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Impact of global climate warming on livestock diseases

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Abstract. In recent years, the issue of global climate change has garnered increasing attention. Rising temperatures have posed significant challenges not only for humanity but also for livestock production. The escalation of the global population has led to the widespread adoption of intensive livestock farming practices, where the health of livestock is paramount to ensuring stability and productivity within the industry. However, climate change may result in a higher incidence of heat stress in livestock, adversely impacting their physiological functions and immune regulation. This disruption can precipitate the onset of diseases, ultimately diminishing livestock production outputs. This article will explore the factors contributing to the emergence of animal diseases as a result of climate change, addressing both intrinsic and extrinsic effects.

Keywords: climate warming; animal diseases; livestock industry; heat stress; immune system.

1. Introduction

The post-industrial acceleration of global warming since the 1980s has shifted from scientific discourse to mainstream societal concern as a pressing issue. Through extensive research and data analysis, scientists have increasingly confirmed that human actions, especially the release of greenhouse gases like carbon dioxide and methane, are principal contributors to global climate change. The impacts of global warming are manifesting worldwide, characterized by rising sea levels, an increase in extreme weather events, crop failures and food shortages, and shifts in biodiversity. Recent years have seen a growing public concern regarding climate issues, fueled by the emergence of new research findings and widespread media coverage of climate change. Governments and non-governmental organizations are advocating for relevant policies and actions, urging global society to adopt effective measures to combat climate change. This phenomenon is not only a scientific concern but also a significant challenge confronting governments, businesses, and individuals across the globe.

Scientific consensus estimates the planet's average surface temperature may climb by approximately 3.7 degrees Celsius before 2100.[1]. As the trend of climate warming becomes increasingly evident, the activity levels of viruses and microorganisms are also to rise, leading to a higher frequency of epidemics. The diseases precipitated by global warming pose serious threats to the livestock industry. For instance, heat stress refers to a series of physiological and biochemical responses generated by an organism when faced with an environment that exceeds its tolerance temperature. It is a non-specific response. Typically, homeothermic animals have a thermoneutral zone, and when environmental temperatures surpass the upper limit of this zone, they experience heat stress. Heat stress not only affects livestock production parameters, such as milk yield and milk quality [2], but also impacts the immune responses of the animals.

The escalating impacts of climate change on livestock industry pose significant challenges to agricultural sustainability. The U.S. livestock sector suffers significant economic repercussions from heat stress, with annual losses exceeding 900 million in dairy production costs (including animal healthcare expenditures) and an additional 300 million burden on beef and pork operations combined[3]. Furthermore, the global demand for meat, eggs, and dairy products, driven by a burgeoning population, places significant pressure on livestock production. It is estimated that by 2050, global demand for milk and meat production will surge by 1,077 million tons and 455 million tons respectively, nearly doubling production levels from 2006[4]. Consequently, the challenges

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posed by global warming significantly complicate the anticipated increases in production capacity critical for fulfilling future demands.

The escalating temperatures and changing climate patterns create an urgent need for research examining the implications of global warming on animal health and disease prevalence. The impacts of climate change on animal disease can be classified into direct and indirect effects, and these dimensions warrant detailed exploration in later discussion.

2. Direct Effects of Global Warming on Animal Disease

2.1. Effects on Embryonic Development

Telomeres are small segments of DNA located at the ends of chromosomes, and their length is closely associated with cellular lifespan—specifically, the more cell divisions occur, the more telomeres erode. High temperatures have been shown to affect telomere length; for instance, research indicates that higher daily air temperatures correlate with shorter telomere lengths[5]. Recent studies involving ectothermic animals, such as lizards, reveal that telomere shortening under elevated temperatures can be transmitted from mothers to offspring, leading to the hypothesis known as the "aging loop hypothesis" [6]. Therefore, one can reasonably infer that with the ongoing rise in global temperatures, the telomere lengths of livestock may gradually decrease, resulting in reduced lifespans for these animals.

Furthermore, intergenerational and transgenerational effects are likely to be magnified in the context of global warming. En vironmental factors can influence epigenetic mechanisms, which may be passed down through generations. Animals exposed to extreme climate events and other environmental stresses during gametogenesis can exhibit stable epigenetic changes in their germline, which may then be inherited by subsequent generations. For example, Studies have shown that when the mother of cows is subjected to heat stress during late pregnancy, the milk production of their offspring decreases in the first, second, and third stages. Additionally, maternal heat stress during terminal gestation phases adversely influences survival rates of female offspring from birth to their first calving[7].

2.2. Effects on Gut Microbiota

Temperature is a crucial factor controlling microbial growth. Excessive temperatures can lead to protein denaturation, dissociation of base pairing, and increased fluidity of the plasma membrane, while colder temperatures slow physiological processes: enzyme efficacy decreases, nucleic acids adopt secondary structures, and plasma membranes become rigid. Consequently, microorganisms adjust their cellular processes to thrive within specific temperature ranges, responding to environmental stress when temperatures exceed these optimal ranges[8] (Huus & Ley, 2021).

The gut microbiota significantly influences the regulation of the host's immune response., maintaining gut homeostasis, and suppressing inflammation. Both mice and livestock are highly prone to heat stress effects on their gut microbiomes. Studies have revealed significant alterations in the gut microbiota of heat-stressed mice, with notable reductions in beneficial bacteria such as Bacteroides, which is essential for short-chain fatty acid production and glucose homeostasis, as well as Oscillospira and Faecalibacterium, which are butyrate producers. Heat stress can lead to decreased abundances of these beneficial bacteria[9].

2.3. Decreased Immunity

The advent of mechanized production has made large-scale livestock farming increasingly common. Therefore, a developed immune system is crucial for livestock and poultry farming. The establishment of the mammalian immune system begins during embryo development and takes time to mature. However, elevated temperatures can induce heat stress that affect the immune system's

development. Acute heat stress might initially enhance the immune system's function, whereas chronic heat stress can hinder its capacity to regulate internal balance.

Research indicates that heat stress can impair both cellular and humoral immunity in cattle. Neonates born to cows subjected to acute heat stress during late gestation show decreased lymphocyte percentages and reduced blood immune markers (such as TNF α and Toll-like receptor 2) in the initial weeks postpartum. Furthermore, heat stress experienced by cows during late gestation can compromise passive immunity in calves. Moreover, heat stress induces activation of the hypothalamic-pituitary-adrenal (HPA) axis, leading to a significant increase in peripheral cortisol levels. This increase in cortisol may suppress the production and release of cytokines.[10-11].

Moreover, climate warming-induced heat stress can induce oxidative stress in organisms, generating reactive oxygen species (ROS) leading to cellular dysfunction[12]. Mitochondria are central to oxidative stress responses; heat stress can induce mitochondrial dysfunction, and acute heat stress can affect the function of uncoupling proteins within the mitochondrial transport protein family, resulting in increased ROS levels[13]. Research has demonstrated that lactating dairy cattle exhibit pronounced oxidative stress responses, with scientific evidence showing significantly elevated oxidative stress levels during the periparturient period compared to late gestational stages. This physiological state potentially predisposes bovines to production diseases, including clinical mastitis and placental retention disorders.[14].

3. Indirect Effects of Global Warming on Animal Diseases

3.1. Pathogen Transmission

Climate change is not only increasing the microbial populations within livestock housing but may also enhance the virulence and vitality of these microorganisms. Vector-borne viruses are significant causes of livestock diseases, transmitted through arthropods. With climate change, the distribution of these vectors may shift, appearing in new regions, thereby enlarging the transmission range and potentially introducing novel diseases. Mosquitoes are among the most well-known vectors of arboviruses affecting livestock. Global warming is expected to expand the geographical range of mosquitoes. For example, *Ae Albopictus* is distributed in temperate and tropical regions, and the *Ae Aegypti* is mainly distributed in tropical and subtropical regions. However, In the past 30 years, *Ae Aegypti* and *Ae Albopictus* has expanded its geographical distribution worldwide. Estimates suggest that by the end of this century, regions conducive to the proliferation of *Aedes albopictus* may increase by 50% within the context of climate change[15-16].

3.2. Feed Mycotoxins

The occurrence of mycotoxins in animal feed presents a critical issue affecting livestock health. Mycotoxins, which are secondary metabolites derived from fungi, with significant implications for feed safety. Cereals are among the most prevalent components of animal feed, yet they are at risk of contamination with mycotoxins during various stages, including farming, harvesting, transportation, and storage. The detrimental effects of mycotoxins observed in both humans and animals encompass carcinogenic, teratogenic, immunotoxic, neurotoxic, hepatotoxic, nephrotoxic, reproductive, developmental, and gastrointestinal issues[17]. With ongoing climate change, elevated temperatures are anticipated to increase the abundance of heat-tolerant mycotoxin-producing fungal species, such as Aspergillus species linked to aflatoxin production. Such developments can severely impact agricultural yield, leading to decreased food safety and heightened mycotoxin contamination across global crops. Climate-mediated bioaccumulation of these toxins in food animals presents dual threats to veterinary health systems and human consumers, necessitating One Health approaches to exposure monitoring.

4. Conclusion

It is evident that climate change has influenced animal diseases, placing significant pressure on the development of the livestock industry. Variations in temperature can alter the epigenetic factors during animal embryonic development, reduce productivity. Additionally, climate change affects the diversity and quantity of microbial species in the intestines of livestock. The heat stress induced by global warming can lead to oxidative stress while simultaneously influencing the immune response of livestock. Furthermore, global warming is likely to expand the distribution range of certain vector-borne viruses, increasing the risk of disease transmission. Therefore, to enhance climate resilience in livestock production systems, proactive adaptation strategies should prioritize thermal regulation management through comprehensive environmental controls. This involves implementing infrastructure upgrades for enhanced climate-proofing, activating timely heat stress mitigation protocols, and ensuring that breeding animals are kept in a comfortable environment during gestation. Moreover, attention should be given to maintaining hygienic conditions within farms to reduce the transmission of diseases, alongside providing balanced nutrition to enhance the immune capabilities of the animals.

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