# Reducing the risk of heat stress for livestock development in Kazakhstan

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***Abstract.*** *The last three decades in Kazakhstan turned out to be the warmest in the history of meteorological observations, and led to an increase in the average annual temperature by 1.91 °C. Global warming has become a serious risk for the intensive development of animal husbandry in the country. To reduce the stressful effects of abnormal heat and cool animals, a number of domestic farmers use shadow screens, various forms of forced convection and evaporative cooling, which include fans and sprayers, sprinklers. However, these measures do not give the desired result: they are energy-intensive, inefficient and do not form a normalized microclimate in livestock premises. The article describes the formation of a normalized microclimate for keeping cattle in the summer in the southern, southeastern and western regions of Kazakhstan.*

***Keywords:*** *CLIMATE CHANGE, ANIMAL HUSBANDRY, HEAT STRESS, NORMALISED MICROCLIMATE, AMBIENT AIR TEMPERATURE, RENEWABLE ENERGY SOURCES, HORIZONTAL GROUND HEAT EXCHANGER, REVERSIBLE HEAT PUMP*

## *Introduction*

Currently, the demand for livestock products has increased significantly in the world, which is associated with demographics, an increase in animal protein consumption per capita and an increase in consumer incomes. However, climatic conditions accompanied by global warming are one of the main factors limiting the efficiency of livestock production. The ongoing natural disasters have not bypassed the countries of Central Asia, including Kazakhstan. In the southern, southeastern and western regions of the republic, heat stress associated with high temperatures causes morbidity, direct or indirect decrease in productivity and even mortality. The ongoing extreme weather events with climate change lead to significant economic losses and problems with animal welfare.

In the republic, livestock facilities of small and medium-sized peasant or farm enterprises are designed to contain from 20 to 100 heads of cattle, which are the most common type of livestock buildings. They are built on any available land using local materials, rather than materials that could be more suitable to minimize the heat load.

Today, the main problems of the livestock industry in the country are:

-a high proportion of livestock in the households of the population, individual entrepreneurs, peasant or farm farms that are not covered by technological processes and are not provided with sufficient feed;

-a high proportion of mongrel cattle, primarily in households of the population and individual entrepreneurs;

-weakness of the forage base, low proportion of forage crops in crop rotation, on irrigated lands, as well as degradation and low productivity of pasture lands;

-low level of development of pastures due to their insufficient watering;

-a low level of formation of a normalized condition for the preservation and rearing of animals from the effects of heat stress in the sultry summer and cold winter months.

The adopted "Concept for the development of the agro-industrial complex of the Republic of Kazakhstan for 2021-2030" [1], it is noted that in order to create conditions for the development of domestic livestock, detailed roadmaps for the development of meat and dairy farming, sheep breeding, poultry farming, including measures aimed at solving the problems of a solid feed base, breed transformation, strengthening the material and technical base and the formation of comfortable conditions for keeping animals against the background of the ever-increasing negative impact of global climate change in the southern regions of the country. In order to reduce the environmental impact of the livestock industry, the share of government spending on supporting investments focused on the conservation of natural resources will gradually increase.

Many specialists and scientists from foreign countries are engaged in research on the effects of heat stress on farm animals. Physiological and metabolic changes resulting from the thermoregulation response to heat stress negatively affect the productivity and health of animals. In hot conditions, the decrease in animal productivity is largely due to both direct and indirect effects of heat stress on reducing feed consumption.

## *Prerequisites and means for solving the problem*

Low feed intake directly affects growth rates, and can also have a strong negative impact on the quality of beef meat. Heat stress can contribute to greater marbling of muscles and the deposition of fat in internal tissues instead of subcutaneous fat [2]. The authors of the work [3] note that a hot climate can lead to the fact that beef will turn out darker. The frequency of dark beef formation decreases if the heifers on feedlots are in the shade and heat stress can contribute to greater marbling of muscles and fat deposition in internal tissues instead of subcutaneous fat [4].

Researchers [5] also found that low reproduction of dairy and meat cows is directly related to seasonal high levels of atmospheric air temperature. A decrease in the frequency of pregnancy by about 24% at an atmospheric temperature equal to or exceeding 28 ° C is described by scientists in [6]. Heat stress has a serious effect on pregnancy in dairy cows as well. As a result of a statistical analysis of pregnancies in 20,606 cows from seven farms, it was found that pregnancy rates amounted to 39.4% (THI <72,0), 38,5% (72,0 - 73,9), 36,9% (74,0- 75,9), 32,5% (76,0- 77,9) and 31,6% (>78,0) [7]. This indicates that the pregnancy rate of dairy cows decreases depending on the temperature and relative humidity of the surrounding air with an increase in atmospheric air temperature of more than 28 °C (with THI above 72.0). Similar studies conducted by the authors of the article [8] noted that the frequency of pregnancy was significantly higher after embryo transfer than after artificial insemination (day 21 - 47.6% vs. 18.0%; days 45-60 - 29.2% vs. 13.5%; p <0.001).

Heat stress not only reduces milk yield, but also affects milk content and the number of somatic cells. Analyses of milk produced by cows in Croatia in 2005-2010 showed that the fat and protein content in milk decreased significantly as a result of an increase in the temperature and humidity index THI (p <0.01). A separate analysis conducted in dairy cows in Georgia, USA, also showed a decrease in the fat and protein content in milk by 0.012 kg and 0.009 kg, respectively, for each unit of increase in ambient air temperature at an outdoor temperature of more than 27 °C. [9,10,11]. These studies prove that heat stress has a significant impact on the productivity of dairy cows in summer, which indirectly affects changes in feed intake, milk yields and milk components.

In many countries with temperate or hot summer climates, shade is preferred to reduce the effects of high temperatures. Shade can be economically beneficial to reduce the effects of summer heat, to maintain the efficiency of milk production, reproduction of offspring, and may be necessary for survival. Trees, being the most effective shade carriers, combine protection from the sun with the effect of radiation absorption created by cool leaves that evaporate moisture [12].

In the scientific article [13], the results of testing sprinklers with fans with a diameter of 1.2 m installed at an angle of 30 degrees to the vertical, which flowed around the animals at about 28 m3 per cow, are presented. According to the authors of the work, there have been improvements in the conditions of keeping animals in the pen. Studies conducted in Israel [14] showed that using a cooling system in a cattle pen five times a day increased milk yield by 2.4 kg per day compared with uncooled cows.

Currently, various domestic and foreign companies offer equipment and installations that allow you to arrange a suitable microclimate in the cowshed. These are shadow screens, various forms of forced convection and evaporative cooling, which include fans and sprayers, sprinklers, etc. [15,16,17]. Even at the stage of construction of the livestock premises, individual entrepreneurs provide for higher ceilings in production, install powerful fans and large quantities of water drinkers. Researchers [18] reported that when used with tunnel ventilation of evaporative cooling pads made of fibrous material and a water lining, the room temperature decreases by 2.3-5.6 °C during the hottest periods of the day. At the same time, the cooling efficiency is only 55-75% of evaporative cooling.

In [19], the cooling of the supply air with cooling gaskets and a ground-to-air heat exchanger were studied. The effect of sprinklers installed in feeding grounds and recreation areas has been studied so that cows feel comfortable and do not reduce feed consumption [20]. According to the authors of the research, such events create a milder indoor microclimate, due to reduced exposure to solar radiation and a decrease in ambient temperature. In livestock farming systems with lower costs, various adaptation strategies can be effective in reducing-assessing the effects of heat stress in small-scale farmers' systems [21]. These include, for example, the use of simple canopies to provide shade, animal baths, roof impregnation and the installation of fans in the canopies [22]. It has been shown that some types of shade trees in pasture farming systems, especially in Latin America, are an effective means of reducing heat stress [23].

Attempts are also being made to use a combination of ventilation and cooling systems. The organizations that offer these equipment promises to avoid stagnant zones, install fans capable of evenly distributing air masses throughout the room, install natural air exchange systems using curtains, skates and windows. In addition, various designs are offered that protect against wind, snow and have the ability to automatically and manually adjust.

However, all these measures used to reduce heat stress in animals do not give the desired result: they are energy-intensive, inefficient and do not form a normalized microclimate in livestock premises. In addition, in the southern, southeastern and western regions of the republic, the effect of thermal stress on cattle rearing has been poorly studied. The economic feasibility of using livestock premises as the main element of the cooling system and creating the necessary microclimate in small and medium-sized farms engaged in cattle breeding has not been evaluated.

## *Solution of the examined problem*

To form a normalized microclimate of the livestock premises in the hot conditions of the southern region of Kazakhstan, we selected a reversible heat pump with an integrated renewable energy source. Considering that the use of ground heat is one of the most dynamically developing areas in the world for the use of renewable energy sources in heat pump technology, we have chosen the use of ground heat through horizontal ground heat exchangers as a low-potential source of heat.

The thermophysical properties of the soil, characterizing its reaction to the processes of heat transfer, heat capacity, thermal conductivity and thermal conductivity, were produced using TRIME electronic mobile equipment with PICO 64 and PICO 32 rod sensors manufactured by IMKO (Austria).

To measure the temperature of the soil at the depth where the ground heat exchanger will be located, we have developed a thermal measuring device formed by garlands of a set of DS18B20 digital temperature sensors. The temperature sensors were fixed to a wooden bar and some ends were installed directly into the ground with mandatory observance of measures ensuring the reliability of the thermocouple, while others were connected to a small waterproof housing (Fig.1).

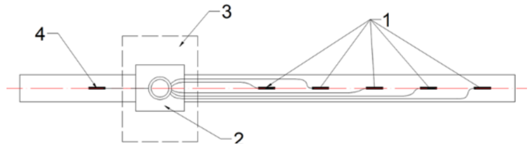


***Figure 1.*** *Diagram of a digital temperature sensor device for measuring soil temperature at different depths: 1- digital sensors for measuring soil temperature; 2-controller with built-in Wi-Fi; 3-waterproof housing; 4- sensor for measuring outdoor temperature.*

From the DS18B20 digital temperature sensor, which has many functions designed to simultaneously measure temperature at several points of an object, via the WeMos D1 controller, a board built on the basis of the ESP-8266EX Wi-Fi chip, information is transmitted to a personal computer, in the form of a Miniitx factor on Intel Atom with minimal power consumption (Fig.2).

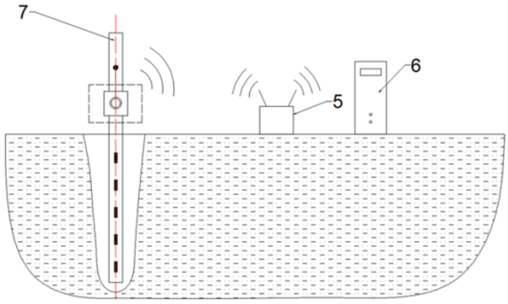


***Figure 2.*** *General diagram of a device for measuring soil temperature at 5 points at the depth of the well. 5-modem; 6-personal computer; 7- a bar for mounting digital temperature sensors.*

Devices for measuring soil temperature at a depth of up to two meters work as follows. The DS18b20 digital temperature sensors, installed at different ground depths, are connected to the ESP 8266 controller via a 1-Wire bus. The controller makes a request to the sensors every second over the 1-Wire bus, according to the 1-Wire protocol, and writes variables to Modbus, at the same time it is connected to the network and has a static IP address. Next, a personal computer with MySQL Server installed requests sensor readings from the controller using the Modbus TCP protocol, with a period of 10 minutes, and writes them to the MySQL database. In turn, through a Telegram bot running on a personal computer, you can read the readings of temperature sensors in real time. You can also download archived data in Excel format for the specified measurement period. The system is also connected to the Internet to remotely receive information about changes in ground temperature at different depths in real time of the day, as well as information from archived data stored on the basis of a personal computer 6.

*Installation and installation of a ground heat exchanger*

In the system of using low-potential ground heat, there are two main methods of geothermal heat extraction: horizontal and vertical heat exchangers. Often, according to technical and economic indicators and the technological simplicity of the organization of heat removal, preference is given to horizontal ground heat exchangers.

Horizontal geothermal collectors were laid in the ground to a depth of 2 meters so that the device was below the freezing level of the soil. As is known, in the conditions of the southern regions of the republic at a depth of 2.0 meters or more, the soil is characterized by a relatively low (10-12 °C), but slightly varying temperature during the cooling and heating period, which makes it possible to consider it as an effective source of low-potential heat for cooling/heating systems.

The amount of heat that can be removed from a meter of a ground heat exchanger depends on many factors: the type of soil, its humidity, and the shading of the site on which the heat exchanger is located. In the area where the research was carried out, at coordinates: 43o31’19.4”N, 76o58’58.8”E, dry clay soil provided an average of 18-20 W/m.

## *Results and discussion*

The established information on the thermophysical properties of the soil: heat capacity, thermal conductivity and thermal diffusivity, at the location of the peasant farm "Altynbaeva S.Zh." in Almaty region, carried out by means of a two-rod probe with solid rods, is shown in Table 1.

Obtained thermophysical parameters of the soil gives an opportunity to rely on accurate and reliable analytical information, rather than using subjective assessment of soil properties.

***Table 1:*** *Thermophysical properties of soil*

| Soil type | Heat capacity, J/(kg·°C) | Thermal conductivity, W/m·°C | Temperature conductivity $m^2$/s |
|---|---|---|---|
| Meadow gray soil | 575 | 1.74 | 2.69 |

Field measurements of soil temperature were carried out in accordance with the requirements for measuring soil temperature, in accordance with "State standard 25358- 2020 GROUNDS. Method of field temperature determination" [24].

As a result, the measurements of soil temperature by means of the thermo-measuring device developed by us on the basis of a set of digital sensors DS18b20, installed at a depth of 2 meters at intervals of 40 cm from the outer surface of the soil, are shown in Table 2.

***Table 2:*** *Ground temperature as a function of measurement depth and change in outdoor air temperature*

| Date of measurement | Measuring section 1 | | | | | Measuring section 2 | | | | | Average ambient temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.4 m | 0.8 m | 1.2 m | 1.6 m | 2.0 m | 0.4 m | 0.8 m | 1.2 m | 1.6 m | 2.0 m | |
| January 18, 2024 | 3.6 | 6.8 | 8.3 | 9.7 | 11.5 | 3.5 | 3.8 | 7.1 | 8.4 | 10.2 | - 13.9 |
| January 31, 2024 | 6.1 | 9.6 | 10.8 | 11.9 | 14.3 | 6.3 | 9.7 | 10.2 | 11.5 | 13.2 | -23.1 |
| February 3, 2024 | 2.5 | 4.6 | 6.1 | 8.3 | 10.4 | 2.7 | 4.9 | 6.2 | 9.2 | 10.4 | -7.4 |
| February 17, 2024 | 2.3 | 5.3 | 7.0 | 8.4 | 10.2 | 2.3 | 3.5 | 6.5 | 8.3 | 9.7 | -6.4 |

As can be seen from the table, the ground temperature changes upward with increasing depth of measurement. At the same time, the deep temperature of the soil increases with a decrease in the temperature of the outside air, but on the contrary decreases with an increase in the temperature of the atmospheric air. This is due to the fact that during the year, the heat transfer process takes place intensively in the surface layers of the soil under the influence of heat fluxes associated with solar radiation. During the cold season, the resulting heat flow is directed from the depth to the surface, in spring and in the first half of summer, opposite from the upper layers into the depths of the soil. In summer, the processes of heat transfer are influenced by vegetation cover (the higher and more often it is, the lower the temperature), in winter the condition and power of the snow cover, which has low thermal conductivity and therefore contributes to the preservation of heat in the soil.

The heat accumulated at a depth of two meters of soil was transported to a reversible heat pump through ground heat exchangers made of PVC plastic pipes with a working diameter of 225 mm. manufactured in accordance with the State Standard 18599-2001 "Pressure pipes made of polyethylene. Technical specifications" [25]. Geothermal collectors were laid in a prepared trench "snake", which is considered the simplest way, the width between the trenches was 1.0 m (Fig.3).

Plastic pipes were laid on a sandy substrate with a thickness of at least 0.1 m. In the bending sections, the connection of geothermal collectors was carried out by special connecting knees. A meter before entering the zone of the reversible heat pump, plastic pipes were insulated with glass wool and the pipes were buried only after they were crimped.

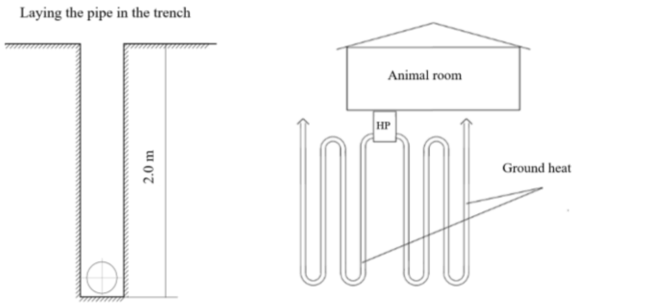


***Figure 3.*** *Schemes for laying plastic pipes and connecting horizontal geothermal collectors with a reversible heat pump.*

## *Conclusion*

As a result of the analysis of the work on the formation of a normalized microclimate for animals in hot climatic conditions, it was found that the equipment and installations proposed by scientists and specialists to equip a suitable microclimate of a cowshed does not give the desired result: they are energy-intensive, inefficient and do not form a normalized microclimate in livestock premises.

A system of integration of a reversible heat pump and a horizontal ground heat exchange collector has been developed, which will ensure a reduction in the effect of thermal stress on cattle and small cattle in hot climatic conditions in the southern, southeastern and western zones of the republic. The advantages of the proposed heat and cooling technologies using renewable energy sources, in comparison with their traditional counterparts, are associated not only with significant reductions in energy costs in systems for the formation of a normalized microclimate of livestock premises, but also with their environmental cleanliness, as well as new opportunities provided in the field of increasing the degree of autonomy of life support systems of buildings.

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