, prevention of infectious diseases, etc. It is of strategic importance to optimize forage production (mainly by improving water and soil management) and to improve the ability of animals to cope with heat stress. In order to achieve this, a fast flow of information and application in agriculture, that is, livestock production, is necessary (*Nardone et al., 2010).* Rapid changes in climatic conditions require the advisory and professional work on farms with breeders. For each breeder, one should analyze the possibilities and look at individual problems. In line with that, each of them should be helped to find a sustainable solution for their farm. When it comes to production technology, solutions can be related to improving microclimate conditions in buildings (use of fans, sprinklers, etc.), changing the way of rearing (ranges, grazing) and feeding the cows (various nutrients, additives, change of feeding time). In terms of selection, individual insemination plans should be developed that will include bulls that have been tested for tolerance to heat stress. Also, breeders must be familiar with the progress of modern methods in selection and the possibilities of application in their farm. If there is a possibility, it should be introduced into the production of milk and milk of other breeds or strains of the same breed, which are more resistant to unfavourable microclimatic conditions. However, the first prerequisite for professional and advisory work is the education of agricultural producers. This is the only way to achieve success because “scientia potentia est”!

The world can still be a nice place to live if agricultural production is maintained in a planned, conscientious and efficient manner in the conditions of increasingly pronounced climate changes.

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