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Heat stress of cattle from embryonic phase until culling

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SUMMARY

Heat stress becomes a serious problem in the livestock sector as it affects cows' performance negatively. The objective of this paper review is to investigate the effects of heat stress during the different phases of the life cycle of cows; embryos, calves, heifers, and cows. Heat stress during early maternal gestation affects the ability of embryos to develop increasing the risk of abortion and early embryonic death. Heat stress during late maternal gestation affects the performance of calves and heifers later in their life, as it reduces growth performance, conducts physiological changes, impaired immunity, changes the behavior, and reduces the length and intensity of the estrus in heifers with decreasing in milk production in the first lactation. On the level of cows, milk quality and production, meat quality, and the final body weight decrease under hot temperatures. Heat stress decreases the conception rate, alters follicle growth, and estrous symptoms. Hormones secretion and physiological changes because of the heat stress conduct to impair the immunity system, and in oxidative stress and death in some cases. Same as for calves and heifers a change in the behavior of cows was detected in order to decrease their temperature.

Keywords: *heat stress; embryos; calves; heifers; cows*

INTRODUCTION

Climate change represents one of the biggest threats to the existence of several species and ecosystems, as well as to the sustainability of livestock systems worldwide, especially in tropical zones and temperate countries (Das et al., 2016). Many studies discovered that since the middle of the 1970s, the Earth's temperature has risen by 0.2 °C per decade, and it is expected that by 2100, the planet's average surface temperature will rise by 0.3 to 4.8 °C (IPCC, 2013).

Hahn and Becker (1984) defined heat stress as the totality of internal and environmental factors that affect an animal and raise its body temperature, trigger physiological reactions, and disturb the behavior. The cow must be in thermal balance with its environment which is primarily controlled by sun radiation, air temperature, air movement, and humidity to maintain homeostasis and it can produce and reproduce (Kadzere et al., 2002). The endocrine system, peripheral nervous systems, and central nervous system all work together to properly manage the heat stress response (Charmandari et al., 2005). Therefore, it is crucial to understand the minimum temperatures and relative humidity levels needed to preserve animal comfort. According to Collier et al. (2006), heat stress in dairy cattle happens when the Temperature and Humidity Index (THI) rises above 68. For beef cattle, when relative humidity is under 80%, the higher threshold temperature is set at 30 °C, and when relative humidity is over 80%, it is set at 27 °C (SCAHAW, 2001). According to Piton (2004), when an animal experiences heat stress, it enters a state of hyperthermia, which compels it to try to regain thermal equilibrium at the expense of its ability to produce and reproduce. Homeotherms' capacity to regulate their internal body temperatures within the normal range is crucial for the smooth operation of physiological processes and biochemical reactions that signify a healthy metabolism (Shearer and Beede, 1990). The cattle lose the caloric energy through one of two pathways–direct thermolysis, also known as the non-evaporative sensitive pathway (radiation, convection, and conduction), or indirect thermolysis, also known as the insensitive evaporative pathway constitutes a strategy for battling heat (Kadzere et al., 2002). The cow relies more and more on evaporative cooling through sweating and panting as the principal non-evaporative methods of cooling are less efficient with the increase of ambient temperature. High relative humidity impairs evaporative cooling, preventing the dairy cow from dissipating enough body heat to prevent an increase in body temperature in hot and humid conditions in summer (West, 2003).

According to Al-Katanani and Hansen (2002), Tropical regions are home to more than 50% of the world's cattle, and heat stress is thought to be a significant economic loss factor for 60% of dairy farms globally. In the United States, it was projected that heat stress caused yearly economic losses to the cattle sector of between $1.69 and $2.36 billion nationwide (St-Pierre et al., 2003). Heat stress has become a significant problem for agriculture production as it is a result of rising global temperatures and humidity with the intensification of livestock production, the increasing number of animals, and the increase in milk production (Renaudeau et al., 2012). The primary causes of heat stress are ambient temperature and relative air humidity, which in turn have a direct impact on the welfare and productivity of animals (Kadzere et al., 2002; Bernabucci et al., 2010). Indeed, major physiological and metabolic problems caused by heat stress affect the cows' performances, resulting in considerable financial losses for the dairy industry

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(West, 2003; Rosenkrans et al., 2010; Bernabucci et al., 2014). Reduced performance, higher mortality, and lower reproduction are the three main causes of the economic losses linked to heat stress (St-Pierre et al., 2003). Furthermore, the energy demand for cooling due to the increasing heat load is increasing year by year in dairy farms with a significant amount of wastewater produced by sprinkler and fan cooling systems that have to be treated (West, 2003).

Heat stress impairs the reproductive capabilities of livestock animals, upsets the hormonal balance, lowers the quality of the oocytes, and thus lowers embryo growth and survival (Gendelman et al., 2012). Additionally, it affects negatively the performance of calves (Laporta et al., 2017) as higher temperature plays an important role in reducing the feed intake which conducts in a decreasing the growth rate (Yazdi et al., 2016). Mitlöhner et al. (2002) showed that hot weather harms the performances of heifers and the same for cows (Collier et al., 1982). Exposed to heat stress during early life affects the future productive life of the animals, the reproduction, rumen, feed conversion efficiency, and physiology of calves, heifers, and cows and the survival of embryos have all been demonstrated to be impacted by heat stress, according to several researchers (Colditz and Kellaway, 1972; Stott et al., 1976; Herbut et al., 2019). Understanding the impact of heat stress during the different phases of the life cycle of cows is important to find solutions to this challenge. Therefore, the objective of this paper review is to investigate the effects of heat stress on embryos, calves, heifers, and cows.

Embryos

The negative effect of heat stress on embryos was confirmed by several researchers as it has a direct consequence on increasing the rate of embryonic abortions and pre-term calving (Al-Katanani et al., 1999). According to Bach et al. (2012), the phenotype of the offspring as adults is now well documented to be influenced by the intern environment of the maternal uterine during conception and gestation. As a consequence, in case of prenatal exposure of the fetus to mother body temperatures over euthermic values or known as utero heat stress (IUHT), might result in long-term alterations in tissue function and structure and negatively affect dairy cows' progeny in the future (Dado-Senn et al., 2020). Berthelot and Paccard (1990) demonstrated early embryonic mortality is primarily caused by an increase in uterine temperature. Additionally, heat stress also affects the metabolism of the developing embryo and the maternal recognition processes (Biggers et al., 1987). Whatever the method, maternal heat stress has detrimental effects on the embryos it produces that last a lifetime and cannot be reversed by postnatal care (Laporta et al., 2020). According to several researchers, high ambient temperatures might increase oxidative stress by generating reactive oxygen species (ROS) or by reducing the activity of antioxidant defense enzymes (Chauhan et al., 2014; Bernabucci et al., 2002). As a result, ROS generation is one of the hypothesized processes by which heat stress might harm the embryo and the oocyte. The formation of ROS can be boosted when the embryo (Sakatani et al., 2004) or the oocyte (Nabenishi et al., 2012) is subjected to high temperatures. As confirmed by Sakatani et al. (2013) free radical synthesis because of oxidative stress plays a crucial role in reducing the development of the embryo in case of heat-chock. Kamano et al. (2014) reported in the level of oocytes or embryos, maternal heat stress has been shown to reduce mitochondrial membrane potential, which is used as a measure for developmental regulation, and decrease also the levels of calcium ions, which have been linked to the impairment of cellular processes. High ambient temperatures can alter follicular growth patterns, impede endocrine interactions, and lower the quality of oocytes and embryos (Madan et Johnson, 1973; Wolfenson, 2000). Exposure to a heat shock earlier or at the 8-cell stage rather than later in development generates a stronger negative effect on embryo development (Edwards and Hansen, 1997). When an embryo is still in the zygote stage of development, exposure to high temperatures can impair its ability to advance to the blastocyst stage (Sakatani et al., 2012). Biggers et al. (1987) found as a result in their study that the heat stress during the first days of pregnancy from days 8 through 16 in beef cows, conduct to decreasing the size of the embryo on day 17. Several experiments in vivo and in vitro were carried out on the negative effects of heat stress on the embryo's development at early stages. In the in vitro experiment conducted by Ortega et al. (2016) where they put the zygote under 40 °C for 12 hours, they found, as a result, decreasing in the number of putative zygotes that cleaved and developed to reach the blastocyst stage. In the experiment of Putney et al. (1988) where they divided super-ovulated heifers into 2 groups, one group was under heat stress and the other one was in normal conditions from 1 to 7 days post estrus, they found as a result 51.8% of embryos from heifers in thermoneutral conditions were recovered in comparison with heifers under heat stress just 20.7% of embryos recovered, with a larger percentage of defective and delayed embryos with degenerate nonviable blastomeres were found in stressed heifers. Another in vivo experiment conducted by Ealy et al. (1993) concluded that heat stress had an adverse effect on embryonic development in vivo when it was administered on day 1 following insemination. Additionally, the percentage of improperly developed and slowly growing embryos rose when Holstein heifers were subjected to heat stress in the first seven days following estrus (Putney et al., 1989). Several studies confirmed the negative effect of heat stress on dry matter intake in cows. As the study by Ouellet et al. (2020) found that heat stress reduces the dry matter intake in pregnant cows. The same results found by Kazedre (2002), dairy cows' dry matter intake (DMI) can decrease in hot areas by up to 40% when the ambient temperature is above 30 °C. West et al. (2003) mention a decrease of 4.5 kg/d or 22% of dry matter intake when the Temperature Humidity Index (THI) is in the range of 71 to 85. As a consequence, placental

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development during pregnancy is significantly influenced by nutrition. Additionally, heat stress lowers blood levels of pregnancy-specific protein B (Thompson et al., 2013), and placental hormones (Collier et al., 1982) and reduces the exchange of amino acids, glucose, and oxygen between the cow and the fetus (Wallace et al., 2002; de Vrijer et al., 2004) indicating a dysfunction and delay in placental development and as a result affect the embryo development (Ouellet et al., 2021). Multiple factors caused by heat stress, such as altered blood flow, reduced nutrient intake, and alterations in placental structure and function, can lead to a restricted intrauterine environment for fetal nutrition and thermal regulation (Ji et al., 2017). The resultant malnutrition and hyperthermia can impede fetal development and lead to long-term damage to tissue structure and function. Further research is necessary to elucidate the precise impact of the timing and duration of heat stress on embryonic development and to explore potential management strategies to mitigate the deleterious effects on reproductive performance.

Calves

The morphology offspring of heat-stressed cows during gestation is shorter and shows a deficit in birth weight, without recovering the weight even at one year of age (Monteiro et al., 2014). As confirmed by Dahl et al. (2016), calves exposed to heat stress in utero are more likely to acquire a smaller mature body size and higher fat reserves than their thermoneutral counterparts. Additionally, they have a smaller weight of organs such thymus, heart, spleen, kidney, and liver (Ahmed et al., 2021). It was explained by Tao and Dahl (2013), the smaller size of the calf is a result of heat stress during the late gestation period, which contributes to a decrease in gestation length by 4 to 5 days. Confirmed by Monteiro et al. (2014) as they found as a result, in heat-stressed cows, the gestation period was 3.8 days shorter than in thermoneutral cows. According to Broucek et al. (2009), calves experience severe reduction in growth weight before and after weaning if they were exposed to high temperatures. Cooled dry cows have calves with higher birth weights in comparison with heat-stressed dry cows (Tao et al., 2012). According to the research of López et al. (2018) where they compared the pre-weaning gains between Holstein calves exposed to heat stress at calving and non-stressed calves, and they found as a result a higher pre-weaning gain in non-stressed calves (466 ± 112 g/calf/day) and just (405 ± 97 g/calf/day) in stressed calves. In the central USA, Wiedmeier et al. (2006) discovered the average daily gain of calves born in September and March is higher compared to those who were born in summer. It was reported by Rauba et al. (2019) calves born in winter have higher starter DMI in comparison to calves born in the hot season. Compared to prenatal heat-stressed calves, calves without prenatal heat stress have higher birth and weaning weights as well as a trend for higher average daily gains (Dado-Senn et al., 2020). According to Tao and Dahl (2013), the decreased weaning weight of calves born during days of high heat may have resulted from a direct decrease in starting feed intake as well as potential long-term impacts of in-utero heat stress on the growing calf. As the appetite of calves decreases under heat stress conditions, calves born in winter show higher average daily gain in comparison with those born in summer (Place et al., 1998). In another study conducted in Egypt by Marai et al. (1995) about the effect of heat stress on Friesian calves, they detected a significant decrease in daily solid gain and relative growth rate followed by decreasing in feed efficiency levels and roughage consumption in summer compared to winter.

According to Follenius et al. (1982), the level of serum cortisol is a sensitive indicator of heat stress. In dairy calves, the cortisol in the blood has been utilized as a physiological indicator of stress (Neuwirth et al., 1979). The calves under heat stress show a high level of cortisol in their blood with increasing glutamic oxaloacetic transaminase (GOT), and glutamic pyruvate transaminase (GPT) concentration levels (Kim et al., 2018), where they are used as markers for liver-damaging (Panteghini, 1990). Marai et al. (1995) showed a seasonal variation in the function of the liver as the level of GPT and GOT were higher in summer, for thyroid function they detected a decrease in the level of T4 in summer, and a reduction in certain blood components that are related to Friesian calf productivity in hot season as packed cell volume, hemoglobin values, urea-N, creatinine, total cholesterol, total lipids, globulin, albumin, total protein, and serum glucose. Kovács et al. (2018) detected an increase in saliva cortisol in dairy calves under the sun radiation by 342% in comparison to a 51% increase in calves under the shade. López et al. (2018) compared the concentration of cortisol, T3, and T4 in the plasma of calves born in different seasons and found as a result that calves born in summer had the highest level of cortisol in their blood, the highest level for T3 and T4 was detected in calves born in winter and fall. Heat stress negatively affects the health of animals as with the increase of heat stress the secretion of cortisol rises linearly which suppresses the immune system and increases the probability of infections (Ju et al., 2014). The immunity of calves is well documented and it is affected by heat stress. As mentioned, Tao et al. (2012), exposing cows to heat stress during the late gestation period decrease the immunity of calves by impairing the cellular immunological function and decreasing the hematocrit levels and the total plasma protein. As confirmed by Nardone et al. (1997) as they found in their research, cows under stress during the late gestation period were shown to have reduced amounts of immunoglobulins in their colostrum. Furthermore, Strong et al. (2015) demonstrated in the first days after calving the heat stress decrease the inner immunity of calves. an experiment conducted by Monteiro et al. (2014) where they gave calves originating from heat-stressed cows during the late gestation and calves from thermoneutral cows the same colostrum and they found as a result the heat-stressed calves show less apparent efficiency of IgG absorption

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at 26% in comparison to non-stressed calves 30.2%. As explained by Ahmed et al. (2021), calves' intestinal apoptosis was exacerbated by late-gestation heat stress, which might account for the reduced IgG uptake and restricted passive immune competence. Dado-Senn et al. (2020) found as a result of their research, non-stressed calves had higher feed intake and showed better health as they experienced fewer infections, fever, and less use of medications in comparison with heat-stressed calves. According to Pollock et al. (1994), calves' immunological responses were suppressed by stress related to weaning and dietary plans. To understand more the effect of heat stress on calves Stott et al. (1976) put the newborn calves in three different environments; in a hutch, in the undercooled shade, and under shade during the hot season. They found as a result Calves in the hutch in an unfavorable environment and exposed to the heat, had greater mortality rate, higher blood corticosteroid concentration, and lower serum immunoglobulin IgG1 between 2 and 10 days postnatal. One of the most important environmental factors that raise the risk of death of calves is the high temperature (Martin et al., 1975). An ambient temperature of more than 24 °C is linked to higher rates of calf mortality (Stull et al., 2008). Calves under prolonged heat stress produce less IgG and have a higher mortality rate compared to thermoneutral calves (Kelley et al., 1982).

It has been demonstrated that respiration rate is a reliable measure of thermal stress (Hahn et al., 1997) with rectal temperature and heart rate. An increase in heart rate was detected in dairy calves when the THI reach 78 and the respiration rate started to increase when the level of THI is 82.4 (Kovács et al., 2020). Bianca (1959) demonstrated an increase of rectal temperature between 40.6 to 41 °C in calves due to heat stress, an increase in a fast way the respiratory rate to 218 respirations/min to fall after some time to reach 167 respirations/min, followed by an increase in heart rate. The study carried out by Kim et al. (2018) about the effect of heat stress on beef calves, found, as a result, an increase in water consumption by 3 L/d in calves under heat stress with an increase of heart rate by 12.75 beat/min and rectal temperature by 0.95 °C when the THI rose from 70.01 to 87.72. Kim et al. (2018) Studied the effect of heat stress on the behavior of calves and they found with the increase in THI the standing time increased, the laying time decreased, and the rumination also reduced. These findings suggest that heat stress can have a significant impact on calf health, growth, behavior and productivity. However, further investigations in different environment are required into the long-term effects of this stress on the productive and reproductive performance of calves in later life.

Heifers

Several researchers investigated the effect of heat stress on the nutritional status of heifers such as the study carried out by Nardone et al. (1997) where they compared two groups of heifers, one under heat stress conditions and the other one on thermoneutrality during the last 3 weeks of their gestation and they found, as a result, the heat stressed group shows a decline in dry matter intake, decreasing in body condition score, increasing in respiratory rates, increasing in rectal temperature, and lower level of immunoglobin (IgG and IgA) in their colostrum. Nonaka et al. (2008) studied the nutritional status of prepubertal Holstein heifers at different temperatures, they found the DMI decreased by 9% and the average daily gain decreased by 22% at 33 °C in comparison with reared heifers at 28 °C, in contrast, they detected an increase in water consumption by 23%. Baccari et al. (1983) demonstrated that Holstein heifers subjected to heat stress conditions with temperatures ranging from 32.5 to 34 °C exhibited reduced feed intake, average daily gain, and feed efficiency when compared to those kept under ambient temperatures ranging from 18 to 20 °C. According to Colditz and Kellaway (1972), Heifers reared under a temperature of 17 °C exhibited 14% higher feed intake and 50% higher average daily gain than those grown at heat-stressed conditions under a temperature of 38 °C. Mitlöhner et al. (2002) conducted a study to investigate the effect of heat stress on feedlot heifers by comparing the performance of shaded and unshaded heifers. After 121 days, they found that shaded heifers had a significantly higher final average body weight than unshaded ones, with a difference of 11.3 kg/heifer. Additionally, shaded heifers had higher dry matter intake (DMI) and average daily gain (ADG) than unshaded heifers, with a difference of 2.9% and 6.1%, respectively. These results indicate that providing shade to feedlot heifers during periods of heat stress can have a positive impact on their performance.

Heifers show better tolerance to heat stress than cows as their body temperature increases less than cows under the same heat stress conditions (Sartori et al., 2002). The study conducted by Purwanto et al. (1993), found as result dairy heifers reared at a temperature of 30 °C have a higher rectal temperature, respiration rate, heart rate, and higher heat production compared to heifers reared at 15 °C. Nonaka et al. (2008) stated that the Rectal temperature tended to rise by 0.2 °C when the ambient temperature was 28 °C, and by 1.2 °C when it was 33 °C with an increase of respiration rate by 35 breaths/min between 28 °C and 33 °C. The same results were confirmed by Panday et al. (2017) as they studied the effect of heat stress on heifers in India and they found an increase in rectal temperature, respiration rate, and heart rate with the increase of temperature from 25 °C to 42 °C. Heifers that were shaded exhibited lower respiration rates and circulating neutrophil percentages than heifers that were under the sun (Mitlöhner et al., 2002). Hormonal changes might result from heat stress, increased insulin and reduced thyroid hormones were often seen in heifers with heat stress as showed by Nonaka et al. (2008) in their research that the level of thyroid hormone T3 and glucose were lower in heifers' blood at a temperature of 33 °C compared to a heifer at a temperature of 20 °C. Monteiro et al. (2016) demonstrated that compared to heifers who were gestated under thermoneutral intrauterine

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circumstances, a greater proportion of those that were exposed to in-utero hyperthermia quit the herd before they reach their first lactation. Ronchi et al. (2000) showed that the prolactin plasma concentrations rose after exposure to heat stress, but cortisol and progesterone levels fell and dry matter intake dropped by 23% in heifers.

Monteiro et al. (2016) studied the effect of heat stress on the reproduction performances of heifers they observed 30 days after insemination the cooled heifers had a smaller number of services per pregnancy (2) in comparison with heat-stressed ones (2.5). No difference was observed in the age of first insemination and the age of first calving. In contrast, Heinrichs et al. (2005) showed that when the calves are exposed to heat stress it affects it is performance later when they are heifers by increasing their age at first calving. Cavestany et al. (1985) stated that in temperatures higher than 35 °C the conception rates for heifers started to decrease. Furthermore, the age at first calving and puberty can be delayed because of heat stress (NRC, 2001). Gangwar et al. (1964) studied the reproductive response of heifers under heat-stress conditions. They found as a result the increase in temperature affected the estrus negatively by decreasing its intensity and duration from 20 hours in normal conditions to 11 hours under hot temperatures. due to the quiet heat or poor estrus manifestation, breeding is difficult (De Rensis and Scaramuzzi, 2003). Bolocan (2009) studied the sexual behavior of heifers in different environments, the result shows in heat stress conditions the estrous symptoms are weak or absent. Under heat stress conditions the heifers search for shade lines and try to avoid standing under the sunlight with an increase in the standing time (Mitlöhner et al., 2002).

Monteiro et al. (2016) demonstrated that Holstein heifers born to cows exposed to heat stress during the late gestation period produced significantly less milk (26.8±1.7 kg/d) in the first lactation, up to 35 weeks after calving, compared to heifers born to cows kept under thermoneutral conditions (31.9±1.7 kg/d). In a study by Mitlöhner et al. (2002), the effect of heat stress on the carcass characteristics of feedlot heifers was investigated by comparing heat-stressed and thermoneutral animals. The study revealed that the (USDA) yield grade was better in the carcasses of thermoneutral heifers compared to those of heat-stressed heifers. Furthermore, the hot carcass weight of thermoneutral heifers was 7.3 kg higher than that of heat-stressed heifers, suggesting that heat stress negatively impacts the carcass quality of feedlot heifers. The deleterious effects of heat stress on the nutritional status, performance, and reproductive outcomes of heifers are well-investigated. Nevertheless, it is imperative to undertake further research to identify the most effective and cost-efficient management practices for mitigating the impact of heat stress on heifers, especially in diverse environments and production systems as the majority of mitigating techniques are just used in dairy cows.

Cows

Heat stress has a direct negative effect on the performances of cows (Collier et al., 1982). Gorniak et al. (2014) mentioned in their research that heat stress significantly reduces milk production in dairy cows. According to Ravagnolo and Misztal (2000), at the start of lactation, dairy cows with high production levels are particularly susceptible to the effects of heat, and their milk production is dramatically reduced when their body temperature exceeds 39 °C. Multiparous cows may be more vulnerable than primiparous cows to the detrimental effects of heat stress on reproductive function, according to the rise in thermotolerance additive genetic variations among parities (Sigdel et al., 2003). According to Bernabucci et al. (2014), the risk of heat stress is higher in multiparous cows with a reduction of milk output can reach 1k/d in comparison with primiparous cows. Another study conducted by West (2003) mentions that if the environmental temperature is 35 °C the amount of milk is reduced by 33% and if the outside temperature is 40 °C the milk production decreases by 50%. Further studies illustrating the impact of heat stress on milk production, such as a study conducted by du Preez et al. (1990) that looked into the impacts of the seasons on milk yield revealed that the milk production of Holstein cows reduced by 10% to 40% in the summer compared to the milk production level in the winter. In addition to lowering milk production, heat stress also has an impact on milk quality and somatic cell count (Bertocchi, 2014). A study conducted by (Ravagnolo et al., 2000) based on 119,337 milk-production values from 15,012 dairy cows discovered the fat and protein content of milk fell by 0.012 kg and 0.009 kg, respectively, for each unit of an increase in THI over 72. Another research by Gantner et al. (2011) in Croatia revealed that an increase in THI resulted in a substantial drop in the milk's fat and protein content in dairy cows. Bernabucci et al. (2015) compared the milk fat in different seasons and they found the lowest value in summer (3.20 g/100 g) in comparison with spring and winter (3.80 g/100 g and 3.61 g/100 g, respectively). In the same study, the casein content in the milk was lower in summer (2.27 g/100 g) in comparison with spring (2.48 g/100 g) and winter (2.75 g/100 g). In contrast, other studies did not show any change in the fat content of the milk under heat-stress conditions (Wheelock et al., 2010; Knapp & Grummer, 1991). Otherwise, Mitlöhner et al. (2001) showed that beef cattle exposed to heat stress experienced lower carcass weights, thinner fat layers had slower growth rates, and less desirable meat qualities in terms of color, tenderness, and pH when slaughtered during or right after this period.

A series of studies have demonstrated a greater risk of mortality in dairy cows during the summer months (Hahn, 1999; Vitali et al., 2009) and during extreme weather events. Similar to dairy cows, heat stress increases the risk of death in beef cattle (Thornton et al., 2009). Mastitis and other viral or metabolic illnesses are more likely to affect cows with compromised immune systems than healthy ones.

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Furthermore, the normal physiological activities of the cow are altered by heat stress, which has a detrimental impact on cow health and increases the problems of udder health in summer (Turk et al., 2015). Baumgard et al. (2013) Discovered that stress induced cortisol can increase blood glucose and as a consequence insulin level rises in the blood. In contrast, cattle exposed to heat stress for an extended period showed decreased plasma cortisol concentrations, according to Christison and Johnson (1972). The same result was found by Ronchi et al. (2001) when they detected a decrease in cortisol concentration in heat-stressed cows. According to Sanders et al. (2009), lameness incidence rises as temperature rises, which may be related to an increase in standing time. Furthermore, the basic physiological processes of the rumen are altered by rising ambient temperatures, which has a detrimental impact on ruminants and increases their risk for metabolic diseases and other health issues (Soriani et al., 2013). Heat stress increases the infiltration of endotoxins, also called lipopolysaccharides, into the bloodstream. Lipopolysaccharides are glycolipids present in the membrane of Gram-negative bacteria. Their increase in the bloodstream is known to cause an inflammatory response (Tough et al., 1997). Prolactin is linked to water balance and lactation (Nicoll and Bern, 1972) and it may have a significant role in thermoregulation when exposed to high ambient temperatures (Salah et al., 1995). Prolactin is considered a stress hormone, therefore, several researchers studied the relationship between prolactin and heat stress Ronchi et al. (2001) where found, as a result, the prolactin level was higher in the heat-stressed cows in comparison with not stressed animals and associated with hyperthermia. The same result was found by do Amaral et al. (2010) who discovered a high level of prolactin increasing in heat-stressed cows and it is associated with lower lymphocyte proliferation and negatively affects the immune system. Another study was conducted on ewes by Hooley et al. (1979) and they had the same result, the heat-stressed ewes had a higher concentration of prolactin in their plasma. Djelailia et al. (2021) found with the increase of the average temperature humidity index from 55 in winter to 78 in summer the prolactin concentration in the blood of Holstein cows increased from 58.52 to 129.79 ngm/L. In contrast, Bocquier et al. (1998) found the increase in prolactin is paradoxical under heat stress conditions since a decrease in ingested nutrients is usually associated with a decrease in prolactin concentration. Heat stress raises the blood levels of hydroxybutyric acid, acetone, and acetoacetate, which may have a role in the supply of energy or the production of milk fat. (Peterson et al., 2012). Heat-stressed cows generally exhibit altered blood acid-base chemistry as a result of the shift in cooling from non-evaporative to evaporative cooling (Kibler and Brody, 1950). The heat generated by the body results from the animal's metabolism; fluctuates to balance the heat lost to the environment and keep the animal's body temperature constant (Silanikove, 2000).

Many studies confirmed that with increasing temperature there is a decrease in the fertility of cows which causes a decrease in the conception rate and an increase in economic loss (Wise et al., 1988). Heat stress decreases heat expression, and alters follicular growth, embryonic development, oocyte quality, and steroidogenesis, all of which reduce fertility, particularly in high-producing females (De Rensis and Scaramuzzi, 2003; Jordan, 2003; Wolfenson et al., 2000). When an animal experiences heat stress, hormone production, in particular of GnRH, LH, and FSH, decreases. This results in lower progesterone and estrogen concentrations, which disrupts follicular growth (Ozawa, 2005). If the heat stress occurs on ovulation day it negatively affects the dominant follicle by reducing its volume and diameter (Badinga et al.,1993). According to Berthelot and Paccard (1990) in the case of hyperthermia in cows, their breathing rate increases, they produce more energy and heat, and it became harder to control the temperature of the body, which conduct to increases the temperature of the uterus and as a result increasing in early embryonic mortality. In the research of Hansen and Aréchiga (1999) the pregnancy rates per insemination in the hot season can be as low as 10–20% in lactating cows. In high ambient temperatures, it is more difficult for cows to engage in a natural mating activity because it shortens and decreases the intensity of the expression of estrous (Orihuela, 2000). In the study conducted by Govindan et al. (2017) they found as a result if pregnant cows are under heat stress it can affect the development of the embryo and decrease the birth weight, and an increase in temperature humidity index of more than 70 decreases the conception rate percentage by 4.6%. Similarly, Amundson et al. (2005) found that Bos taurus cow conception rates decreased by 3.2% with every rise in THI over 70 and by 3.5% for every increase in ambient temperature above 23.4 °C. Additionally, beef cattle had a significantly lower conception rate during the summer (62%) when the THI was equal to or higher than 72.9 (Amundson et al., 2006).

Alterations in physiology, anatomy, or behavior aimed for preserving thermal balance. Cows may alter their behavior to assist in cooling their body if they are subjected to higher heat stress (Polsky and von Keyserlingk, 2017), According to O'Driscoll et al. (2008), measurements of laying behavior are a key sign of the comfort of the cow and give crucial information about how cows interact with their surroundings. To increase their body surface area for heat dissipation, dairy cows will reduce by 30% their laying time when the ambient temperature rises (Schütz et al., 2011). Which results in increased energy demand and altered nutrient utilization, both of which may lead to increased maintenance needs. Cows who are under heat stress consume less feed, become less active, seek out wind and shade, breathe more quickly, and sweat more heavily (West, 2003). According to Vizzotto et al. (2015), dairy cows will mostly seek out and stand in shady patches of pasture to thermoregulate. According to Shultz (1984), the breath rate is considered one of the most important indicators of heat stress as it increases with the increase of ambient temperature. A breath rate

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of more than 60 breaths/min in lactating dairy cows means the animal is heat-stressed (Berman et al., 1985). Ouellet et al. (2021) calculated the breath rate by counting the flank movements of the cows in 1 min and they found, as a result, the heat-stressed cows have a higher respiration rate of 65.3 breaths/min in comparison with not stressed cows 54.6 breaths/min. Same results were found by Berman et al. (1985) in subtropical areas that at temperatures more than 25 °C the respiratory rate started to increase by 50–60 breaths/min. Heart rate also has been studied as an indicator of heat stress in dairy cows, the cattle have a normal heart rate of 55 to 70 beats/minute, which will rise if the temperature rises to heat-stressed levels in reaction to a reduction in arterial pressure and total peripheral resistance (Rübsamen and Hales, 1985). A study conducted by Bun et al. (2018) found that the cows under the shelter had a heart rate of 81 beats/min, and the same cows under the sunlight had a heart rate of 95 beats/min. Djelailia et al. (2021) found in their research that with the increase of the average temperature humidity index from 55 in winter to 78, in summer the heart rate increased by 3 beats/min. According to Janzekovic (2005), when the body's requirement for oxygen increases leads to a larger blood supply, which in turn causes the heart rate to rise in reaction to heat stress. In contrast, Bianca (1959) mentions cattle's heart rates rose during brief periods of heat stress but fell off as the stress became more prolonged or chronic.

The amount of ingested dry matter, production level, and thermoregulation are all influenced by ambient temperature. Heat stress affects negatively the animals by decreasing the DMI (Beede and Collier, 1986). As confirmed by different studies, dairy cows' dry matter intake (DMI) can decrease in hot areas by up to 40% when the ambient temperature is above 30 °C (Kadzere, 2002). As confirmed by West et al. (2003) a decrease of 4.5 kg/d or 22% of dry matter intake when the THI is in the range of 71 to 85 and for every degree Celsius over the thermoneutrality zone of the dairy cow, feed intake decreases by 0.85 kg DM. According to Berman (2005), dairy cows have a variety of adaptive reactions when exposed to heat over a threshold temperature of 35 °C, with a reduction in feed intake ranking as the most significant. This drop is more important especially when diets contain large quantities of cellulose (Cummins, 1992). On the other hand, decreasing the quantity of fiber in the diet lowers the amount of heat the body produces through metabolism. As confirmed by West (2003), dairy cows fed with rations have low fiber contents (14% acid detergent fiber (ADF) against 17 or 21%) under heat-stress circumstances, which boosted feed intake and milk output. In comparison to cows fed with high-fiber diets, those fed with reduced fiber diets during hot weather had higher daily milk yields, lower body temperatures, and slower respiratory rates (Tsai et al., 1967).

Oxidative stress in cows results from the overproduction of ROS and mitochondrial malfunction caused by heat stress. These circumstances may cause or contribute to the development of health problems in cattle (Miller et al., 1993). It is also conceivable that an increase in free radical production caused by the heat stress could harm the mammary epithelium and lower milk production (Elvinger et al.,1992). Recent research strongly suggests that oxidative stress caused by heat stress is a factor in the decreasing level of milk protein (Guo et al., 2021). The negative effects of heat stress on cow performance are significant and well-documented. Many of the cited studies focus on short-term impacts of heat stress, such as reduced milk production and altered hormone levels. However, further research is needed to understand how prolonged exposure to heat stress over multiple lactation cycles can impact the overall health and lifespan of dairy cows.

CONCLUSIONS

The production, reproduction, physiology, immunity, and behavior of calves, heifers, and cows and the survival and development of embryos have all been demonstrated to be impacted negatively by heat stress. Heat stress during the early or late gestation period affects the performance of the offspring later in their life. In order to increase the likelihood of proper placental growth, development of good immunological function, and high productivity for their offspring, cows must be reared in an appropriate environment during the early and late gestation period. Furthermore, it is needed to find solutions to manage and mitigate effectively the heat stress in different phases of a cow's life cycle.

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