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ARTICLE

Challenges of Ensuring Sustainable Poultry Meat Production and Economic Resilience under Climate Change for Achieving Sustainable Food Security

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ABSTRACT

Poultry meat production breeds are distinguished by their rapid growth, prolific output, and excellent nutritional efficiency when raised in optimal environmental conditions to realize their genetic potential. Climate change, characterized by elevated environmental temperatures, undermines optimal conditions for meat production, leading to diminished growth performance, reduced feed efficiency, and increased mortality rates, thereby resulting in substantial economic losses and critical threats to global food security. This project aims to investigate the obstacles to sustainable chicken meat production and improve economic resilience in the face of climate change, focusing on the formulation of strategies that promote sustainable food security. The global production of poultry meat rose by 1.63 million metric tons in 2023/2024 relative to 2022/2023 and is projected to grow by about 2% in 2025, attaining a new high of 104.9 million tons. Heat stress results in an annual economic loss of $2.36 billion in the U.S. chicken industry due to diminished production performance, elevated mortality rates, increased feed costs, and heightened disease resistance. Consequently, initiatives to mitigate the detrimental impacts of climate change on

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poultry production may include the adoption of heat-resistant breeds and the application of sustainable agricultural practices, in addition to formulating comprehensive legislation to address these issues In light of current climate change projections and rising temperatures, the research recommends the adoption of comprehensive measures to improve sustainable poultry production and ensure food security at both local and global levels.

Keywords: Chicken Meat; Poultry Production; Climate Change; Food Security; Economic Sustainability

1. Introduction

The expanding human population is presently confronting an unparalleled challenge regarding global food production and sustainability. Although poultry is acknowledged as one of the most successful and quickly expanding food businesses to tackle this challenge, poultry health and safety continue to be significant concerns that require urgent attention [1]. The most recent United Nations forecasts indicate that the global population will reach 9.7 billion by 2050, resulting in a 60% increase in food demand and a 70% rise in the consumption of animal-derived goods. Meat output has increased threefold in the last 50 years [2]. In 2021, the Organisation for Economic Cooperation and Development (OECD) anticipates that by 2030, the world's meat output will reach 347 million tons, with chicken meat accounting for 52% [3].

The poultry business has significantly profited from advancements in genetics, nutrition, housing, and management techniques. Geneticists have prioritized welfare and health qualities in selection procedures, resulting in modern, high-producing fowl being healthier than three decades ago. Increased production indicates that the birds are nearing their physiological limits, rendering nutrition, environment, and management increasingly critical [4].

In forthcoming decades, the demand for chicken meat is anticipated to rise significantly in accordance with human population expansion. This expansion presents a significant opportunity for the sector. Nevertheless, it conceals numerous challenges, including pollution and land erosion, competition for scarce resources between animal and human nutrition, animal welfare issues, restrictions on growth promoters and antimicrobial agents, and heightened risks of animal infectious diseases and zoonoses [5].

Climate change has significantly impacted the output of broilers. Broilers, developed for accelerated development and substantial meat yield, depend significantly on ideal environmental circumstances to realize their genetic potential. Nonetheless, climate change is altering these settings and presenting several obstacles to broiler production. The principal effect of climate change on broiler production is the diminished capacity of birds to reach their genetic potential for accelerated development. Broilers are selectively bred for particular genetic characteristics that facilitate quick growth and effective feed-to-meat conversion [6].

Poultry constitutes a significant protein source for numerous individuals globally. Nonetheless, several factors affect poultry meat production. Temperature is a paramount stressor influencing poultry production, significantly impacting chickens' productivity and health [7, 8]. In 2011, economic losses in agricultural productivity attributed to elevated temperatures were predicted to surpass $1 billion [9]. Climate change may indirectly influence animal productive performance through a reduction in feed quality and outright feed shortages [10]. It is anticipated that this will have a detrimental impact on the performance of reproductive capacity and growth [11].

In order to produce high-quality, value-added products, poultry farmers must proactively implement adaptations to mitigate future costs, risks, and concerns. The market's elevated price and fluctuating input expenses lead to losses. The farmers must focus on effective management, welfare, and health enhancements. Heat exhaustion, a significant issue, notably impacts broilers, which are essential to the worldwide meat supply within the evolving poultry sector. Notwithstanding advancements in breeding and management, these pressures adversely affect avian development, welfare, and general health, jeopardizing the long-term sustainability of the poultry business [12].

On the other hand, as a result of rising living standards, the demand for poultry products worldwide is projected to increase fourfold by the year 2050. But the quality of feed crops, water availability, illnesses, and poultry reproduction are all negatively impacted by climate change, which presents a major danger to poultry production. The water consumption of chickens is impacted by climate change, which in turn increases the need for agricultural land as a result of higher production levels. Furthermore, concerns about food security intensify. Livestock, including fowl, consume around a third of the world's cereal crops. Therefore, when it comes to improving food security around the world and decreasing emissions, the chicken industry is crucial. Hence, we need to take the required steps to move toward sustainable chicken production [13]. Additionally, sustainable poultry production is an all-encompassing strategy for increasing output with little negative impact on the environment and the health of the birds. To accomplish this, the poultry industry is bolstering its resistance to climate change by implementing cutting-edge techniques and technologies. Some of these methods include making housing more energy- and air-efficient, using water-saving measures, and modifying feeding schedules to suit the birds' demands as they evolve. Cutting down on emissions also requires cutting-edge technological solutions, such as climate control systems that operate automatically, heat-tolerant bird breeding programs, and renewable energy. To further assure the sector's productivity and economic sustainability in light of climate change, there is a focus on creating environmentally friendly farms and executing efficient waste management plans to deal with local problems like increasing sea levels and severe weather [13].

The US also produces more broilers than any other country, and the average American eats 45 kg of chicken a year. The United States broiler business has come a long way in terms of production economics, but there's still a lot of room for improvement when it comes to environmental sustainability. An additional perk of marketing sustainable chicken is the possibility of a price increase [14].

This study examines the problems of maintaining sustainable chicken meat production and economic resilience in the context of climate change to achieve sustainable food security. The study aims to investigate three principal questions:

1. How can the global poultry industry address economic challenges and sustainability opportunities amid rising demand and climate change?
2. How does climate change impact poultry production?
3. What strategies can help the poultry industry effectively mitigate the negative impacts of climate change?

Comprehending the present situation and examining the obstacles to establishing sustainable chicken meat production and economic resilience in the context of climate change is essential for attaining sustainable food security. The poultry sector is essential for supplying animal protein and maintaining global food security. Nonetheless, climatic changes, including increasing temperatures, are expected to cause economic losses and adversely affect global food security. This research aims to deliver a thorough examination of the obstacles confronting the poultry business due to climate change and increasing temperatures, as well as methods to mitigate these concerns. It seeks to enrich the literature with a contemporary viewpoint on the impacts of climate change on food security and sustainability, which continue to be scrutinized globally. Additionally, poultry producers must implement measures to alleviate temperature stress and minimize economic losses. This study will examine the role of poultry meat in attaining global food security and the effects of climate change on this sector, emphasizing the necessity of implementing strategies to address climate change and its adverse impacts on poultry production alongside methods to ensure long-term food security and sustainability in production.

2. Materials and Methods

This study employs a qualitative descriptive research methodology, focusing on analyzing the challenges of sustainable poultry meat production and economic resilience in the face of climate change, with the ultimate goal of achieving sustainable food security. Furthermore, descriptive research, as described by Neuman[15], is characterized by its ability to "present a picture of the specific details of a situation, social setting, or relationship" and "begins with a well-defined issue or question and endeavors to describe it accurately." "...concentrates on 'how' and 'who' inquiries...". Moreover, it is contended that qualitative research designs, including phenomenology and grounded theory, can serve both descriptive and explanatory purposes[16]. Lambert and Lambert suggest employing the term "qualitative descriptive research" to avoid mislabeling the research approach with other methodologies, such as phenomenology, grounded theory, and ethnography[16]. "Naturalistic inquiry" by Lambert and Lambert states that qualitative descriptive research "strives to look at things in their natural state as much as possible within the research context"[16]. The study is qualitative because it looks at the challenges of ensuring sustainable poultry meat production and economic resilience under climate change in order to achieve sustainable food security. It is, therefore, qualitative descriptive research.

Furthermore, the present study's objectives necessitate a thorough content analysis of both electronic and printed materials regarding the occurrences or events under investigation[17]. Furthermore, Bowen asserts that it has three phases: skimming, comprehensive reading, and interpretation[17]. By breaking down large amounts of text into smaller, more manageable pieces, content analysis helps us find the most important meanings within them[18]. It does this by looking for recurring themes and patterns in the text[19].

3. Results and Discussion

3.1. How Can the Global Poultry Industry Address Economic Challenges and Sustainability Opportunities amid Rising Demand and Climate Change?

Poultry is among the most prevalent and swiftly expanding food sectors globally[20]. The Food and Agriculture Organization states that poultry meat is a highly consumed commodity with increasing demand due to its high-quality protein and low-fat content[21]. The consumption and production of chicken meat hold significant economic value in several nations, with projections indicating a global demand rise of 121% from 2005 to 2050[22]. In recent years, the chicken sector has expanded significantly due to comparatively low production costs and rising meat demand. In 2018, the global per capita consumption of chicken meat was estimated at 14.2 kg, making it the most consumed meat product worldwide[23].

Poultry farming is acknowledged as an exceptionally productive method of animal husbandry, greatly enhancing the nutritional security of a considerable segment of the global populace. The implementation of modern intensive agricultural techniques has resulted in a significant rise in worldwide output, reaching 103.83 million metric tons in 2023/2024 compared to 102.2 million metric tons in 2022/2023, as seen in **Figure 1**. In 2023/2024, the United States, Brazil, China, and the European Union were the foremost producers of chicken meat, with production quantities of 21 million tons, 14.9 million tons, 14.8 million tons, and 11.08 million tons, respectively[24].

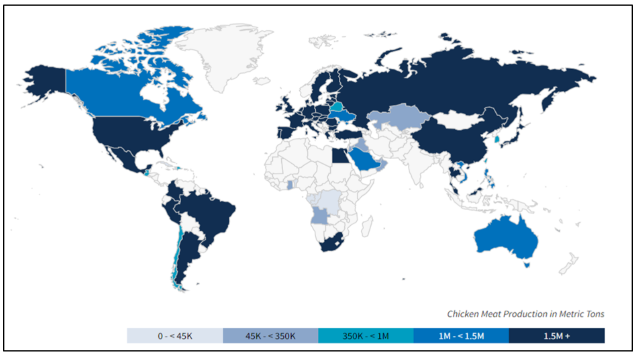

Figure 1. Global chicken meat production by metric tons in 2023/2024[24].

On the other hand, the worldwide production and consumption of poultry meat is anticipated to increase steadily from 2020 to 2022, as illustrated in **Table 1**. Both production and consumption figures are anticipated to grow annually, with a slight increase in per capita supply. The production rates of poultry-producing nations rose from 2022 to October 2024, and this rising trajectory is anticipated to continue until October 2025. Nonetheless, as indicated in **Table 2**, these nations have experienced a rise in poultry consumption throughout that period, and demand is anticipated to persist in its expansion until October 2025. This trend signifies that poultry is increasingly relied upon as a primary source of animal protein to satisfy the demands of a growing worldwide population, owing to its status as a cost-effective and healthy alternative to other meats. Notwithstanding this increase, addressing the needs of an increasing population poses a global challenge: alleviating the impacts of climate change on agriculture. To satisfy demand while mitigating environmental and climate-related issues, a more robust emphasis on sustainable manufacturing is essential.

Table 1. Global poultry production from 2020 to 2022 [25].

Items	Year		
	2020	**2021**	**2022**
Poultry meat production (1000 metric tons)	136,842	136,249	139,122
Poultry meat consumption (1000 metric tons)	132,237	132,330	135,380
Poultry meat supply quantity (kg/capita)	16.92	16.79	17.04

Table 2. Top countries in chicken meat production and consumption as ready to cook equivalent "1,000 metric tons" from 2022 to 2025 [26].

Country	2022	2023		2024		Oct, 2025		
	Production	Consumption	Production	Consumption	Production	Consumption	Production	Consumption
USA	20,993	17,676	21,082	17,866	21,384	18,412	21,726	18,700
China	14,300	14,401	14,800	15,002	15,000	14,830	15,300	15,115
Brazil	14,460	10,023	14,900	10,135	15,000	10,105	15,100	10,105
European Union	10,880	9,881	11,084	10,157	11,385	10,325	11,530	10,420
Russia	4,800	4,750	4,800	4,812	4,800	4,850	4,850	4,895
Mexico	3,763	4,666	3,888	4,890	3,985	4,951	4,085	5,070
Thailand	3,300	2,309	3,450	2,332	3,490	2,610	3,580	2,385
Turkey	2,418	1,772	2,330	1,871	2,400	2,065	2,600	2,250
Argentina	2,319	2,138	2,319	2,298	2,485	2,320	2,545	2,370
United Kingdom	1,847	2,484	1,858	2,569	1,900	2,610	1,920	2,640

Poultry livestock profitability is largely contingent upon feed, which constitutes 60–70% of the whole production cost, with protein sources being among the more costly constituents [27]. Insufficient conversion of chicken feed to meat diminishes output, ultimately causing substantial financial losses. U.S. chicken farmers are expected to save yearly expenses by almost $50 million for each one percent improvement in feed conversion [28]. These limitations are exacerbated by heat stress, which causes yearly economic losses of $128–165 million in the poultry industry [29]. This phenomenon has significant ramifications for the U.S. chicken industry, resulting in an estimated yearly economic loss of $2.36 billion [30]. Chickens are prone to elevated morbidity and mortality due to high ambient temperatures. Such techniques jeopardize chicken safety and have repercussions for human nutrition and the economic viability of the poultry industry overall [12].

The United States is the foremost producer of broiler chickens globally, accounting for nearly 20% of the world's chicken production [21]. Americans consume approximately 45 kilograms of chicken per capita each year, resulting in substantial economic and environmental impacts. Beal et al. performed a techno-economic analysis and life cycle evaluation to examine the sustainability performance of the U.S. broiler sector on an annual basis, employing several scenarios depicted in **Figure 2** [14]. Research indicates that broiler production in the United States has been predominantly optimized for economic gain, yielding substantial amounts of broiler meat at acceptable profit margins. Furthermore, the utilization of renewable energy, sustainable corn practices, and scenarios with minimal greenhouse gas emissions demonstrated considerable sustainability [14].

Poultry is one of the most prevalent and swiftly expanding food sectors globally [20]. The Food and Agriculture Organization states that poultry meat is the most extensively eaten commodity, with increasing demand attributed to its high-quality protein and low-fat content [21]. The annual global output of chicken meat is expected to be between 73 million and 100 million tons [31]. The consumption and production of chicken meat hold significant economic value in several nations, with projections indicating a global demand rise of 121% from 2005 to 2050 [22].

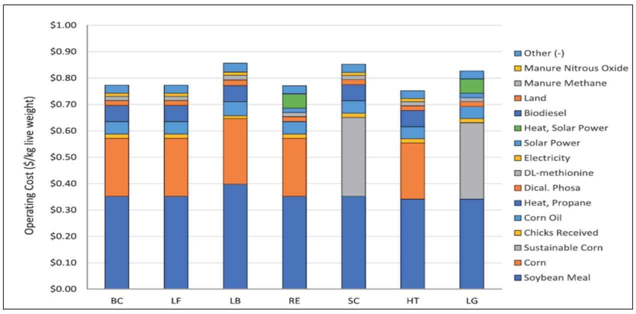

Figure 2. Annual operating expenses and contribution breakdown for each case.

Note: Abbreviations: B.C., Baseline Case; H.T., High Temperature case; LB, Large Bird scenario; LF, Large Farm scenario; L.G., Low GHG case; RWN EN, Renewable Energy case; S.C., Sustainable Corn Scenario [14].

Conversely, global poultry output is projected to increase by almost 2% in 2025, reaching a record high of 104.9 million tons. The majority of nations are anticipated to report production increases, with the most significant growth projected in China, the United States, Turkey, the European Union, Brazil, and Mexico. The increase is bolstered by slight enhancements in feed costs and consumer demand propelled by economic growth. Furthermore, global exports are projected to increase by 2% in 2025, reaching a record 13.8 million metric tons, following a period of stagnant trade in 2023 and 2024. Economic development is anticipated to stimulate moderate consumption increases as chicken continues to be an affordable source of animal protein attractive to middle-income consumers. All principal exporters (Brazil, the U.S., the EU, and Thailand) will see growth, with Brazil securing the most significant portion due to its competitive pricing and service capabilities in the main expanding markets (Mexico, Saudi Arabia, Singapore, the UAE, and the U.K.). Brazil, as a leading producer of maize and soybeans, possesses a competitive edge in chicken meat production owing to its cheap feed prices, which constitute two-thirds of production expenses in the country. The United States possesses an abundant feed supply and competitive feed prices, yet feed costs exceed those in Brazil. Moreover, labor expenses in Brazil are far cheaper than those in the United States. Competitive labor costs facilitate the transportation of items like boneless beef [26].

3.2. How Does Climate Change Impact Poultry Production?

Climate change generates a detrimental environment for broiler chickens. These circumstances impede their growth and development, obstructing the attainment of their entire genetic potential, which is essential for obtaining optimal production outcomes. Moreover, climate change intensifies the pre-existing difficulties encountered by broiler production systems. Elevated feed expenses undermine the industry's economic sustainability and restrict access to high-quality nourishment for avian, limiting their development potential. Alongside feed shortages, climate change increases broilers' vulnerability to heat stress. Climate change adversely affects broiler productivity, including nutrition, immunological function, health, and disease susceptibility [6] (see **Figure 3**). Climate change adversely affects poultry production by generating detrimental growing circumstances, including elevated temperatures and heightened humidity, which impede chicks from attaining their genetic potential. This results in reduced productivity and higher feed costs due to rising prices and limited availability of high-quality nutrients. Moreover, heat stress heightens hens' susceptibility to illnesses, resulting in increased expenses for treatment and care. These challenges compromise the economic viability of the poultry business, thus impacting its long-term sustainability and expansion.

Furthermore, elevated ambient temperatures have detrimental economic effects on the chicken business since they diminish growth rate, body weight, meat quality, sperm quality, fertility, and hatchability. High ambient temperatures adversely impact poultry performance parameters. Consequently, birds selectively bred for performance have increased vulnerability to heat stress-induced death. Heat stress encountered by birds during transit leads to diminished meat quality, increased mortality, and welfare issues. Molecular markers are now being examined to discover prospective candidate genes linked to production, reproduction, and growth traits in chickens with elevated heat tolerance and disease resistance[32].

Elevated ambient temperatures have become a significant limitation for the future advancement of the poultry business, particularly in tropical and subtropical areas. The scarcity of resources combined with severe environmental conditions presents the most critical challenges to optimizing broiler production. Heat stress disrupts the physiological biochemistry of broiler chickens, eventually diminishing feed intake and feed efficiency, resulting in reduced performance and output. In elevated ambient temperatures, feed efficiency is compromised due to lipid accumulation and oxidative stress. Moreover, broiler chickens possess a limited temperature range for withstanding heat stress, resulting in alterations in blood cell composition, acid-base equilibrium, immune function, hepatic health, and antioxidant capacity—all of which undergo significant physicochemical changes due to heat stress[33].

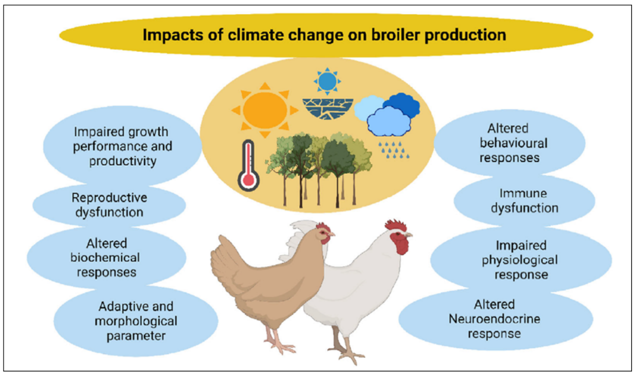

Figure 3. Diagram illustrating the effect of climate change on chicken production[6].

Conversely, broiler's physiology, productivity and health can be adversely affected by elevated temperatures, as demonstrated by numerous studies[8, 34, 35]. In addition, Sohail et al. discovered that broilers subjected to prolonged heat stress had decreased body weight and feed consumption, accompanied by an elevated feed conversion ratio[36]. A separate study demonstrated a reduction in food consumption and an increase in blood glucose levels[37]. Moreover, persistent heat stress can impair fat metabolism, obstruct muscular development, and adversely influence the quality and nutritional profile of meat[38]. Moreover, increased environmental temperature can result in heightened mortality percentage, as well as decreased production efficacy and feed intake[39]. The impact of heat stress on chickens might differ according to parameters like the length and severity of the stress, the physiological condition and age of the birds, their sex, and their genetic predisposition[11].

To ensure the long-term sustainability and profitability of chicken operations, it is vital to alleviate heat stress and boost feed conversion efficiency. The financial implications of this necessity underscore its importance. According to Humphrey, the modern food quality framework places a premium on food safety[40]. The global chicken industry is facing a major obstacle in the form of high temperature stress. It is becoming more and more clear that stress can have negative effects on food safety. The problem is made worse by transporting broilers from farms to processing plants at high temperatures, which leads to a significant reduction in meat quality[41].

3.3. What Strategies Can Help the Poultry Industry Effectively Mitigate the Negative Impacts of Climate Change?

Heat stress represents a substantial risk to the poultry sector. This issue is expected to escalate as climate change further elevates ambient temperatures. Furthermore, heat stress adversely affects several facets of chicken production, including meat quality, production performance, productivity, and overall welfare. The adverse impacts of heat stress on chicken productivity are significant[11]. Moreover, heat stress is a threat that may lead to substantial revenues lost in poultry production in tropical and arid regions worldwide. The extent of heat-stressed chickens is primarily influenced by poultry's thermoregulatory capacity, humidity, thermal radiation, age, metabolic rate, and the severity and length of the heat stress. Modern commercial broilers possess a quick metabolism, resulting in elevated heat production and susceptibility to heat stress[42].

Poultry producers should proactively implement adjustments to mitigate future costs, hazards, and concerns. The industry's elevated and fluctuating input costs, resulting in losses, must compel manufacturers to prioritize effective management, welfare, and health enhancement, therefore producing high-quality and value-added products. Heat stress, a critical concern, predominantly affects broilers, which are essential to the world meat supply in the evolving poultry sector. Notwithstanding improvements in breeding and management, these pressures adversely affect avian development, welfare, and overall health, jeopardizing the long-term sustainability of the poultry business [12].

Conversely, Beal et al. asserted that human resource management practices and performance are pivotal elements influencing the outcomes of techno-economic analysis and life cycle assessment in poultry, alongside their implications for sustainability. It was determined that poultry production necessitates varying requirements for energy, cost, climatic conditions, and management practices, which in turn affect the results of techno-economic analysis and life cycle assessment across diverse production farms and even among different farms within the same region [14]. Furthermore, heat stress is a significant environmental element that diminishes poultry output globally. Consequently, implementing poultry health management methods is crucial for the industry's performance regarding productivity and reproduction, aimed at improving chicken production efficiency, disease resistance, and reproductive outcomes [32].

Furthermore, heat stress significantly endangers chicken health and productivity, exacerbating their vulnerability to food insecurity due to escalating ambient temperatures and climate change. Climate change has resulted in elevated temperatures and unpredictable weather patterns in recent years, rendering chickens increasingly susceptible to this environmental stressor [43]. Moreover, selective breeding over the years has resulted in accelerated chicken growth and enhanced feed effectiveness. However, these traits are associated with faster metabolic rates and a higher susceptibility to heat stress [44, 45]. As a result, research on heat stress's impact on chicken production, as well as the development of management strategies to mitigate its negative effects, is crucial [11]. In order to address the impact of heat stress on chicken production, it is necessary to develop and implement effective strategies that take a comprehensive approach. These strategies should include the following:

3.3.1. Education and Awareness

Serve a crucial function in bolstering resistance to climate change effects on chicken production by advising farmers and industry personnel on sustainable methods and contemporary technology to tackle these issues. Education and awareness initiatives encompass educating people about the implementation of advanced management methods, utilizing efficient cooling systems, adhering to appropriate feeding programs, and promoting the conservation of natural resources such as water and electricity. These initiatives enable the industry to implement sustainable methods that enhance efficiency and educate the community on the significance of preserving food security in the face of rapid climate change.

3.3.2. Implementing Legislation and Policies to Combat Climate Change

National law is essential for the poultry sector in combating climate change by establishing a legal framework that delineates standards and duties for farmers. Such a law enables governments to formulate effective regulations aimed at diminishing greenhouse gas emissions linked to chicken raising and fostering sustainable production methods. These regulations promote investment in clean technology and enhance resource efficiency, resulting in fewer environmental effects from the sector. Moreover, national regulation elevates public consciousness about the significance of sustainability within the chicken industry. It aids farmers in acclimating to climate change, bolstering food security, and safeguarding community health.

3.3.3. Development of Genetically Resilient Chicken Strains

The development of genetically resilient broiler strains that can withstand various climate-related challenges while maintaining production is fundamentally based on genetic selection for multi-trait resilience, which includes factors beyond mere heat tolerance [18]. Modern broiler strains have been genetically modified for rapid growth, making them vulnerable to heat stress due to increased metabolic rates. The genetic composition of these lines has been hybridized with other strains to develop a novel line that withstands the hot and humid conditions characteristic of tropical climates. The bare neck gene is a dominant autosomal gene associated with reduced feathering in the neck region, which aids in heat dissipation. Similarly, Frizzle gene cases resulted in reduced featherweight and increased heat radiation by diminishing the insulating properties in broilers. Genetic methods have resulted in improved heat tolerance capacity [33].

Nutritional, genetic, and managerial measures have been attempted with varying degrees of effectiveness to reduce heat stress. Nonetheless, these measures have not adequately and sustainably mitigated heat stress. Consequently, it is essential to implement proactive strategies to alleviate the impacts of heat stress on poultry, guarantee optimal output, and improve chicken welfare. Embryonic heat treatment adjusts the temperature of the embryonic environment to enhance broiler heat tolerance and growth performance. A primary advantage of this strategy is its cost-efficiency and time savings compared to traditional management approaches. Due to its numerous benefits, embryonic heat treatment is a viable approach to improve broiler output and profitability within the poultry sector. Embryonic heat therapy elevates the typical incubation temperature during the mid or late-embryonic stage to promote genetic thermal tolerance and enhance embryo metabolism. This study is to synthesize the existing literature and empirical data about the advantageous impact of pre-hatch temperature manipulation on broiler health and performance [43].

Recently, epigenetic modifications and early-life thermal acclimatization are effective heat stress treatments for chickens. Early thermal conditioning exposes chicks to sub-lethal heat stress while developing. This increases their heat tolerance through physiological and molecular changes. Choosing epigenetic markers with high heat tolerance may also affect how chickens react to heat stress through epigenetic alterations, which change gene expression patterns without changing DNA sequence. Furthermore, early heat training and the consequent epigenetic alterations may enhance the thermotolerance of chickens [11].

3.3.4. Environmental Strategies Focused on Enhancing Management Practices

Ventilation, chicken house design, and stocking density reduction can reduce heat stress. These methods improve ventilation and comfort in chicken houses to reduce heat stress [11]. Modular housing and high-tech ventilation systems are needed to keep broilers healthy and happy in hot areas [12]. Moreover, positive and negative pressure ventilation systems are widely used in poultry farming to control the indoor environment of poultry houses, especially in tropical regions, where hot and humid climates can pose challenges for regulating animal temperature. Knowing that heat stress affects poultry meat quality, negative pressure systems have been shown to provide lower air and temperature conditions, and poultry raised in this system have better meat quality. Negative pressure ventilation systems are recommended for broiler producers in tropical regions due to their ability to provide better thermal parameters and chicken meat quality [46].

3.3.5. Nutritional Management and Technologies

During heat stress, feed consumption and nutrient intake in poultry generally decline, adversely impacting the performance and production of the birds. Consequently, altering the nutritional content to enhance the feed intake of hens is a crucial factor during heat stress. Optimal feeding techniques that enhance feed consumption, reduce thermal stress, and mitigate the adverse impacts of heat stress in poultry are essential for effective nutritional management of birds at elevated temperatures [47]. Moreover, Syafwan et al., documented various feeding strategies that could mitigate heat load in poultry, including restricted feeding during elevated temperatures to lessen heat accumulation, selective feeding of protein or energy-dense feed components, provision of feeds with varying particle sizes or structures to decelerate digestion, and administering wet diets to concurrently enhance water consumption [48].

Feed withdrawal, often used for 6 to 8 hours daily during peak heat times, might potentially reduce heat escalation and mitigate the detrimental consequences of heat stress in chickens. Feed withdrawal prevents the accumulation of heat burdens resulting from metabolic heat produced during the processes of feed digestion, absorption, assimilation, and excretion. Therefore, it is essential to restrict feeding to the cooler hours of the day, ideally during the morning, evening, or overnight, to mitigate the effects of heat stress. The substantial thermal output from feed intake causes a peak heat load to occur between 09:00 and 11:00 h, especially when feeding at 06:00 h. Consequently, feeding around midday would result in detrimental cumulative effects since the heat produced from feed usage would align with the peak temperature of the day, particularly during the summer months in tropical and subtropical areas [49]. The use of feed withdrawal during the day, coupled with a brief feed limitation before heat exposure, improves thermal resistance, decreases heat generation, curtails the rise in body temperature, and reduces death rates in heat-stressed chickens [42]. Moreover, strategies for feeding broilers that focus on adding immune-boosting and antioxidant substances to their food are very important for reducing the negative effects of heat stress on their bodies [12]. Furthermore, using extracts from specific natural substances may mitigate the effects of elevated temperatures on chickens. Supplementing with Moringa oleifera increases the productivity of broilers and reduces damage caused by heat stress by lowering oxidative stress and inflammation [50]. On the other hand, feeding Japanese quail Spirulina platensis improves their production and overall physiological homeostasis, especially when they are under heat stress [51].

3.3.6. Research and Development

Research and development play a crucial role in addressing the impacts of climate change and rising temperatures on chicken production by fostering sustainable and innovative solutions that guarantee production continuity and efficiency. This includes the creation of heat-resistant chicken breeds, the improvement of cooling systems in poultry facilities, and the optimization of energy and water use. We employ modern technology, artificial intelligence, and specialized feeding programs to improve poultry health and production in light of evolving climatic conditions. These advancements enable precise monitoring and adjustment of environmental variables, thereby enhancing resilience in the poultry industry. Research and development facilitate the sector's response to environmental issues, promote sustainable food security, improve competitiveness, and stabilize the food supply.

4. Conclusions

Elevated ambient temperatures, attributable to climate change, diminish the growth performance, feed efficiency, and survival rates of meat production, leading to considerable economic losses and threats to world food security. The present study examines obstacles to sustainable chicken meat production and enhances economic resilience during climate change, emphasizing food security strategies. Despite a 1.59% increase in worldwide chicken meat production in 2023/2024 relative to 2022/2023, and a projected 2.69% rise in 2025, the U.S. poultry industry incurs yearly losses of $2.36 billion due to productivity challenges associated with heat stress, mortality, feed expenses, and disease resistance. Consequently, heat-resistant breeds and sustainable agriculture could assist the chicken industry in adapting to climate change. The current research underscores the necessity for comprehensive laws to tackle these difficulties and recommends extensive initiatives to enhance sustainable poultry production while ensuring local and global food security in light of climate change projections and rising temperatures.

Author Contributions

This work was carried out in collaboration with all authors. Conceptualization, A.O.A. and A.M.A.A.; methodology, A.M.A.A.; software, A.O.A.; validation, F.S.N., A.M.A.A. and A.O.A.; formal analysis, A.O.A.; investigation, F.S.N.; resources, A.O.A.; data curation, A.M.A.A.; writing—original draft preparation, F.S.N.; writing—review and editing, A.M.A.A.; visualization, A.O.A.; supervision, AO.A.; project administration, F.S.N.; funding acquisition, A.O.A. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used for this study are available upon request from the authors.

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Conflicts of Interest

All authors disclosed no conflict of interest.

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