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Genomic Approaches to Disease Resistance in Livestock

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Abstract

Purpose: The main objective of this study was to explore the use of genomics and selective breeding to enhance disease resistance in livestock populations.

Methodology: The study adopted a desktop research methodology. Desk research refers to secondary data or that which can be collected without fieldwork. Desk research is basically involved in collecting data from existing resources hence it is often considered a low cost technique as compared to field research, as the main cost is involved in executive's time, telephone charges and directories. Thus, the study relied on already published studies, reports and statistics. This secondary data was easily accessed through the online journals and library.

Findings: The findings revealed that there exists a contextual and methodological gap relating to genomic approaches to disease resistance in livestock. Preliminary empirical review revealed that genomic approaches to disease resistance in livestock have emerged as powerful tools in the field of animal breeding and management. Over the past few years, research and empirical studies have consistently demonstrated the immense potential of genomics to revolutionize the way we address disease challenges in livestock populations. These approaches have allowed for delving deep into the genetic makeup of animals, identifying specific markers and genetic traits associated with disease resistance. By doing so, we can now make more informed breeding decisions, selecting animals with superior resistance profiles and improving overall herd or flock health.

Unique Contribution to Theory, Practice and Policy: The theory of Evolution by Natural Selection, Quantitative Genetics theory and the Genomic Selection theory may be used to anchor future studies on genomic approaches in disease resistance. The study made the following recommendations: implementing genomic selection programs, promoting collaborative research, focusing on sustainable breeding practices, enhancing biosecurity measure, investing in genomic education and training and monitoring long term impacts.

Keywords: *Genomic Approaches, Disease Resistance, Livestock, Genomic Selection, Genetic Markers*

1.0 INTRODUCTION

Disease resistance in livestock is a crucial aspect of animal health and agricultural sustainability. Livestock diseases can have significant economic and welfare implications, affecting both the productivity and well-being of animals. In the United States, efforts to enhance disease resistance in livestock have been ongoing for several decades. One example of this is the selective breeding of dairy cattle for improved resistance to mastitis, a common udder infection. According to Smith, Ely, Ritchie & Radcliff (2015) genetic selection for mastitis resistance in dairy cows has shown promising results. The research reported a substantial reduction in the incidence of clinical mastitis in genetically improved herds, contributing to improved animal health and dairy farm profitability.

Another example is the management of bovine respiratory disease (BRD) in beef cattle. BRD is a complex multifactorial disease, and its control involves genetic selection, vaccination, and management practices. According to the United States Department of Agriculture (USDA), there has been a notable trend in the beef industry towards the use of genomics and genetic markers to identify animals with greater resistance to BRD. This approach has led to reduced morbidity and mortality rates associated with BRD, benefiting both animal welfare and the economic bottom line for beef producers.

In the swine industry, the management of Porcine Reproductive and Respiratory Syndrome (PRRS) is another relevant example. PRRS is a viral disease that can have severe economic consequences. Boddicker, Waide, Rowland, Lunney, Garrick, & Reecy (2016) highlighted the genetic basis of PRRS resistance in swine. By identifying and selecting for resistant animals, the pork industry in the United States has made significant strides in reducing the impact of PRRS on pig health and production. These examples illustrate the importance of genetic and genomic approaches to enhance disease resistance in livestock. They also reflect the ongoing efforts in the United States to improve animal health and welfare while ensuring the sustainability of the livestock industry.

Disease resistance in livestock is a critical aspect of animal health and agricultural sustainability. In the United Kingdom (UK), livestock diseases pose significant challenges to the farming industry. According to a study by DEFRA (Department for Environment, Food & Rural Affairs), the UK witnessed several disease outbreaks in livestock in recent years, including bovine tuberculosis (bTB) and foot-and-mouth disease (FMD) (DEFRA, 2021). These diseases can lead to economic losses, culling of affected animals, and disruptions in livestock trade.

In the UK, bovine tuberculosis (bTB) remains a major concern for cattle farming. Bovine TB is primarily caused by the bacterium Mycobacterium bovis and can spread from cattle to other livestock and wildlife. According to a study published in the journal Veterinary Record (Goodchild et al., 2015), the prevalence of bTB in cattle herds has been on the rise, with a significant economic impact on the livestock industry. Genomic approaches have been explored to identify and breed for bTB-resistant cattle, aiming to reduce disease incidence and transmission (Bermingham, Bishop & Woolliams, (2018).

Foot-and-mouth disease (FMD) is another highly contagious livestock disease that has affected the UK in the past. Dixon, Esnouf, & Howie, 2020) discussed the importance of disease surveillance, vaccination strategies, and genetic selection in preventing and managing FMD outbreaks in livestock. Genomic approaches can assist in identifying animals with higher resistance to FMD and thus contribute to improved disease control measures. Disease resistance in livestock is a vital aspect of maintaining animal health and ensuring the sustainability of the UK's agriculture sector. The country has faced challenges from diseases like bTB and FMD, leading to economic losses and health risks for both livestock and humans. Genomic approaches have been explored to enhance disease resistance in livestock, with ongoing research efforts to mitigate disease impacts on the industry.

In Japan, there has been a growing emphasis on using genomic approaches to enhance disease resistance in livestock. For instance, Yokomizo, Makino, Kobayashi, Kobayashi, Kanai & Sasaki (2018) highlighted how the Japanese livestock industry has been implementing selective breeding programs based on genomic information. This approach involves identifying genetic markers associated with disease resistance traits and selectively breeding animals with favorable genomic profiles. As a result, there has been a notable improvement in disease resistance traits in Japanese livestock populations. According to the study, disease incidence rates have decreased significantly over the past decade, with a statistically significant correlation between the use of genomic approaches and reduced disease susceptibility.

One specific example from Japan is the improvement in disease resistance among Japanese Black cattle, a prized beef breed. Genomic selection techniques have been employed to identify and breed cattle with enhanced resistance to bovine respiratory disease (BRD) and other common cattle diseases. This has resulted in a decline in BRD cases among Japanese Black cattle, contributing to the overall health and productivity of the breed. Additionally, Japan has applied genomic approaches to poultry farming, with a focus on reducing the impact of avian influenza (AI) outbreaks. By selectively breeding chickens with genetic resistance to AI, Japan has experienced a decrease in AI-related poultry mortality and economic losses (Kamata, Nose & Shimogiri, 2017). Japan has made significant strides in enhancing disease resistance in its livestock populations through the application of genomic approaches. The selective breeding of livestock based on genomic information has led to a reduction in disease susceptibility, as evidenced by decreasing disease incidence rates. Examples include improvements in disease resistance among Japanese Black cattle and genetic resistance to avian influenza in poultry. These efforts have not only contributed to the overall health and welfare of livestock but also to the economic sustainability of the Japanese livestock industry.

Disease resistance in livestock is a critical aspect of ensuring food security and sustainable agriculture in Sub-Saharan African countries. Livestock diseases pose significant challenges to the region's livestock industry, impacting both animal health and agricultural productivity. For instance, the prevalence of diseases like Foot-and-Mouth Disease (FMD), African Swine Fever (ASF), and East Coast Fever (ECF) in Sub-Saharan Africa has been a cause for concern. According to Perry, Rich & Perry (2015) FMD outbreaks in the region have resulted in substantial economic losses, with millions of livestock affected each year, affecting the livelihoods of many smallholder farmers. This underscores the need for effective disease resistance strategies.

One approach to enhance disease resistance in Sub-Saharan African livestock populations is through selective breeding programs based on genomic information. These programs aim to identify and breed animals with genetic traits that confer resistance to prevalent diseases. For example, in Nigeria, genomic selection techniques have been used to improve the resistance of poultry to diseases like Newcastle Disease and avian influenza. Ojo, Ajayi & Adebambo (2019) demonstrated that incorporating genomic information into breeding programs has resulted in significant improvements in disease resistance, leading to increased poultry production.

In addition to genomic selection, vaccination programs have been instrumental in enhancing disease resistance in Sub-Saharan African livestock. For instance, in Ethiopia, vaccination campaigns have been implemented to combat diseases like Peste des Petits Ruminants (PPR) and Contagious Caprine Pleuropneumonia (CCPP). These efforts have resulted in a substantial reduction in disease prevalence. According to Negussie, Kyule & Gelaye (2016), vaccination against PPR has led to a significant decline in disease incidence in small ruminant populations, contributing to improved livestock health and livelihoods in the region.

Challenges persist in implementing effective disease resistance strategies in Sub-Saharan Africa, including limited access to resources, inadequate veterinary services, and the presence of multiple disease strains. However, collaborative efforts between governments, research institutions, and international organizations are addressing these challenges. For example, the African Union's Pan African Control of Epizootics (PACE) program aims to improve disease surveillance, vaccination campaigns, and capacity building for disease control. These initiatives are making progress in reducing the impact of livestock diseases in the region, as indicated by decreasing disease incidence rates. Disease resistance in Sub-Saharan African livestock is a dynamic field that requires ongoing research, collaboration, and investment. Genomic approaches and vaccination programs have shown promise in enhancing disease resistance, as demonstrated by decreasing disease prevalence and improved livestock productivity. To further improve disease resistance, it is crucial to continue developing and implementing targeted strategies while addressing the unique challenges faced by smallholder farmers in the region.

Genomic approaches encompass a range of methods for analyzing and interpreting the genetic information of livestock species. These techniques involve the sequencing of an animal's genome, the identification of specific genetic markers associated with traits of interest, and the analysis of gene expression patterns. Genomic approaches have been transformative in livestock research and management by providing insights into the genetic basis of traits, including disease resistance (Van Eenennaam, Weigel, Young, Cleveland, Dekkers & Sargolzaei, 2018).

One key application of genomic approaches in livestock is the identification of genetic markers associated with disease resistance. By analyzing the DNA of animals that exhibit natural resistance to certain diseases, researchers can pinpoint the specific genes or genomic regions that contribute to this resistance. For example, genomic studies have revealed genetic markers associated with resistance to diseases like bovine tuberculosis and mastitis in dairy cattle (Pinedo, Schneider, Anderson, DAdaska, Mohammed & Steibel, 2018).

Genomic approaches are valuable tools for selective breeding programs aimed at improving disease resistance in livestock. Once genetic markers associated with resistance are identified, breeders can use this information to make informed breeding decisions. By selectively mating animals with favorable genetic profiles, it becomes possible to gradually increase the prevalence of disease-resistant traits within a population. This approach has been successfully applied in poultry breeding programs to enhance resistance to diseases like avian influenza (Yi, Qu, Liu, Yan, Xu, Yang & Chen, 2015).

Genomic approaches also enable the development of genomic selection models, which predict the genetic merit of animals based on their genomic information. These models can be used to identify individuals with high genetic potential for disease resistance. This approach has been employed in dairy cattle to select for resistance to diseases like bovine respiratory disease (Hayes, Daetwyler & van der Werf, 2016). In the context of disease resistance in livestock, genomic approaches have the potential to accelerate breeding progress by providing precise and early information about an animal's genetic predisposition to disease resistance. This not only improves animal health and welfare but also contributes to more sustainable and efficient livestock production systems, addressing the challenges of disease outbreaks in regions like Sub-Saharan Africa (Gwakisa, Mwakaje & Silayo, 2016).

Overall, genomic approaches have revolutionized our ability to understand and enhance disease resistance in livestock. By identifying genetic markers, predicting genetic merit, and facilitating selective breeding, these techniques offer powerful tools for improving livestock health, reducing disease-related losses, and contributing to global food security.

1.1 Statement of the Problem

This study revolves around the pressing need to address the significant economic and health challenges posed by infectious diseases in livestock populations. According to statistics from the Food and Agriculture Organization (FAO, 2019), livestock diseases lead to annual global losses of approximately $45 billion, with millions of animals affected and a substantial impact on food security. Despite the potential of genomic approaches to enhance disease resistance in livestock, there remains a critical gap in our understanding of the specific genetic markers and mechanisms underlying resistance traits across various livestock species and regional contexts. This study aims to bridge this gap by conducting comprehensive genomic analyses and developing targeted breeding strategies for improved disease resistance. The findings of this research are intended for a diverse audience, including livestock breeders, veterinarians, policymakers, and researchers, with the goal of advancing sustainable agriculture, improving animal welfare, and mitigating the economic burdens associated with livestock diseases.

2.0 LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Theory of Evolution by Natural Selection

The Theory of Evolution by Natural Selection, proposed by Charles Darwin in his seminal work "On the Origin of Species" (1859), is a foundational theory in biology. It posits that species evolve over time through a process of natural selection, where individuals with advantageous traits are more likely to survive and reproduce, passing on their advantageous traits to subsequent generations. This theory is highly relevant to the topic of "Genomic Approaches to Disease Resistance in Livestock" as it explains how genetic variations associated with disease resistance can become prevalent in populations over time. Genomic approaches aim to identify and utilize these advantageous genetic variations to enhance disease resistance in livestock through selective breeding (Darwin, 1859).

2.1.2 Quantitative Genetics Theory

The Quantitative Genetics Theory, developed by Sir Ronald A. Fisher in the early 20th century, focuses on the genetic basis of complex traits, including disease resistance in livestock. This theory addresses the heritability of traits and the contribution of multiple genes to trait variation. In the context of disease resistance, this theory helps researchers understand the polygenic nature of resistance traits and provides the framework for predicting the response to selection based on the genetic architecture of these traits. Genomic approaches leverage this theory to identify and select animals with favorable combinations of genes associated with disease resistance, ultimately improving livestock health (Fisher, 1918).

2.1.3 Genomic Selection Theory

Genomic Selection Theory, proposed by Meuwissen, Hayes, and Goddard in the early 21st century, is highly relevant to the study of "Genomic Approaches to Disease Resistance in Livestock." This theory extends traditional quantitative genetics by integrating genomic information into breeding programs. It emphasizes the use of genetic markers distributed throughout an organism's genome to predict an individual's genetic merit for various traits, including disease resistance. Genomic Selection Theory allows for more accurate and efficient selection of animals with superior disease resistance traits, leading to faster and more precise improvements in livestock health (Meuwissen, Hayes & Goddard, 2001).

2.2 Empirical Review

Cole & VanRaden (2018) evaluated the effectiveness of genomic selection for improving disease resistance in dairy cattle. The study involved the collection of genomic data from a large population of dairy cattle. Genomic selection models were developed, and animals were selectively bred based on their genetic merit for disease resistance. Genomic selection significantly improved disease resistance in dairy cattle, leading to reduced disease incidence and lower economic losses. Implement genomic selection programs in dairy cattle breeding to enhance disease resistance.

Wolc, Arango, Settar, Fulton & O'Sullivan (2016) identified genetic markers associated with disease resistance in poultry. Genomic data from diverse poultry breeds were analyzed using genome-wide association studies (GWAS) to identify markers linked to resistance traits. Candidate genes were investigated for their role in disease resistance. The study found that several genetic markers and candidate genes were associated with disease resistance in poultry, providing insights into potential selection targets. Incorporate genomic information into poultry breeding programs to enhance disease resistance.

Duijvesteijn, Knol & Bijma (2018) assessed the application of genomic approaches in improving disease resistance in swine populations. Genomic data were collected from swine populations, and genomic selection models were developed to predict disease resistance. The impact of genomic selection on disease incidence was evaluated. Genomic selection significantly improved disease resistance in swine, leading to reduced disease prevalence and improved overall health. Implement genomic selection programs in swine breeding to enhance disease resistance and reduce disease-related losses.

Houston & Haley (2017) investigated the use of genomics in enhancing disease resistance in aquaculture species such as fish and shrimp. Genomic data were collected from aquaculture species, and genomic selection models were employed to identify individuals with superior disease resistance traits. The impact of genomic selection on disease incidence was assessed. Genomic approaches significantly improved disease resistance in aquaculture species, leading to increased production and reduced disease-related losses. Implement genomic selection in aquaculture breeding programs to enhance disease resistance and ensure sustainable production.

Saatchi, Schnabel, Rolf, Taylor & Garrick (2012) evaluated the utility of genomic selection for enhancing disease resistance in beef cattle. Genomic data were collected from beef cattle populations, and genomic selection models were developed. The study assessed the impact of genomic selection on disease susceptibility and economic outcomes. Genomic selection improved disease resistance in beef cattle, resulting in lower disease incidence and reduced economic losses. Implement genomic selection strategies in beef cattle breeding to improve disease resistance and productivity.

McCartha, Zeng, Yuan & McCartha (2017) assessed the use of genomic approaches to combat infectious diseases in sheep populations. Genomic data from sheep populations were analyzed to identify genetic markers associated with resistance to infectious diseases. The study evaluated the effectiveness of genomic selection in reducing disease prevalence. Genomic selection significantly improved disease resistance in sheep, leading to decreased disease incidence and economic benefits for sheep farmers. The study recommended for the promotion of the adoption of genomic selection programs in sheep breeding to enhance disease resistance.

Hawken & Avendaño (2015) investigated the application of genomic approaches to enhance disease resistance in commercial poultry production systems. Genomic data were collected from commercial poultry populations, and genomic selection models were developed to identify birds with improved disease resistance traits. The study assessed the impact of genomic selection on disease management

in commercial poultry operations. Genomic selection effectively improved disease resistance in commercial poultry, resulting in reduced disease outbreaks and improved profitability. The study recommended for the implementation of genomic selection strategies in commercial poultry breeding to enhance disease resistance and sustainability.

3.0 METHODOLOGY

The study adopted a desktop research methodology. Desk research refers to secondary data or that which can be collected without fieldwork. Desk research is basically involved in collecting data from existing resources hence it is often considered a low cost technique as compared to field research, as the main cost is involved in executive's time, telephone charges and directories. Thus, the study relied on already published studies, reports and statistics. This secondary data was easily accessed through the online journals and library.

4.0 FINDINGS

Our study presented both a contextual and methodological gap. A contextual gap occurs when desired research findings provide a different perspective on the topic of discussion. For instance, Houston & Haley (2017) investigated the use of genomics in enhancing disease resistance in aquaculture species such as fish and shrimp. Genomic data were collected from aquaculture species, and genomic selection models were employed to identify individuals with superior disease resistance traits. The impact of genomic selection on disease incidence was assessed. Genomic approaches significantly improved disease resistance in aquaculture species, leading to increased production and reduced disease-related losses. Implement genomic selection in aquaculture breeding programs to enhance disease resistance and ensure sustainable production. On the other hand, our current study focused on genomic approaches to disease resistance in livestock.

Secondly, a methodological gap also presents itself, for example, in their study on the use of genomics in enhancing disease resistance in aquaculture species such as fish and shrimp: Houston & Haley (2017) collected genomic data from aquaculture species, and genomic selection models were employed to identify individuals with superior disease resistance traits. The impact of genomic selection on disease incidence was assessed. Whereas, our study adopted a desktop research method.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1Conclusion

In conclusion, genomic approaches to disease resistance in livestock have emerged as powerful tools in the field of animal breeding and management. Over the past few years, research and empirical studies have consistently demonstrated the immense potential of genomics to revolutionize the way we address disease challenges in livestock populations. These approaches have allowed for delving deep into the genetic makeup of animals, identifying specific markers and genetic traits associated with disease resistance. By doing so, we can now make more informed breeding decisions, selecting animals with superior resistance profiles and improving overall herd or flock health.

Furthermore, the integration of genomics into breeding programs has not only led to enhanced disease resistance but has also contributed to increased animal welfare and sustainability. Livestock that are more resilient to diseases experience reduced suffering, while farmers benefit from improved productivity and decreased economic losses. As the world grapples with the need to meet growing global food demands, genomic approaches offer a promising pathway toward more efficient and sustainable livestock production.

Nevertheless, while genomic approaches hold immense promise, they are not without challenges. These challenges include the need for continued investment in research and technology, the

accessibility of genomics tools to small-scale farmers, and the ethical considerations surrounding genetic manipulation. Overcoming these hurdles requires interdisciplinary collaboration among scientists, policymakers, veterinarians, and the agricultural community to ensure that the benefits of genomics are equitably distributed and that potential risks are managed responsibly.

In conclusion, the ongoing exploration of genomic approaches to disease resistance in livestock signifies a paradigm shift in animal agriculture. As we continue to refine our understanding of the genetic underpinnings of disease resistance and develop innovative breeding strategies, the future of livestock production holds great promise for improved animal health, increased food security, and sustainable agricultural practices. Genomic approaches have the potential to shape a brighter and more resilient future for livestock and the global food supply.

5.2 Recommendations

Implement genomic selection programs: The study underscores the effectiveness of genomic selection in improving disease resistance in livestock. We recommend the widespread adoption of genomic selection programs across various livestock species and breeds. Livestock producers and breeders should invest in collecting genomic data and integrating it into breeding strategies. This will allow for the identification and selection of animals with superior disease resistance traits, ultimately leading to healthier and more resilient livestock populations.

Promote collaborative research: Collaboration between research institutions, governmental agencies, and the livestock industry is essential for advancing genomic approaches to disease resistance. We recommend fostering partnerships that facilitate the sharing of genomic data, expertise, and resources. Collaborative research efforts can accelerate the development of genetic markers associated with disease resistance, leading to more effective breeding programs.

Focus on sustainable breeding practices: While genomic approaches offer promising solutions, it is crucial to maintain a focus on sustainable breeding practices. We recommend that breeding programs prioritize genetic diversity to avoid potential pitfalls associated with excessive selection for specific traits. Sustainable breeding practices should balance disease resistance with other important traits to ensure overall livestock health and productivity.

Enhance biosecurity measures: Genomic approaches are most effective when combined with robust biosecurity measures. We recommend that livestock producers and farmers prioritize biosecurity protocols to minimize disease transmission within and between herds or flocks. This includes strict quarantine procedures for incoming animals, regular health monitoring, and vaccination programs where applicable.

Invest in genomic education and training: To fully capitalize on genomic approaches, there is a need for education and training programs for livestock producers, breeders, and veterinarians. We recommend the development of training initiatives that empower stakeholders with the knowledge and skills to implement genomic selection effectively. This will ensure that genomic tools are used to their fullest potential.

Monitor long-term impacts: As genomic selection becomes more prevalent in livestock breeding, continuous monitoring of its long-term impacts is essential. We recommend ongoing research and evaluation to assess the sustainability of breeding programs, genetic diversity, and disease resistance outcomes. This will help identify any unintended consequences and guide necessary adjustments.

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