IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, November 2023

Assessing the Effects of Climate Change on Dairy Cow Production Systems: A Review of Emerging Challenges

Virendra Kumar Prajapati[1] and Dr. Narendra Singh Gurjar[2]
Research Scholar, Department of Agricultural[1]
Research Guide, Department of Agricultural[2]
Sunrise University, Alwar, Rajasthan, India

Abstract: *We refer to planetary-scale changes as "global changes." This general term covers a wide range of subjects, including the use of resources, the development of energy, population growth, land use and cover, the carbon and nitrogen cycles, pollution and health, and climate change. The challenges that climate change, one facet of global change, poses to Europe's dairy cow production systems are covered in the article. Accelerated global warming threatens ecosystems, biodiversity of plants and animals, and the security and safety of food supplies. It is generally established that the direct and indirect effects of global warming, when coupled with an increase in the frequency of weather extremes, constitute a serious danger to cattle production, even in areas with moderate climates like Central Europe. We will discuss potential and observed consequences of climate change, including increased temperatures, more frequent hot days, and heat waves. We'll concentrate on the challenges confronting grassland production, the standard of fodder, overall nutrition, health and wellbeing of cows, and the efficiency of dairy production. Both direct and indirect effects are linked to animal performance. There are strong indications that when an animal is chosen for high-yielding features, its susceptibility to climate change increases. Cumulative effects (e.g., higher temperature with rising loads of diseases and their vectors) amplify these impacts. To address the consequences, many possible adaptation and mitigation strategies need to be developed on several levels. Breeding plan adjustments, health care management, and production system (housing, feeding, and management) adjustments are included in this*

Keywords: Heat stress, Feed quality and availability, Disease outbreaks

I. INTRODUCTION

Cattle will be impacted by the combined effects of changed air temperature, precipitation, frequency, and severity of severe weather occurrences. Impacts that are both direct and indirect are covered. Climate change adaptation and mitigation techniques are becoming more and more necessary. A variety of tools, from management, nutrition, and health to plant and animal breeding, should be used in these methods. Anticipated changes will selectively push traits essential to biological fitness (and production). Genetic flexibility is essential for livestock systems to thrive in the future, especially for high-yielding animals. The costs associated with these changes will fall on producers and consumers.

Even in more moderate locations such as Central Europe, climate forecasts for the future indicate to an increased frequency of heat waves and droughts, particularly during the summer. By 2050, it's expected that the dairy-producing and somewhat maritime north of Germany would see a 15% drop in summer precipitation and a 2°C rise in annual mean ambient temperature. Furthermore, there is expected to be a little increase in the number of hot days (above 30°C) (Gauly et al., 2013). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), by 2100, the average global surface temperature is expected to have risen by 0.3°C to 4.8°C (IPCC, 2014). Regarding the effects on dairy calves, who experience heat stress when exposed to high ambient conditions, the frequency of days that result in heat stress has grown over the previous few decades in a number of regions (Solymosi et al., 2010). It is crucial to keep in mind, however, that a plethora of recently published studies also highlight the

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, November 2023

extent, duration, and nature of the effects of climate change. Additionally, the impacts will differ significantly throughout different livestock species, varieties, and people. Therefore, the species (genotype) and intensity of each relevant geographical area are important factors.

The issues that climate change is bringing to the dairy producing sector must be recognized. The primary focus of this research will be the European dairy cow production systems.

The primary effects of climate change are an increase in the frequency of hot days, heat waves, warm periods, and other extreme weather events (like floods and hail). These factors have a substantial impact on animal physiology, welfare, health, and reproduction and are thus pertinent to the production of livestock (Zampieri et al., 2016). It is logical to assume that every link in the value chain of dairy production will be impacted by climate change, particularly in the form of extreme weather. For instance, studies show that heat waves lower the amount and composition of milk available, which has an impact on the quantity and quality of various dairy products (Cowley et al., 2015). Climate change will thus have a huge economic effect on the dairy business. Therefore, in order to address these issues, mitigating measures such as management strategies, dietary modifications, components that maintain health, and heat-tolerant plant and animal breeding programs must be developed. Based on the estimations of some writers (e.g. Fitzgerald et al., 2009), there may be more neutral than negative economic consequences of climate change in Central Europe if such measures are put into place.

How can climatic conditions and the effects on animals be quantified?

One of three approaches may be used to evaluate potential climate-related impacts on cattle: (a) parameters based on the environment; (b) animal-related qualities; or (c) a combination of the two. Regarding the ambient conditions, wind speed, precipitation, sun radiation, relative humidity, and air temperature are significant factors. Indicators that take into account some of these parameters are often used to quantify the effects of heat load on animals and establish their thermal comfort zone. There are restrictions on the availability and validity of certain parameters. Thus, most studies have focused on the easiest parameters to obtain: relative humidity and air temperature. This is why one of the most often used indicators is the Temperature-Humidity-Index (THI), which combines relative humidity and air temperature into a single, variable-weighted value. There are now several THI formulas in use, and they are developed in various climate zones with differing focus on ambient humidity. Furthermore, there is variation in the methods by which they use the metrics (relative humidity, wet bulb temperature, and dew point temperature) that represent humidity (Berman et al., 2016). When different indices are employed for different components and places, it affects the transferability of THI thresholds, leading to varied thresholds. The THI was developed by the National Research Council (1971) and is a measure of air temperature (in °C) plus relative humidity (in %). Most studies done in places with moderate climates, like Central Europe, have used the THI. The Comprehensive Climate Index (CCI) (Van Laer et al., 2015), the Heat Load Index (HLI) (Gaughan et al., 2009), and the Back Globe Humidity Index (BGHI) (Buffington et al., 1981) are a few additional lesser-known metrics. The latter two incorporate ambient wind speed and solar radiation in addition to air temperature and humidity. When predicting how pasture would be affected by the weather, these two factors could be more reliable than those that are used inside.

Although the THI has been widely researched and used to assess thermal comfort or discomfort in dairy cattle, its validity, sensitivity, and reliability are limited in a number of ways. It is well known that individual traits, including performance, breed, and pregnancy, influence an animal's vulnerability to heat stress in dairy cattle. There are also differences in climate assessment across farms and regions (e.g. Renaudeau et al., 2012). This indicates that it seems to be inadequate to reliably quantify the incidence of heat stress using just the THI. Therefore, when assessing heat stress in dairy cattle, information from animal studies must be taken into consideration as well. While impacts on behavior and performance (mostly daily milk output) become more evident after a longer heat period, changes in physiological indicators, such as body temperature or respiration rate, give insight into animals' short-term reactions to heat (e.g. Lambertz et al., 2014). According to Liang et al. (2013), the most common method for determining body temperature in cattle is rectal temperature. The next sites to check for body temperature are the vagina and milk (Galán et al., 2018). Other areas to check for body temperature are the udder, rumen, peritoneum, or tympanum (Liang et al., 2013). Ammer and associates (2016). Accurately reflecting the body's core temperature with a low-invasive, highly feasible method is the aim of obtaining temperature measurements at several body regions. However, it's crucial to keep in mind that any type of body temperature measurement is affected by a number of endogenous factors like breed, milk yield, parity, intake of water and feed, and even the method used to measure it (Liang et al., 2013; Ammer et al., 2016). These external factors also include the time of day, season, and weather. Physiological indicators (heart rate, respiration rate, sweat rate, and metabolic heat generation), behavioral traits (eating, resting, drinking, and grazing), and biomarkers that aid in the detection of metabolic issues brought on by heat stress are some other indicators that come from animals. Galán et al. (2018) state that these standards might be useful in developing mitigation plans that can be put into action prior to the emergence of significant health or productivity problems. Moreover, the alterations in biochemical, cellular, and metabolic parameters brought about by heat stress can prove to be valuable indicators in the future. As was previously said, the effects of heat stress on an animal's behavior and performance depend on how long it is exposed to the heat load. De Andrade Ferrazza et al. (2017) state that the previous day's climate has a bigger influence on the DM intake (DMI) than the present conditions. Before heat stress has a discernible effect on milk production, three consecutive hot days are needed in a moderate setting (Lambertz et al., 2014).Gauly and Ammer

Climate change, performance, product quality and reproduction

The organism must raise its heat dissipation and body temperature when external factors, such as ambient temperature, surpass the upper limit of each individual thermoneutral zone. This heat load has an impact on the organism both directly and indirectly on its performance. Nonetheless, there is a significant correlation between the production of milk and the degree of hyperthermia. For this reason, it is almost impossible to precisely quantify the lower and upper critical boundaries of the thermoneutral zone for dairy cattle as a whole. On the other hand, large milk outputs accentuate the previously noted negative relationship between ambient heat and feed intake. The organism itself produces less heat when its feed intake is reduced, and this reduction is necessary to balance the thermal burden. It follows that it is clear that dairy cattle with high production levels are more susceptible to heat stress (Zimbelman et al., 2010).

Clearly, there are delayed rather than immediate impacts of climate on milk output. According to West et al. (2003), hot weather two days before (THI between 72.1 and 83.6) was responsible for a drop in milk output and DMI. Daily THI and both milk output and feed consumption had a correlation of −0.76 and −0.24, respectively, according to Bouraoui et al. (2002). The daily milk output fell by 0.41 kg for every increasing index unit when the THI surpassed 69. Climate effects on the organic and inorganic milk constituents were studied in addition to milk production, with varying degrees of success. All investigations have shown that there is no influence with regard to milk lactose, which is one of the primary constituents after water (Cowley et al., 2015). Results on the impact of heat stress on milk fat content have generated controversy. Liu et al. (2017) reported changes in the triacyl-glycerol (TAG) profile and decreased phospholipid levels brought on by heat stress, which may alter the properties of milk fat (such as its fatty acid content). Heat stress tends to reduce the amount of casein and milk protein, although Cowley et al. (2015) found no changes in the percentage of milk fat under heat stress conditions. This has an impact on the efficiency of cheese-making procedures and milk coagulation properties, particularly when utilizing raw milk (Cowley et al., 2015). Mariani et al. (1993) observed significant seasonal fluctuations in milk's mineral content, which are most likely the result of several variables including nutrition.

For dairy producers, the most significant impact of heat stress is most likely diminished fertility. The decreased reproductive performance in dairy cattle is caused by an increase in internal body temperature brought on by both short- and long-term heat stress. Reduced conception rates, fewer anestrus-induced fertile days, and longer gestational ages are among the effects of heat stress on fertility (Kadokawa et al., 2012). Heat stress causes changes in follicle development, including pre-ovulatory follicle temperature, as well as in the enclosing oocyte and embryo (Campen et al., 2018). High temperatures on the day of insemination were positively correlated with conception rates, according to in vivo studies (Nabenishi et al., 2011). Sakatani et al. (2015) estimated the impact of heat stress on cow oocyte fertilization using an in vitro model and concluded that arising oxidative stress causes polyspermy, which lowers the zygote's capacity for further development. Heat stress may have direct impacts on the uterus, embryo, and early fetus in pregnant cows. However, advanced-stage embryos, such as blastocysts and morula, have developed a considerable degree of thermotolerance (Paes et al., 2016). Numerous hormonal therapy approaches were looked at in an effort to reduce the aforementioned impacts at the farm level. By using GnRH during artificial insemination, the conception rate might be increased (e.g. Lo´ pez-Gatius et al., 2006). However, the tactic is only applicable to cows that exhibit estrus.

Nonetheless, there is debate on the effectiveness of these hormone programs when exposed to heat stress (e.g. Akbarabadi et al., 2014). Reciprocal effects are significant in addition to the direct impact of heat stress on reproductive performance. The effects of intramammary infections and heat stress on ovarian function in dairy calves, as well as the interactions between the two stressors, are outlined by Roth and Wolfenson (2016). They proposed that heat stress and mastitis had a compounding detrimental impact on reproduction. In any event, it's critical to emphasize that heat load may affect a cow's reproductive physiology in both the short and long term (Safa et al., 2019).

Furthermore, the goal of a number of research was to determine how heat stress affected bull fertility. They documented detrimental effects of testicular heat on DNA integrity and sperm quality parameters. Bulls under heat stress had lower motility rates in their ejaculates and higher percentage of sperm with aberrant morphology (Malama et al., 2017). According to a retrospective research conducted by Sabés-Alsina et al. (2019) on the sperm quality of frozen-thawed semen, there is a higher likelihood of a correlation between sperm quality measures and climatic conditions one or two months before to semen collection than there is during the month of semen collection. This problem received less attention at this evaluation since good housing and management circumstances may more readily protect dairy bulls, particularly those housed in commercial artificial insemination clinics.

Climate change, animal health, behavior and welfare

Climate change will either directly or indirectly affect animal health, behavior, and welfare as a result of other impairments. Factors such as the genetic makeup of the animals, the degree of exposure, and their particular physical state (such as pregnancy) alter the effects. Production levels are thought to enhance sensitivity and susceptibility to stress (Sanker et al., 2013), which in turn raises the effect on welfare, behavior, and health. But compared to large systems, intensive production systems may be less impacted, particularly in least-developed nations where there are no viable adaptation measures (Rust, 2019).

Challenges in dairy farming due to climate change

Climate conditions may have a direct impact on animal health, increasing the risk of temperature-related diseases and deaths. Changes in the immunological and endocrine systems may be the source of these effects (Das et al., 2016). There are known seasonal variations in the number of somatic cells in milk, with values rising in the summer (e.g. Testa et al., 2017).

Indirect impacts of the weather on health: modifications in heat-stressed cattle's eating habits, such as an increase in concentrate intake or a reduction in forage intake, may exacerbate the development of acidosis, which may result in lameness in the animals. Furthermore, since they need to access their stored energy for maintenance and performance, high-yielding dairy calves are more susceptible to subclinical or clinical ketosis during the summer months when their feed intake is reduced (Lacetera et al., 1996).

Because indirect impacts of climate change on animal behavior and welfare are more complicated, measuring and determining them is less practical. They are connected to variations in feed and water availability and quality, as well as the persistence and dispersal of diseases and vectors. More study is required, according to Polsky and von Keyserlingk's (2017) conclusion, to fully comprehend the discomfort, annoyance, aggressiveness, and malaise brought on by heat stress, particularly the short-term increase in hunger and thirst and the long-term foot lesions and lameness. It is recognized, therefore, that merely a brief duration of heat stress during the latter stage of pregnancy may have significant effects on the health, development, and performance of the calves, which may have a long-term influence on these animals (Laporta et al., 2017).

Changes brought about by climate change may affect vectors and pathogens, for instance. One such example is the distribution and incidence of pasture-borne parasitic helminth infections (nematodes and trematodes). Alongside the consequences of climate change, these illnesses exhibit recent changes in epidemiology, seasonality, and geographic distribution (Morgan et al., 2013). Novel approaches are needed to address these intricate shifts in the epidemiology of parasites and vectors. The research' findings are highly dependent on the time of year and the place. A systematic monitoring of climate-driven changes across Europe was proposed as a means of creating a better regional adaptation plan (Charlieret al., 2016). Certain management techniques, such as raising animals inside or outdoors, using novel diagnostic instruments, creative control methods, the sustainable use of medications, and the thoughtful incorporation

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, November 2023

of new control procedures, must be included in these strategies (Vercruysse et al., 2018). Databases with details on the local environment, disease distribution, and climate may provide crucial information for successful control measures. The distribution and population dynamics of the virus and its vector are impacted by climate change. According to Rinaldi et al. (2013), the distribution of the Rift Valley fever virus, an abortogenic virus spread by insects, varies with the range of the insect vector associated with climate change. Nevertheless, the best mitigation techniques for diseases and vectors will be extremely system-specific and reliant on the appropriate management actions. The effects of illnesses linked to climate change may be reduced if mitigation and adaptation strategies for cattle were given more attention (Bett et al., 2017).

In addition to activity reduction and/or modifications (Cook et al., 2007), heat stress may also be identified by behavioral changes such as increased water consumption, decreased feed intake, or shifting feed intake to cooler periods of the day (Ammer et al., 2017). Heat-stressed dairy calves exhibit altered standing and sleeping behaviors, which may further reduce visible estrus signs like mounting, as reported by Allen et al. (2015). Heinicke et al. (2019) reported that heat stress decreased dairy cattle's activity, while early-lactating animals were less responsive than later-lactating cows. In addition, they demonstrated separate cow-related variables. According to Allen et al. (2015), standing might aid in cooling off cows and increase their exposure to heat stress, which could further impact milk supply in cases when extended laying times are needed.

Climate change, feed and dairy cow nutrition

Climate change will impact feed production because to rising CO2 levels in the atmosphere, rising temperatures, and shifting water availability and distribution (Chapman et al., 2012). Numerous models that project grassland production and nutritional value in the context of climate change have been published (e.g. Ma et al., 2015). According to Phelan et al. (2016), there is a positive correlation between Europe's changing climate and the length of the grazing season. According to the authors, there will be a net increase in the grazing season of up to 2.5 months in the majority of European nations.

Climate change is expected to boost forage output, particularly in the north, but it will also have a detrimental impact on feed quality, which is mostly dependent on water availability. Craine et al. (2010) estimated the impact of climate variables on the availability of protein and energy in fodder by analyzing over 21,000 cow fecal samples. In continental climatic zones, they discovered lower CP and more digestible organic materials in the diet along with higher temperatures and less precipitation. Thus, in addition to the direct impacts of heat stress, cows will also face extra challenges as a result of dietary changes in the future, especially if milk production rise. It does, however, demonstrate once again that the resulting impacts on feed quantity and quality may vary throughout animals, systems, and areas. According to Gauly et al. (2013), grassland systems' plant composition requires adjustments to species that can withstand changing environmental circumstances. Deeper-rooted legumes, for example, may be able to use water that other species cannot use; therefore, growing species in different swards may improve grassland water utilization (Chen et al., 2007) as well as ruminant dietary digestibility (Perring et al., 2010). In addition to production techniques, managing the grassland (such as cutting timing, fertilizer type, and grazing duration) may provide crucial alternatives to address climate change.

Gauly and Ammer

impacts on feed production (Holden et al., 2008, for example). While irrigation would also boost yields, this alternative is only available in certain areas due to water supply constraints.

Over the last ten years, researchers have examined the effects of various feeding techniques designed to lessen the detrimental effects of heat waves on dairy cattle's nutritional supply and performance (such as yield and fertility) (e.g. Kaufman et al., 2017). The outcomes have been rather encouraging. It is well established that when dairy cattle are under heat stress, they would rather consume concentrates than roughage since roughage fermentation processes increase metabolic heat burden. Nevertheless, ruminant-adapted nutrition is limited when concentrate levels are increased in the diet.

The effects of feed additives, such as vitamins, on the animals' capacity to withstand heat stress were studied. The effects of vitamin niacin on lipid metabolism and blood vessel dilatation were examined. Zimbelman et al. (2010)

demonstrated that under moderate heat load, cows fed niacin-protected rumen exhibited lower vaginal and rectal temperatures. Regarding feed additives, there have been conflicting findings regarding the effects of raising the energy density in the ration of high-yielding cows kept in hot and muggy climates, as well as the effects of functional oils (oils derived from Ricinus communis that have uses other than energy production) and/or fat (Moallem et al., 2010). According to Wang et al. (2010), providing supplemental saturated fatty acids (SFA) to animals under heat stress resulted in a drop in body temperature during the warmest part of the day and an increase in milk production. According to the scientists, this resulted from supplemental SFA taking the role of fermentable carbs, which decreased the production of metabolic heat.

Climate change and dairy husbandry

Farmers face increasing hurdles when managing a dairy herd during frequent and intense heat episodes, especially with high-performing animals. In order to reduce heat stress in dairy cattle, there are a number of options available at the husbandry and management system level. These include structural changes or adaptations like cooling techniques; providing enough shade (Kendall et al., 2007); and managing feeding times, such as moving to cooler periods in the evening, night, and early morning (Legrand et al., 2009). According to Nikkhah et al. (2011), shifting feeding schedules to the evening or early morning may help to minimize the heat burden on high-temperature days. Ominski et al. (2002), however, state that this has no effect on the vaginal temperature, feed intake, or performance of dairy calves under heat stress.

Cooled waterbeds, misters, fans, and sprinklers are available cooling solutions. According to Calegari et al. (2012), emerging technologies like tunnel ventilation are examples of potential adjustments. In the meanwhile, dairy cattle must have efficient cooling systems in order to minimize heat stress. One solution is to sprinkle water briefly, allowing it to evaporate more with the help of barn fans. Thus far, similar technologies are widely used around the globe, especially in hot climates. Three distinct cooling systems were examined for efficiency by Kendall et al. (2007): shade, sprinklers, and a mix of both. They amply illustrated why using sprinklers alone (60%) and in conjunction with shade (67%) reduced respiration rates more effectively than using shade alone (30%). In order to reduce heat stress during hot circumstances, Avendan´ o-Reyes et al. (2010) compared three cooling management systems by varying the timing and duration of cooling via vents. The authors reasoned that in order to get better results, the chilling time needed to be prolonged. Furthermore, more frequent cooling sessions throughout the day that include both ventilation and sprinklers provide better cooling outcomes. Numerous research works detailed how cold affects the ability to reproduce. For example, Honig et al. (2016) discovered that cooling management had a favorable impact on the duration of the estrus cycle, overall fertility, and ovarian functioning in dairy cats exposed to heat stress. When it comes to cooling down after cows have been subjected to summertime heat load on pasture, providing shade alone is less effective than using sprinklers. Nonetheless, when considering the preferences of the cows, a greater number of cows (65%) had selected shade over sprinklers (Schütz et al., 2011). In addition to the temperature drop brought on by shadow, a lower solar radiation within the shade signifies a bigger impact on the heat load. Van Laer et al., for example, observed that shade had a positive impact on animal performance (2015).

Climate change and genetics

Many adaptation strategies to climate change include the immediate effects on animals during periods of extreme heat. However, they don't lead to a long-term solution for the problem. Al-Kanaan et al. (2015) suggest that a long-term strategy for dairy cattle may include genetic adaptation of the animals, i.e., incorporating resistance to heat stress as a functional trait in breeding programs. Selection indices may thus take into account traits associated with heat stress, such as the cows' ability to maintain a steady rectal temperature. One further potential breeding trait is the color of the hair coat, for example. Anzures-Olvera et al. (2019) reported that milk production was marginally reduced in Holstein cows with dominant black hair kept in a hot environment, but that the composition, body temperature, and reproductive potential were unaffected. In the face of changing weather patterns, animals with greater heat tolerance are better able to control their body temperature. Variations in milk production may also be a reflection of breed and individual variability (Dikmen and Hansen, 2009). The most effective way to assess cows' capacity for heat stress is to look at

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, November 2023

how their body temperature, heart rate, and respiration rate change in hot conditions. A possible disadvantage of this approach might be the absence of accurate thermal data.

Climate change tolerance presents challenges for the dairy industry based on pre-existing data that was collected for various purposes. In the meanwhile, several breeds and regions of the globe have adopted and created statistical models to evaluate heat tolerance and breeding values for heat tolerance (Nguyen et al., 2017). Selection for heat stress is done in a timely manner to stop future degradation in heat stress tolerance, together with other qualities that contribute to profitability. When THI values were less than 72, Ravagnolo et al. (2000) calculated a heritability for milk production of 0.17 and an additive variance of heat tolerance that was not substantially different from 0.0. There was a −0.36 genetic association. Protein and fat levels were comparable. Persistent heat stress causes alterations in the expression of genes involved, which modify the physiological state and trigger an adaptation. Australian dairy cattle's genomic estimated breeding values for heat tolerance were created by Nguyen et al. (2017). Heat tolerance was shown to have positive genetic connections with fertility but negative correlations with several production attributes based on correlations with other breeding variables. The genetic components of heat stress in Holstein cows were estimated by Aguilar et al. (2009). As the parities grew, so did the predicted genetic variation. For general additive effects, genetic correlations ranged from 0.84 to 0.98, while for milk output, they varied depending on parity and lactation stage and were around -0.45.

Although Bohmanova et al. (2008) discovered comparable estimated breeding values for heat tolerance, it is important to take into account possible interactions between genotype and environment. Bernabucci et al. (2014), however, summarise their research and conclude that selection aims should include the genetic component of heat tolerance, which is crucial.

Breeding for high yields has long been associated with increased susceptibility to harsh weather events. Even though they are very small, negative relationships like the one between milk output and reproductive efficiency also exist in more heat-tolerant breeds, such as Zebu cattle. Breed-specific variations in heat tolerance are extensively documented. Cattle from the Zebu and Sanga breeds, in particular, are warm-climate breeds that have adapted to their environment. Different features such as the quantity, shape, and ability of sweat glands to transport water might lead to genetic variations (Pereira et al., 2014). It is not obvious, nevertheless, that these morphological variations equate to functional variations (Berman, 2011). According to Souza-Cácares et al. (2019), certain breeds have the capacity to create greater quantities of specific heat shock proteins (HSP), which may play a role in the processes of adaptation to hot conditions.

II. CONCLUSION

The dairy industry is already feeling the effects of climate change, and these effects will only become worse. There will be direct as well as indirect impacts. The effects on health and performance, the availability and quality of feed and water, and the effects on disease and the transmission of vectors are the three main categories of impacts on dairy production systems. Higher death rates, weakened immune systems, a wider spread of infectious diseases, reproductive problems, changes in feed intake and growth, and decreased milk yields—particularly in high-yielding dairy cattle—will all result from this, which will have a negative economic impact on the production level. Thus, in order to provide long-term solutions, it is imperative to design efficient mitigation and adaptation techniques integrating husbandry systems, management, nutrition, health, and plant and animal breeding.

REFERENCES

[1]. Aguilar I, Misztal I and Tsuruta S 2009. Genetic components of heat stress for dairy cattle with multiple lactations. Journal of Dairy Science 92, 5702–5711. https://doi.org//10.3168/jds.2008-1928

[2]. Akbarabadi MA, Shabankareh HK, Abdolmohammadi A and Shahsavari MH 2014. Effect of PGF2α and GnRH on the reproductive performance of postpartum dairy cows subjected to synchronization of ovulation and timed artificial insemi- nation during the warm or cold periods of the year. Theriogenology 82, 509–516. https://doi.org//10.1016/j.theriogenology.2014.05.005

[3]. Al-Kanaan A, König S and Brügemann K 2015. Effects of heat stress on semen characteristics of Holstein bulls estimated on a continuous phenotypic and genetic scale. Livestock Science 177, 15–24.

[4]. Allen JD, Hall LW, Collier RJ and Smith JF 2015. Effect of core body temperature, time of day, and climate conditions on behavioral patterns of lactating dairy cows experiencing mild to moderate heat stress. Journal of Dairy Science 98, 118–127. https://doi.org//10.3168/jds.2013-7704

[5]. Ammer S, Lambertz C and Gauly M 2016. Comparison of different measuring methods for body temperature in lactating cows under different climatic condi- tions. Journal of Dairy Research 83, 165–172.

[6]. Ammer S, Lambertz C, von Soosten D, Zimmer K, Meyer U, Dänicke S and Gauly M 2017. Impact of diet composition and temperature–humidity index on water and dry matter intake of high-yielding dairy cows. Journal of Animal Physiology and Animal Nutrition 102, 103–113.

[7]. Anzures-Olvera F, Véliz FG, Santiago A de, García JE, Mellado J, Macías-Cruz U, Avendan˜ o-Reyes L and Mellado M 2019. The impact of hair coat color on physio- logical variables, reproductive performance and milk yield of Holstein cows in a hot environment. Journal of Thermal Biology 81, 82–88. https://doi.org//10. 1016/j.jtherbio.2019.02.020

[8]. Avendan˜ o-Reyes L, Álvarez-Valenzuela FD, Correa-Caldero´ n A, Algándar- Sandoval A, Rodríguez-González E, Pérez-Velázquez R, Macías-Cruz U, Díaz-Molina R, Robinson PH and Fadel JG,2010. Comparison of three cooling management systems to reduce heat stress in lactating Holstein cows during hot and dry ambient conditions. Livestock Science 132, 48–52. https://doi.

[9]. org//10.1016/j.livsci.2010.04.020

[10]. Berman A 2011. Invited review: are adaptations present to support dairy cattle productivity in warm climates? Journal of Dairy Science 94, 2147–2158. https:// doi.org//10.3168/jds.2010-3962

[11]. Berman A, Horovitz T, Kaim M and Gacitua H 2016. A comparison of THI indices leads to a sensible heat-based heat stress index for shaded cattle that aligns tempera- ture and humidity stress. International Journal of Biometeorology 60, 1453–1462.

[12]. Bernabucci U, Biffani S, Buggiotti L, Vitali A, Lacetera N and Nardone A 2014. The effects of heat stress in Italian Holstein dairy cattle. Journal of Dairy Science 97, 471–486. https://doi.org//10.3168/jds.2013-6611

[13]. Bett B, Kiunga P, Gachohi J, Sindato C, Mbotha D, Robinson T, Lindahl J and Grace D 2017. Effects of climate change on the occurrence and distribution of livestock diseases. Preventive Veterinary Medicine 137, 119–129. https:// doi.org//10.1016/j.prevetmed.2016.11.019

[14]. Bohmanova J, Misztal I, Tsuruta S, Norman HD and Lawlor TJ 2008. Short com- munication: genotype by environment interaction due to heat stress. Journal of Dairy Science 91, 840–846.

[15]. Bouraoui R, Lahmar M, Majdoub A, Djemali M and Belyea R 2002. The relation- ship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research 51, 479–491.

[16]. Buffington DE, Collazo-Arocho A, Canton GH, Pitt D, Thatcher W and Collier RJ 1981. Black globe-humidity index (BGHI) as comfort equation for dairy cows. Transactions of the ASAE 24, 0711–0714. https://doi.org//10.13031/2013.34325

[17]. Calegari F, Calamari L and Frazzi E 2012. Misting and fan cooling of the rest area in a dairy barn. International Journal of Biometeorology 56, 287–295. https:// doi.org//10.1007/s00484-011-0432-7

[18]. Campen KA, Abbott CR, Rispoli LA, Payton RR, Saxton AM and Edwards JL 2018. Heat stress impairs gap junction communication and cumulus function of bovine oocytes. The Journal of Reproduction and Development 64, 385–392. https://doi. org//10.1262/jrd.2018-029

[19]. Chapman SC, Chakraborty S, Fernanda Dreccer M and Mark Howden S 2012. Plant adaptation to climate change – opportunities and priorities in breeding. Crop and Pasture Science 63, 251–268. https://doi.org//10.1071/CP11303

[20]. Charlier J, Ghebretinsae AH, Levecke B, Ducheyne E, Claerebout E and Vercruysse J 2016. Climate-driven longitudinal trends in pasture-borne helminth infections of dairy cattle. International Journal for Parasitology 46, 881–888. https://doi.org//10.1016/j.ijpara.2016.09.001

[21]. Chen S, Bai Y, Lin G, Huang J and Han X 2007. Isotopic carbon composition and related characters of dominant species along an environmental gradient in Inner Mongolia, China. Journal of Arid Environments 71, 12–28.

[22]. Collier RJ, Collier JL, Rhoads RP and Baumgard LH 2008. Invited review: genes involved in the bovine heat stress response. Journal of Dairy Science 91, 445–454. https://doi.org//10.3168/jds.2007-0540

[23]. Cook NB, Mentink RL, Bennett TB and Burgi K 2007. The effect of heat stress and lameness on time budgets of lactating dairy cows. Journal of Dairy Science 90, 1674–1682.

[24]. Cowley FC, Barber DG, Houlihan AV and Poppi DP 2015. Immediate and residual effects of heat stress and restricted intake on milk protein and casein composi- tion and energy metabolism. Journal of Dairy Science 98, 2356–2368. https:// doi.org//10.3168/jds.2014-8442

[25]. Craine JM, Elmore AJ, Olson KC and Tolleson D 2010. Climate change and cattle nutritional stress. Global Change Biology 16, 2901–2911. https://doi.org//10. 1111/j.1365-2486.2009.02060.x

[26]. Das R, Sailo L, Verma N, Bharti P, Saikia J, Imtiwati and Kumar R 2016. Impact of heat stress on health and performance of dairy animals: a review. Veterinary World 9, 260–268. https://doi.org//10.14202/vetworld.2016.260-268

[27]. de Andrade Ferrazza R, Mogollo´ n Garcia HD, Vallejo Aristizábal VH, de Souza Nogueira C, Veríssimo CJ, Sartori JR, Sartori R and Pinheiro Ferreira JC 2017. Thermoregulatory responses of Holstein cows exposed to experimentally induced heat stress. Journal of Thermal Biology 66, 68–80. https://doi.org// 10.1016/j.jtherbio.2017.03.014

[28]. Dikmen S and Hansen PJ 2009. Is the temperature-humidity index the best indi- cator of heat stress in lactating dairy cows in a subtropical environment? Journal of Dairy Science 92, 109–116.

[29]. Fitzgerald JB, Brereton AJ and Holden NM 2009. Assessment of the adaptation potential of grass-based dairy systems to climate change in Ireland – the maximised production scenario. Agricultural and Forest Meteorology 149, 244–255.

[30]. Galán E, Llonch P, Villagrá A, Levit H, Pinto S and Del Prado A 2018. A systematic review of non-productivity-related animal-based indicators of heat stress resil- ience in dairy cattle. PLoS ONE 13, e0206520. https://doi.org//10.1371/journal. pone.0206520

[31]. Gaughan JB, Lacetera N, Valtorta SE, Khalifa HH, Hahn GL and Mader TL 2009. Response of domestic animals to climate challenges. In Biometeorology for adaptation to climate variability and change (ed. KL Ebi, I Burton and GR McGregor), pp. 131–170. Springer-Verlag, Heidelberg, Germany.

[32]. Gauly M, Bollwein H, Breves G, Brügemann K, Dänicke S, Das¸ G, Demeler J, Hansen H, Isselstein J, König S, Lohölter M, Martinsohn M, Meyer U, Potthoff M, Sanker C, Schröder B, Wrage N, Meibaum B, Samson-Himmelstjerna G von, Stinshoff H and Wrenzycki C 2013. Future consequences and challenges for dairy cow production systems arising from climate change in

[33]. Central Europe – a review. Animal 7, 843–859. https://doi.org//10.1017/ S1751731112002352

[34]. Ghizzi LG, Del Valle TA, Takiya CS, da Silva GG, Zilio EMC, Grigoletto NTS, Martello LS and Renno´ FP 2018. Effects of functional oils on ruminal fermenta- tion, rectal temperature, and performance of dairy cows under high temperature humidity index environment. Animal Feed Science and Technology 246, 158–166. https://doi.org//10.1016/j.anifeedsci.2018.10.009

[35]. Heinicke J, Ibscher S, Belik V and Amon T 2019. Cow individual activity response to the accumulation of heat load duration. Journal of Thermal Biology 82, 23–32. https://doi.org//10.1016/j.jtherbio.2019.03.011

[36]. Holden NM, Brereton AJ and Fitzgerald JB 2008. Impact of climate change on Irish agricultural production systems. In Climate change – refining the impacts for Ireland (ed. Environmental Protection Agency), pp. 82–131. Environmental Protection Agency, Wexford, Ireland.

[37]. Honig H, Ofer L, Kaim M, Jacobi S, Shinder D and Gershon E 2016. The effect of cooling management on blood flow to the dominant follicle and estrous cycle length at heat stress. Theriogenology 86, 626–634. https://doi.org//10.1016/j. theriogenology.2016.02.017

[38]. Intergovernmental Panel on Climate Change 2014. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. In Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change (ed. CB Field, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, TE Bilir, M Chatterjee, KL Ebi, YO Estrada, RC Genova, B Girma, ES Kissel, AN Levy, S MacCracken, PR

[39]. Mastrandrea and LL White), pp. 1–1132. Cambridge University Press, Cambridge, UK.

[40]. Kadokawa H, Sakatani M and Hansen PJ 2012. Perspectives on improvement of reproduction in cattle during heat stress in a future Japan. Animal Science Journal 83, 439–445. https://doi.org//10.1111/j.1740-0929.2012.01011

[41]. Kaufman JD, Kassube KR and Ríus AG 2017. Lowering rumen-degradable protein maintained energy-corrected milk yield and improved nitrogen-use efficiency in multiparous lactating dairy cows exposed to heat stress. Journal of Dairy Science 100, 8132–8145. https://doi.org//10.3168/jds.2017-13026

[42]. Kendall PE, Verkerk GA, Webster JR and Tucker CB 2007. Sprinklers and shade cool cows and reduce insect-avoidance behavior in pasture-based dairy systems. Journal of Dairy Science 90, 3671–3680.

[43]. Lacetera N, Bernabucci U, Ronchi B and Nardone A 1996. Body condition score, metabolic status and milk production of early lactating dairy cows exposed to warm environment. Rivista di Agricoltura Subtropicale e Tropicale 90, 43–55.

[44]. Lambertz C, Sanker C and Gauly M 2014. Climatic effects on milk production traits and somatic cell score in lactating Holstein-Friesian cows in different hous- ing systems. Journal of Dairy Science 97, 319–329.

[45]. Laporta J, Fabris TF, Skibiel AL, Powell JL, Hayen MJ, Horvath K, Miller-Cushon EK and Dahl GE 2017. In utero exposure to heat stress during late gestation has prolonged effects on the activity patterns and growth of dairy calves. Journal of Dairy Science 100, 2976–2984. https://doi.org//10.3168/jds.2016-11993

[46]. Legrand AL, von Keyserlingk MAG and Weary DM 2009. Preference and usage of pasture versus free-stall housing by lactating dairy cattle. Journal of Dairy Science 92, 3651–3658.

[47]. Liang D, Wood CL, McQuerry KJ, Ray DL, Clark JD and Bewley JM 2013. Influence of breed, milk production, season, and ambient temperature on dairy cow retic- ulorumen temperature. Journal of Dairy Science 96, 5072–5081.

[48]. Challenges in dairy farming due to climate change

[49]. Liu Z, Ezernieks V, Wang J, Arachchillage NW, Garner JB, Wales WJ, Cocks BG and Rochfort S 2017. Heat stress in dairy cattle alters lipid composition of milk. Scientific Reports 7, 961. https://doi.org//10.1038/s41598-017-01120-9

[50]. Lo´ pez-Gatius F, Santolaria P, Martino A, Delétang F and De Rensis F 2006. The effects of GnRH treatment at the time of AI and 12 days later on reproductive performance of high producing dairy cows during the warm season in northeastern Spain. Theriogenology 65, 820–830.

[51]. Ma S, Lardy B, Graux AI, Klumpp K, Martin R and Bellocchi G 2015. Regional- sclae analysis of carbon and water cycles on managed grassland systems. Environmental Modelling & Software 72, 356–371. https://doi.org//10.1016/j. envsoft.2015.03.007

[52]. Malama E, Zeron Y, Janett F, Siuda M, Roth Z and Bollwein H 2017. Use of computer-assisted sperm analysis and flow cytometry to detect seasonal varia- tions of bovine semen quality. Theriogenology 87, 79–90. https://doi.org//10. 1016/j.theriogenology.2016.08.002

[53]. Mariani P, Zanzucchi G, Blanco P and Masoni M 1993. Variazioni stagionali del contenuto in fosforo del latte di massa di singoli allevamenti. L'industria del Latte 29, 39–53.

[54]. Moallem U, Altmark G, Lehrer H and Arieli A 2010. Performance of high-yielding dairy cows supplemented with fat or concentrate under hot and humid climates. Journal of Dairy Science 93, 3192–3202. https://doi.org//10.3168/jds.2009-2979

[55]. Morgan E, Charlier J, Hendrickx G, Biggeri A, Catalan D, Samson-Himmelstjerna G von, Demeler J, Müller E, van Dijk J, Kenyon F, Skuce P, Höglund J, O'Kiely P, van Ranst B, Waal T de, Rinaldi L, Cringoli G, Hertzberg H, Torgerson P, Wolstenholme A and Vercruysse J 2013. Global change and helminth infections in grazing ruminants in Europe: impacts, trends and sustainable solutions. Agriculture 3, 484–502. https://doi.org//10.3390/agriculture3030484

[56]. Nabenishi H, Ohta H, Nishimoto T, Morita T, Ashizawa K and Tsuzuki Y 2011. Effect of the temperature-humidity index on body temperature and conception rate of lactating dairy cows in southwestern Japan. Journal of Reproduction 57, 450–456.

[57]. National Research Council 1971. A guide to environmental research on animals. National Academy of Sciences, Washington, DC, USA.

[58]. Nguyen TTT, Bowman PJ, Haile-Mariam M, Nieuwhof GJ, Hayes BJ and Pryce JE 2017. Short communication: implementation of a breeding value for heat toler- ance in Australian dairy cattle. Journal of Dairy Science 100, 7362–7367. https:// doi.org//10.3168/jds.2017-12898

[59]. Nikkhah A, Furedi CJ, Kennedy AD, Scott SL, Wittenberg KM, Crow GH and Plaizier JC 2011. Morning vs. evening feed delivery for lactating dairy cows. Canadian Journal of Animal Science 91, 113–122.

[60]. Ominski KH, Kennedy AD, Wittenberg KM and Nia SAM 2002. Physiological and production responses to feeding schedule in lactating dairy cows exposed to short-term, moderate heat stress. Journal of Dairy Science 85, 730–737.

[61]. Paes VM, Vieira LA, Correia HHV, Sa NAR, Moura AAA, Sales AD, Rodrigues APR, Magalhães-Padilha DM, Santos FW, Apgar GA, Campello CC, Camargo LSA and Figueiredo JR 2016. Effect of heat stress on the survival and development of in vitro cultured bovine preantral follicles and on in vitro maturation of cumulus- oocyte complex. Theriogenology 86, 994–1003. https://doi.org//10.1016/j.

[62]. theriogenology.2016.03.027

[63]. Pereira AMF, Titto EL, Infante P, Titto CG, Geraldo AM, Alves A, Leme TM, Baccari F and Almeida JA 2014. Evaporative heat loss in Bos taurus: do different cattle breeds cope with heat stress in the same way? Journal of Thermal Biology 45, 87–95. https://doi.org//10.1016/j.jtherbio.2014.08.004

[64]. Perring MP, Cullen BR, Johnson IR and Hovenden MJ 2010. Modelled effects of rising CO2 concentration and climate change on native perennial grass and sown grass-legume pastures. Climate Research 42, 65–78.

[65]. Phelan P, Morgan ER, Rose H, Grant J and O'Kiely P 2016. Predictions of future grazing season length for European dairy, beef and sheep farms based on regres- sion with bioclimatic variables. Journal of Agricultural Science 154, 765–781. https://doi.org//10.1017/S0021859615000830