THE EFFECT OF CLIMATE CHANGE ON DAIRY CATTLE

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Abstract

Cattle farming provides important, basic foodstuffs worldwide, and many body parts that are unfit for human consumption can be utilized through further processing. The impact of global warming has already become apparent today with a more common frequency of extreme weather events. As the number of hot days and heat waves is expected to increase, changes may also occur in animal husbandry. Individual weather parameters, especially temperature, affect all aspects of breeding. Due to the increasing warm periods in recent years, the decline in production is becoming more and more significant, as our farm animals react very strongly to persistently high temperature. In the case of intensively dairy cows, the daily milk production and the reproductive biological indicators decrease due to heat stress.

Keywords: cattle, global climate change

Összefoglalás

A szarvasmarha-tenyésztés világszerte fontos, alapvető élelmiszereket szolgáltat, továbbá - a táplálkozásra nem alkalmas - számos testrészét további feldolgozás útján hasznosítani lehet. A globális felmelegedés hatása a szélsőséges időjárási események gyakoriságának növekedésével már napjainkban is megnyilvánult. Mivel várhatóan a forró napok és a hőhullámok száma nőni fog, változások következhetnek be az állattenyésztésben is. Az egyes időjárási paraméterek, különösen a hőmérséklet, hatással van az állattenyésztés valamennyi aspektusára. Az utóbbi években fokozódó meleg időszakok miatt a termelés-visszaesés egyre jelentősebb, ugyanis gazdasági haszonállataink igen erősen reagálnak a tartósan magas hőmérsékletre. Az intenzíven tejelő tehenek esetében a hőstressz következtében csökken a napi tejtermelés, továbbá romlanak a szaporodásbiológiai mutatók is.

Kulcsszavak: szarvasmarha, globális klímaváltozás

Climate change

Climate is a system that involves the interaction of physical properties and processes in the atmosphere with the environment of a given place (a definable finite element of the atmosphere) and with each other over a long period of time. By extending the concept of climate, it can also be related to weather: the climate of a given place is a system that determines weather changes, as well as the equilibrium state where weather fluctuations take place (Péczely, 1998). It is important to note that the climate change of a given place is not independent of the processes taking place in other areas, so the global climate is not just the sum of local climates (Bártfai et al., 1997). Climate is a combination of elements that includes temperature, humidity, precipitation, radiation, air movement and atmospheric pressure (Johnson, 1987). Climatologists pay close attention to the study of climate change. Evidence for the observed

effects of climate change is the strongest and most comprehensive in natural systems. There are two forms of climate variability: climate fluctuation and climate change. Climate fluctuation occurs when the higher and lower values follow each other, but the fluctuation remains within the extreme values. Climate change occurs when the interval of fluctuations in climatic elements shifts to either higher or lower values, and this condition persists for a longer period of time. This interval is determined by the current lowest and highest values of the given meteorological element, these are the so-called extreme values (Varga-Haszonits et al., 2004).

A sudden rise in global surface temperature was detected in the recent decades, associated with significant changes in the frequency of extremely hot and cold events (Alexander et al., 2006). According to IPCC report (2007), by the end of the 20th century, temperature will rise with 1.1-6.4 °C. Since 1950, changes have been observed in several extreme weather and climatic events, including declining cold temperature extremes, increasing hot temperature extremes, increasing frequency and long-term occurrence of heat waves, rising sea levels and increasing heavy rainfalls in several regions (IPCC, 2014).

Zoometeorology examines the relationships between breeding animals and weather factors. The body of farm animals is strongly connected to the meteorological factors (solar radiation, air movement, humidity, temperature) that affect their production. Global climate change is dramatically increasing the number of extreme weather events, making productive varieties extremely sensitive to external environmental factors.

The effect of sunlight duration

The life processes and production of animals are influenced by the length of illumination. The changing brightness of the Sun is one of the direct manifestations of climate change. Some evidence supports the fact that the brightness of the Sun has increased throughout history

(energy production, rate of fusion, conversion of hydrogen to helium), yet there is little information on changes in the brightness of the Sun on a climatic time scale (Varga-Haszonits et al., 2004). In a study of limousine cattle, Leinonen et al. (2001) found that light perceived by animal's eyes leads to gonadotropic hormone production in the adenohypophysis, which results in the onset of sexual symptoms. Furthermore, pituitary hormone production is also enhanced by light, which controls the duration of pregnancy, biological rhythm, and 24-hour vegetative function through thyroid and adrenal function. Only 10-25% of the radiation is reflected from the animals with a dark outer cover, the rest is absorbed, while in case of light-haired animals 70-80% is reflected (Anda et al., 2010).

Regarding the sensitivity of grazed animals, sunburn and heat stroke are very important, as sunlight is one of the most important heat stress factors (increases the temperature of the environment and body), and shading is one of the major tasks. Calves - young and growing animals - are strongly exposed to this effect. As a result of sunlight, the metabolism and feed uptake increase, the fertilization rate is better, and it also stimulates the mood.

Effect of airflow

Animals are affected by two types of airflow: wind and draft. In the case of wind, gust is dangerous, as the speed of the wind can increase suddenly, thereby mechanical load exponentially rises. Draft is usually common in barns, where it is unfavorable due to its permanence. It is possible to defend passively with windshield boards and forest strips. Actively, animals can run away or group together, which allows to concentrate wind effects on a small surface.

Around the body surface of the cattle - supplementing the beneficial effect of the outer fur - a ~10 cm thick, buffered layer of air is formed, providing some protection. The higher the wind

speed is, the greater the heat dissipates, cold can caught and the buffer air layer can be removed. In addition to the negative effects, however, the wind also has a refreshing, air-exchanging, warm-air-carrying, balancing effect (Anda et al., 2010). Strong flow of air draws heat away from the body, which is especially dangerous for newborn and young animals, as their energy reserve quickly depletes, they die.

Effect of precipitation and humidity

Local precipitation has a mainly negative effect on grazed animals, increases the feeling of cold (but the cooling effect is positive in summer), and can cause deworming, where intermediate hosts quickly appear (Thompson, 1973). During rainy periods, diseases spread, epidemics break out and external and internal parasites multiply. Humidity of 75-85%, coupled with high temperature values, increases respiration and heart rate, which provides growth of viruses, fungi and bacteria. If precipitation and relative humidity occur together, they can strengthen each other's effects. Precipitation can be prevented if the animals hide in natural or artificial shelters, while the modification of humidity is only partially possible, e.g. by reducing water phases in the barn (Anda et al., 2010).

The effect of air temperature

All weather effects are present in mammals via the autonomic nervous system and the hormonal system. The body responds to the changing temperature of the environment with thermoregulation. If a rapid adaptation to weather is required, the autonomic nervous system plays the main role. When it becomes necessary to compensate weather stimulus, hormonal regulation prevails (Makulska et al., 2003). The body of newborn animals shows an increased sensitivity to temperature (Rosenberg et al., 1983). In cold weather, blood circulation speeds

up, blood pressure rises and thus produces more heat, the body is protecting against cooling. In this case, food intake also increases. Cold stress has a negative effect on the body, but animals can tolerate it longer than too high a temperature. In warm weather, the body defends itself by evaporation (in the form of sweating), fluid intake increases while food intake decreases. In serious cases, anorexia can occur (Kovács, 1990). For animals, high temperature soon becomes unbearable because they are less resistant (Dinu et al., 2004). Cattles are particularly sensitive to higher temperatures. Milk loss can be 50% above 30 °C, and at 22 °C feed intake of animals is already reduced. The secretory function of the thyroid gland is reduced, which also slows down the metabolism. The rectification temperature of cows exceeds 39 °C after spending a few hours at 26-30 °C. Due to heat stress, fertilization does not occur due to the reduced biological activity of germ cells. In the case of bulls, the temperature of the testicles also rises as a result of persistent warm temperature, thus producing less and worse sperm (Bártfai et al., 1997).

Effects of heat stress on cattles

The body temperature of a cattle is within a narrow range, like our farm animals. It is a homeotherm species with a constant body temperature, so heat production and heat release are normally in balance. This balance is provided by different thermoregulatory mechanisms (Bárdos et al., 2007). Within this narrow range, the animal does not need to put extra energy into cooling or heating the body (this means a range of 0 - 20 ° C for dairy cattles). Their body temperature is relatively independent of the environmental temperature, but this requires a certain amount of energy to keep body temperature. This is necessary for the proper function of physiological processes.

Subsistence is always more important than production. The energy absorbed by the feed is primarily used for subsistence and in the production energy availability is only additionally utilized. From an economic point of view, therefore, the amount or energy- forced to be used for subsistence – is important. This energy is influenced by a number of factors such as race, body weight, age, sex and production. The most important influencing factor is the temperature of the environment. The temperature range in which the animal uses the least energy to maintain body temperature is called the comfort zone, where the well-being of the animals is also the best (Dankó et al., 2017).

The internal temperature of the body is responsible for the activation of regulatory mechanisms. The thermoregulatory centre is located in the hypothalamus, its frontal core group is called the cooling-, while its hind core the heating centre. The response depends on the temperature of the blood in the hypothalamus. If the blood temperature is higher than normal, the parasympathetic tone increases, if it is lower, the sympathetic tone plays a greater role. At higher temperature, sweating, wheezing, dilation of the skin vessels and increased salivation occur. At lower temperature, the skin vessels constrict, hair ruffles, tremors occur and hormones of thyroid and adrenal flow into the circulation, glycogen and fat stores are mobilized, which actually increases cellular oxidation, resulting heat production (Bárdos et al., 2007).

Bak and Pazsiczki (2008) found that the most preferred temperature range for homeothermic animals is the thermoneutral zone (maximum production with the most efficient energy use). Within the thermoneutral zone, 3 more zones can be separated: cool production zone (-15-0 °C), optimal production zone (0-20 °C) and warm production zone (20-26 °C). In the warm production zone, milk production and feed consumption are already slightly reduced, but this is still an acceptable temperature range for the cow. The thermoneutral zone is surrounded by lower and upper critical temperature values, which are 26 °C and 5 °C for Holstein-Friesian.

It is important to note that these limits may differ (e.g., depending on age, variety, quantity and quality of feed) (Dash et al., 2016).

If the animals are not able to keep their internal body temperature (the two limits are exceeded), they respond by decreasing or increasing the intensity of metabolism, the respiratory rate, the rectal temperature and the number of heartbeats increase. In this case, the balance between heat production and heat release is upset, homeothermia ends and heat stress develops. Decreased growth rate, milk yield and reproductive performance can be observed (Das et al., 2016). The comfort zone of dairy cows is between –15 and + 26 °C (Ribács, 2012). Heat stress occurs when the temperature of the environment exceeds the value that the body can compensate (Kovács and Kovács, 2012). In this case, such environmental conditions are created (due to environmental temperature, relative humidity, solar radiation and air movement) that do not cover the cow's thermoneutral zone.

Dairy cows are very sensitive to heat stress due to their intensive metabolic processes, limited renal and gastrointestinal water retention (Bernabucci et al., 2010). At the level of varieties and individuals, high variability can be observed in heat tolerance and responses to environmental changes, but Kovács and Kovács (2012) found that husbandry technology significantly influences sensitivity to heat stress. Improper feeding practices and deficiencies in husbandry technology can increase the harmful effects of heat stress (Gergácz, 2009). Heat management is playing an increasingly important role in ensuring animals, which is also supported by increasingly strict requirements (nationally and internationally). These laws and directives have a number of climatic implications (Pazsiczki, 2005). The most important solution is to prevent the development of heat stress by reducing or preventing the decline in dry matter uptake, and thus to prevent the deterioration of production indicators. It should also be noted that prevention is intended to reduce negative effects, not to reduce heat stress.

Heat stress is also a serious problem for dairy farms in Hungary (especially in the Great Hungarian Plain, which sometimes has an extremely continental climate). Hungary's climate is expected to warm further due to global climate change. In particular, summer temperatures reflect this warming process. Heat stress reduces the live weight of calves and also has a negative effect on the following lactation performance. The fertilization index deteriorates, the number of oestrus decreases and embryonic death becomes more frequent (Rensis and Scaramuzzi, 2003). In case of persistent heat, rumen acidosis and the associated lameness become more common (Bernabucci et al., 2010). As an effect of temperature change, the heat dissipation is modified. If the environment is much cooler than the cow's body temperature (ie. the air temperature is between 18 and 21 °C), the animal can dissipate 60-70% of its own heat by so-called dry heat dissipation. With wet heat release, the larger part of the excess heat is forced to be released by the animal as air temperature rises. Temperature is not the only environmental factor that influences the intensity of heat stress. It should be taken into account that the heat stress causing factor is also humidity dependent, but in Hungary the limit is usually above 26 °C (Orosz and Latos, 2006), when the rate of wet heat release reaches 80–90%. At this temperature, the humidity in the barn starts to rise, which inhibits wet heat release, causing a thermal stress to the cow. Based on the relationship between temperature and relative humidity, a so-called HPI index (temperature / humidity) can be established, which shows the cow's sense of comfort (Takács, 2013). This index gives the intensity of heat load, which measures the combined effect of environmental temperature and relative humidity (Allen et al., 2013). There are many limit values in the literature, and using the same formula, these present a deviation in the dangerous degree of heat stress. Heat increases pneumonia, especially when coupled with high relative humidity (Morse et al., 1989).

Heat stress can upset the hormonal balance in the body of animals, which affects the levels of sex hormones. Disorders of animal reproduction are the first to appear among the physiological changes induced by heat stress, reducing the length and intensity of oestrus. A certain degree of reproduction seasonality can be shown even in the case of intensively producing varieties, despite the fact that most of our farm animals have lost the seasonal nature of their reproduction. Normal spermiogenesis requires less heat than body temperature. Recent researches have shown that follicular maturation is a temperature-sensitive process. Summer heat stress affects follicular maturation, its dynamics, the development of the corpus luteum and the quality of ovum and embryo. If less mature dominant follicles develop during the sexual cycle, sex steroid production by theca and granulosa cells is disrupted. Estrogen level in the blood will be lower and, due to the nature of the heat stress (acute or chronic), plasma progesterone level will increase or decrease. As a result of hormonal changes, the uterine environment also changes, which also reduces the quality of the embryo. Not only does summer heat stress (July-September) show a lower conception rate on fertility, but it also affects in autumn (October-November). This is due to the prolonged effect that summer heat affects follicles that become dominant follicles in 49–50 days (De Rensis and Scaramuzzi, 2003; Wolfenson et al., 2000).

The central nervous system senses the presence of the stressor, which starts the general adaptation syndrome. Adaptation syndrome has three stages: the alarm response, the resistance phase and the exhaustion phase. Adrenaline - a hormone in the adrenal medulla - plays a key role in this process. It is mainly responsible for the first phase, i.e. the emergency response, while cortisol, which is the hormone of the adrenal cortex, is responsible for the second and third phases. In this case, the hypothalamic – pituitary – adrenal cortex system is activated, and cortisol secretion in the adrenal gland is increased (under the influence of CRF-ACTH

hormones). The effect of elevated ACTH hormones reduces estradiol-induced oestrus symptom (Hansen and Aréchiga, 1999).

At the beginning of lactation, all cows develop a negative energy balance, the metabolic stress, which increases the harmful effects of heat stress. Fat mobility is increased due to the lack of energy, thereby increasing the concentration of keto substances in the blood, which can have a significant negative effect on the reproductive biological performance. In a ketotic animal, follicles exposed to high concentrations of glucose, BHB and NEFA produce less estradiol. They are less sensitive to LH, and are less likely to ovulate and reach the dominant stage (Leroy et al., 2006). Due to summer heat stress, ketosis is 1.4 times more common in summer calving cows than in winter calving ones (Andreu, 2016). Furthermore, Andreu's (2016) studies show that ketosis in the first and second weeks after calving reduces the chance of pregnancy by 50%. He found that the time from calving to conception was nearly 40 days longer than in non-ketotic animals.

A decrease in the number of pregnant days may also be associated with the negative effects of heat stress. Temperature above the prolonged thermoneutral zone in the late stages of pregnancy affects maternal and fetal metabolism, and stress also modifies the functioning of the hormonal system. Calving begins earlier because fetal stress occurs sooner (Collier et al., 1982).

Conclusions

The effects and prevention of heat stress have a very high importance in animal husbandry. In summer, the primary goal is to maintain the homeostasis and production of the cow and to avoid fluctuations in reproductive biology. In dairy cattle farming, especially in intensive milk processing, preventing the harmful effects of heat stress is a daily task during the summer months.

Agriculture is one of the most exposed sectors to environmental impacts. While in crop production plant breeding quickly provides resistant varieties, in the case of farm animals it is a bigger challenge due to the longer generation interval, which is especially true for cattles. As a result, it is important to develop practical methods and technologies that can reduce production losses and maintain their economy even in extreme weather conditions.

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