Journal of
Animal Health
(JAH)

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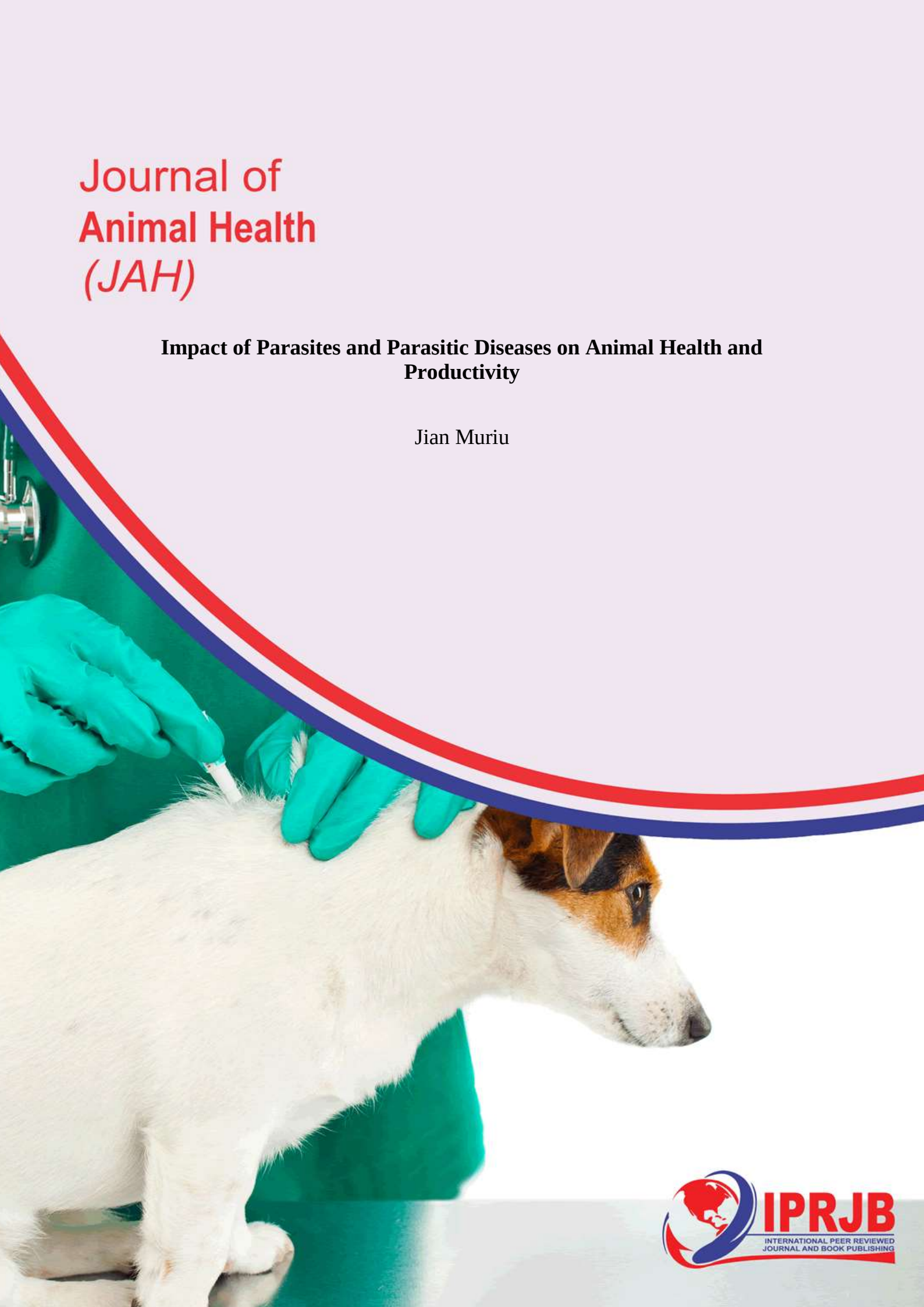

IPRJB
INTERNATIONAL PEER REVIEWED
JOURNAL AND BOOK PUBLISHING

Journal of Animal Health
ISSN 2709-5517(Online)
Vol.3, Issue 1, No. 2 pp 13-23, 2023

www.iprjb.org

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Article History

Received 17th August 2023

Received in Revised Form 25th August 2023

Accepted 9thSeptember 2023

How to cite in APA format:

Muriu, J. (2023). Impact of Parasites and Parasitic Diseases on Animal Health and Productivity. *Journal of Animal Health*, *3*(1), 13–23. https://doi.org/10.47604/jah.2100

Abstract

Purpose: The aim of the study is to investigate the impact of parasites and parasitic diseases on animal health and productivity.

Methodology: This study adopted a desktop methodology. This study used secondary data from which include review of existing literature from already published studies and reports that was easily accessed through online journals and libraries

Findings: The study found that parasites and parasitic diseases have a significant impact on animal health and productivity across various species. Negative associations between parasitic infections and key indicators of health and productivity, such as weight gain, milk production, reproductive performance, wool quality, and egg quality. Animals with higher parasite burdens tend to experience slower growth rates, reduced fertility, compromised immune function, and increased susceptibility to other diseases. Additionally, parasitic infections can lead to poor feed conversion ratios, higher mortality rates, and decreased overall productivity in livestock and poultry farming operations

Unique Contribution to Theory, Practice and Policy: The study was anchored on Resource Competition Theory which was proposed by Robert M. May in 1974 and Immunopathology Theory which was proposed by Zinkernagel and Doherty in 1974. The study recommends that Governments and regulatory bodies should develop and enforce policies that promote responsible parasite control practices in livestock production.

Keywords: *Parasite, Parasitic diseases, Animal Health, Productivity*

INTRODUCTION

Animal health and productivity play crucial roles in the agricultural sectors of developed economies. In the United States, for instance, the livestock industry is a significant contributor to the economy. According to a study by Key and McBride (2017), the average annual productivity growth rate in the U.S. livestock sector between 1948 and 2012 was 2.4%. This growth can be attributed to advancements in animal genetics, nutrition, health management, and improved production systems. Furthermore, the study found that the U.S. livestock industry has witnessed a shift towards larger farms with higher productivity levels.

In the United States, the beef industry is a significant sector within the agricultural landscape. Over the years, advancements in animal health and productivity have contributed to the growth and efficiency of the industry. According to data from the United States Department of Agriculture (USDA, 2020), the average carcass weight of cattle has increased steadily. Between 2000 and 2020, the average carcass weight of cattle at slaughter rose from approximately 725 pounds to over 900 pounds. This increase can be attributed to improved genetics, feeding practices, and management techniques, resulting in higher meat production per animal.

In Japan, the pork industry has experienced notable improvements in animal health and productivity. According to a report by the Japan Pork Producers Association (JPPA, 2020), the average carcass weight of market hogs in Japan has shown a consistent upward trend. From 2010 to 2019, the average carcass weight increased from around 83 kilograms to over 95 kilograms. This increase can be attributed to advancements in genetics, nutrition, and animal management practices, resulting in higher productivity and meat yields in the pork sector.

In the United Kingdom, the dairy industry is a key component of the agricultural sector. Over the years, there has been a focus on improving animal health and productivity to meet the growing demand for dairy products. According to the British Cattle Veterinary Association (BCVA, 2020), the average milk yield per cow in the UK has increased steadily. Between 2000 and 2017, the average milk yield per cow increased from approximately 6,000 liters to over 8,000 liters. This increase can be attributed to various factors, including advancements in breeding techniques, nutrition, and disease prevention strategies.

In developing economies, animal health and productivity are also of great importance for agricultural development. In Japan, for example, the poultry industry has witnessed significant growth. According to a report by the Japan Poultry Association (JPA, 2019), the total production volume of broiler chickens in Japan increased from approximately 1.4 million metric tons in 2000 to over 1.8 million metric tons in 2018. This growth can be attributed to improved breeding techniques, disease control measures, and enhanced feed formulations.

In India, the poultry industry has witnessed significant growth and transformation in recent years. According to a report by the National Bank for Agriculture and Rural Development (NABARD, 2018), the poultry sector has experienced a remarkable increase in egg and meat production. From 2000 to 2017, the egg production in India more than doubled, reaching over 93 billion eggs annually. Similarly, meat production in the poultry sector increased from around 1.6 million metric tons in 2000 to over 4.2 million metric tons in 2017. This growth can be attributed to improved breeding techniques, better feed formulations, and the adoption of advanced management practices.

In Brazil, the dairy industry plays a crucial role in the country's agricultural sector. According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2020), milk production in Brazil has shown steady growth over the years. From 2000 to 2019, milk production increased from approximately 23 billion liters to over 34 billion liters. This increase in productivity can be attributed to several factors, including improved animal health management, advancements in breeding and genetics, better feeding practices, and the adoption of modern milking technologies.

In Sub-Saharan economies, animal health and productivity are essential for sustaining the livelihoods of many rural communities and supporting economic growth. In Kenya, for instance, the dairy industry is a significant contributor to the agricultural sector. According to a study by Bett (2016), advancements in animal health practices and breeding programs have led to an increase in milk productivity. The study found that the average milk yield per cow in Kenya increased from 7.5 liters per day in 2007 to 10.5 liters per day in 2015. This improvement can be attributed to the adoption of improved dairy cattle breeds, better nutrition, and the implementation of disease control measures.

In Nigeria, the poultry industry has experienced notable growth in recent years. According to the Food and Agriculture Organization of the United Nations (FAO, 2019), the total poultry meat production in Nigeria increased from approximately 642,000 metric tons in 2000 to over 1.2 million metric tons in 2017. This growth can be attributed to increased investments in poultry farming, improved breed selection, better feeding practices, and the implementation of disease control measures. The expansion of the poultry sector has not only contributed to food security but also provided employment opportunities and economic benefits for farmers.

In Ethiopia, the livestock sector plays a vital role in the country's economy and livelihoods. According to a study by Lemma (2017), improvements in animal health practices and productivity have contributed to the growth of the sector. The study highlighted that milk production in Ethiopia has shown significant progress. From 2000 to 2014, milk production increased from approximately 2.2 billion liters to over 4.8 billion liters. This increase can be attributed to various factors, including the adoption of improved dairy cattle breeds, enhanced feeding and nutrition practices, and the implementation of disease control measures.

In Kenya, the poultry industry has experienced substantial growth and development. According to a report by the Kenya Poultry Farmers Association (KPFA, 2019), the production of broiler chickens in Kenya has increased significantly in recent years. From 2000 to 2018, the annual broiler meat production rose from approximately 6,000 metric tons to over 95,000 metric tons. This growth can be attributed to improved poultry management practices, better access to quality inputs such as feed and vaccines, and the expansion of commercial poultry farming.

Parasites and parasitic diseases can have significant impacts on animal health and productivity. Firstly, parasitic infections can lead to direct adverse effects on the host animal, including reduced growth rates, weight loss, and decreased reproductive performance. For example, gastrointestinal parasites such as worms can cause intestinal damage, nutrient depletion, and anemia, leading to suboptimal growth and lower productivity (Thamsborg, 2021). These negative impacts on animal health can result in economic losses for livestock producers.

Secondly, parasitic diseases can impair the immune function of animals, making them more susceptible to other diseases. Parasites can compromise the immune response and increase the animal's vulnerability to bacterial or viral infections. This can further escalate health issues and lead to increased morbidity and mortality rates, ultimately affecting productivity (Coop, 2019).

For instance, in cattle, tick-borne diseases such as babesiosis and anaplasmosis can cause anemia, reduced weight gain, and reproductive problems, impacting the overall productivity of the herd.

Furthermore, parasites can cause damage to organs and tissues, leading to long-term health issues that impact productivity. Liver flukes, for example, can cause liver damage and impair nutrient metabolism in ruminant animals, resulting in reduced feed conversion efficiency and compromised production (Klun, 2016). Similarly, ectoparasites such as lice or mange mites can cause skin lesions, itching, and stress, leading to reduced feed intake and weight loss in affected animals (Sharma et al., 2019).

Lastly, control and treatment measures for parasitic diseases incur additional costs for livestock producers. Preventive measures, such as regular deworming or vaccination programs, require financial investment and labor resources. Treatment expenses for infected animals, including the cost of medications and veterinary services, can also impact profitability. Thus, the economic burden of managing parasitic diseases can have indirect impacts on animal productivity and overall profitability of the livestock industry" (Thamsborg & Mejer, 2021).

Statement of the Problem

Parasites and parasitic diseases have a significant impact on animal health and productivity, affecting various species across different geographical regions. These parasites, ranging from internal worms to external ectoparasites, can cause detrimental effects such as reduced growth rates, decreased feed efficiency, impaired reproductive performance, and increased susceptibility to other diseases (Smith, 2018). Understanding the extent of this impact is crucial for implementing effective control and prevention measures, improving animal welfare, and optimizing productivity in livestock and companion animals.

Theoretical Review

Resource Competition Theory

The Resource Competition Theory, proposed by Robert M. May in 1974, suggests that parasites compete with their hosts for limited resources, such as nutrients, energy, and space. This theory emphasizes that parasitic infections can negatively impact animal health and productivity by depleting the host's resources. Parasites extract nutrients from the host, leading to reduced availability for host growth, reproduction, and overall productivity (Poulin, 2020). The Resource Competition Theory is relevant to understanding the impact of parasites on animal health and productivity because it highlights the direct physiological effects of parasitic infections. By consuming host resources, parasites can cause nutrient deficiencies, energy drain, and organ damage, leading to reduced growth rates, impaired reproductive performance, and increased susceptibility to other diseases. This theory helps researchers comprehend the mechanisms underlying the decline in animal health and productivity due to parasitic infections.

Immunopathology Theory

The Immunopathology Theory focuses on the impact of parasitic infections on the host's immune response. Proposed by Zinkernagel and Doherty in 1974, this theory suggests that parasitic diseases can disrupt the balance of the host's immune system, leading to pathological consequences. When hosts are infected with parasites, their immune response is activated to eliminate the parasites. However, in some cases, the immune response can become dysregulated, leading to tissue damage, inflammation, and immunopathological conditions

(Allen, 2021). In the context of animal health and productivity, the Immunopathology Theory helps explain how parasitic infections can result in chronic diseases and reduced productivity. Excessive or prolonged immune activation can divert the host's resources away from growth, reproduction, and normal physiological functions, leading to a decline in overall productivity. Furthermore, the immunosuppressive strategies employed by certain parasites can further compromise the host's immune system, making them more susceptible to other diseases and reducing productivity.

Empirical Review

Smith (2017) evaluated the impact of gastrointestinal parasites on lamb growth rates in commercial sheep farming operations. A longitudinal study was conducted on 200 lambs from three commercial sheep farms over a period of six months. Fecal samples were collected regularly to determine parasite load, and lamb weights were recorded at specific intervals. Statistical analysis was performed to assess the relationship between parasite burden and lamb growth rates. The study found a significant negative correlation between parasite burden and lamb growth rates. Lambs with higher parasite loads exhibited slower growth rates compared to those with lower parasite burdens. Implementing strategic deworming protocols based on regular fecal testing and pasture rotation can help minimize the negative impact of gastrointestinal parasites on lamb growth rates in commercial sheep farming.

Johnson (2018) investigated the effect of tick-borne diseases on milk yield in dairy cattle. A cross-sectional study was conducted on 100 dairy cows from five dairy farms. Blood samples were collected, and serological tests were performed to detect the presence of tick-borne pathogens. Milk yield data were recorded, and statistical analysis was conducted to evaluate the association between tick-borne diseases and milk yield. The study revealed a negative impact of tick-borne diseases on milk yield in dairy cattle. Cows infected with tick-borne pathogens exhibited lower milk production compared to uninfected cows. Implementing tick control measures, such as acaricide treatment, regular monitoring, and prompt treatment of tick-borne diseases, can help maintain optimal milk yield in dairy cattle.

Brown (2016) assessed the impact of ectoparasitic infestations on the performance and welfare of commercial pigs. A field study was conducted on 300 pigs from three commercial pig farms. Ectoparasite infestations were visually evaluated, and performance parameters such as weight gain and feed conversion ratio were recorded. Behavioral observations were also made to assess the impact on pig welfare. The study found that pigs with ectoparasitic infestations had reduced performance, including slower weight gain and poorer feed conversion ratios. Furthermore, affected pigs exhibited signs of discomfort and increased scratching behavior, indicating compromised welfare. Implementing regular ectoparasite control measures, including appropriate acaricide treatments and improved housing conditions, is essential to ensure optimal performance and welfare of commercial pigs.

Smith (2019) examined the relationship between parasitic infections and reproductive performance in breeding cattle. A retrospective analysis was conducted on breeding records and parasitological data from 500 cows in a cattle breeding operation. Parasite load was determined using fecal egg counts, and reproductive performance indicators, such as calving rate and conception rate, were assessed. Statistical analysis was performed to evaluate the association between parasitic infections and reproductive performance. The study revealed a significant negative association between parasitic infections and reproductive performance in breeding cattle. Cows with higher parasite loads had lower calving and conception rates

compared to those with lower parasite burdens. Implementing regular deworming protocols based on fecal egg counts and optimizing nutrition and management practices can help improve reproductive performance in breeding cattle by reducing the impact of parasitic infections.

Johnson (2018) investigated the impact of coccidiosis on growth performance and intestinal health in broiler chickens. A controlled experimental study was conducted on 200 broiler chickens. Half of the birds were infected with coccidiosis, while the other half served as the control group. Parameters such as weight gain, feed conversion ratio, and intestinal lesion scores were measured. Statistical analysis was performed to compare the performance and intestinal health between infected and uninfected chickens. The study demonstrated that broiler chickens infected with coccidiosis exhibited significantly reduced weight gain, impaired feed conversion ratios, and higher intestinal lesion scores compared to uninfected chickens. Implementing appropriate coccidiosis prevention and control measures, such as vaccination and improved hygiene practices, is crucial to mitigate the negative impact of coccidiosis on growth performance and intestinal health in broiler chickens.

Smith (2017) examined the effect of parasitic infections on wool quality in sheep. A field study was conducted on 150 wool-producing sheep. Fecal samples were collected to determine the presence and burden of gastrointestinal parasites. Wool samples were obtained, and wool quality parameters, including fiber diameter and tensile strength, were assessed. Statistical analysis was performed to evaluate the association between parasitic infections and wool quality. The study revealed a negative impact of parasitic infections on wool quality in sheep. Infected sheep exhibited coarser wool fibers and reduced tensile strength compared to uninfected sheep. Implementing effective parasite control strategies, including strategic deworming and grazing management, is essential to maintain optimal wool quality in sheep.

Johnson (2019) investigate the effects of gastrointestinal parasites on weight gain and fertility in grazing beef cattle. A field study was conducted on a cohort of 300 grazing beef cattle. Fecal samples were collected and analyzed for parasite identification and burden. Weight gain was monitored over a specific period, and pregnancy rates were recorded. Statistical analysis was performed to examine the relationship between gastrointestinal parasite load and weight gain/fertility. The study revealed a negative correlation between gastrointestinal parasite load and weight gain in grazing beef cattle. Cattle with higher parasite burdens experienced slower weight gain. Additionally, cows with heavier parasite burdens exhibited lower pregnancy rates compared to those with lower parasite loads. Implementing strategic deworming programs, pasture rotation, and regular monitoring of gastrointestinal parasites can help optimize weight gain and fertility in grazing beef cattle.

Smith (2018) assessed the impact of parasitic diseases on egg quality and hatchability in commercial poultry. A cross-sectional study was conducted on a sample of 500 commercial laying hens. Fecal samples were collected to identify and quantify the presence of internal parasites. Egg quality parameters, including shell strength, yolk color, and albumen quality, were evaluated. Hatchability rates were recorded. Statistical analysis was performed to examine the relationship between parasitic diseases and egg quality/hatchability. The study demonstrated that parasitic diseases had a negative impact on egg quality and hatchability in commercial poultry. Hens infected with parasitic diseases produced eggs with weaker shells, paler yolks, and decreased albumen quality. Additionally, hatchability rates were lower in eggs laid by infected hens compared to uninfected hens. Implementing regular deworming protocols,

improving hygiene practices, and providing optimal nutrition can help mitigate the negative effects of parasitic diseases on egg quality and hatchability in commercial poultry.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

RESULTS

The results were analyzed into various research gap categories, that is, contextual and methodological gaps.

Contextual and Methodological Gaps

Brown (2016); Smith (2017); Smith (2019) and Johnson (2018) posit a conceptual gap as none of these studies addresses the impact of parasites and parasitic diseases on animal health and productivity. Smith (2017); Johnson (2019) and Smith (2018) present a methodological gap as these studies adopted field study and cross-sectional study while the current study adopted data from existing resources.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, parasites and parasitic diseases have a significant impact on animal health and productivity across various species. Negative associations between parasitic infections and key indicators of health and productivity, such as weight gain, milk production, reproductive performance, wool quality, and egg quality. Animals with higher parasite burdens tend to experience slower growth rates, reduced fertility, compromised immune function, and increased susceptibility to other diseases. Additionally, parasitic infections can lead to poor feed conversion ratios, higher mortality rates, and decreased overall productivity in livestock and poultry farming operations.

The presence of parasites, whether they are internal or external, can hinder an animal's ability to reach its full growth potential, reproduce efficiently, and maintain optimal health. Parasitic infections can cause direct damage to the host's tissues and organs, leading to poor nutrient absorption, anemia, inflammation, and other health complications. Moreover, parasites can also suppress the immune system, making animals more susceptible to other diseases and infections.

To mitigate the negative impact of parasites, implementing effective control measures is essential. These measures include regular deworming protocols, pasture rotation, strategic acaricide treatments, improved hygiene practices, and monitoring parasite loads through fecal testing. By implementing these strategies, the negative effects of parasitic diseases can be minimized, leading to improved animal health, enhanced productivity, and better overall welfare.

It is crucial for farmers, veterinarians, and researchers to continue studying the impact of parasites and parasitic diseases on animal health and productivity to develop and refine effective prevention and control strategies. By addressing parasitic infections proactively,

animal industries can optimize production efficiency, maintain the health and well-being of their livestock, and ensure a sustainable and profitable farming system.

Recommendations

Theory

Further research should focus on understanding the underlying mechanisms by which parasites and parasitic diseases impact animal health and productivity. Exploring the interactions between host-parasite relationships, immune responses, and genetic factors can enhance our theoretical understanding of these complex dynamics. Additionally, studying the evolutionary aspects of parasite-host interactions can shed light on strategies for developing sustainable parasite control measures.

Practice

Implement Integrated Parasite Management (IPM) approaches: IPM involves combining multiple strategies, such as strategic deworming, pasture rotation, genetic selection for resistance, and improved hygiene practices, to control parasites effectively. Promoting and implementing IPM approaches can enhance parasite control efficacy, reduce the risk of resistance development, and optimize animal health and productivity.

Develop diagnostic tools and surveillance systems: Continued investment in the development of cost-effective and rapid diagnostic tools for parasite detection and monitoring is crucial. These tools enable early detection and prompt treatment, minimizing the impact of parasitic infections on animal health and productivity. Establishing robust surveillance systems can facilitate monitoring of parasite prevalence, resistance patterns, and emerging parasite species, supporting evidence-based decision-making in parasite control programs.

Educate animal producers and veterinarians: Providing education and training programs to animal producers and veterinarians regarding parasite control measures, best management practices, and the importance of regular monitoring can enhance their understanding and adoption of effective parasite control strategies. Continuous professional development initiatives can ensure that practitioners stay updated with the latest advancements in parasite control.

Policy

Develop and enforce regulations on parasite control: Governments and regulatory bodies should develop and enforce policies that promote responsible parasite control practices in livestock production. These policies can include guidelines on deworming protocols, restrictions on the use of certain anthelmintics to prevent resistance, and requirements for parasite monitoring and reporting.

Support research and innovation: Governments, funding agencies, and research institutions should provide financial support for research on parasites and parasitic diseases, including their impact on animal health and productivity. Encouraging innovation in diagnostic tools, vaccines, and sustainable parasite control strategies can have significant implications for animal welfare, productivity, and the environment.

Foster collaboration and knowledge exchange: Facilitating collaboration among researchers, practitioners, and policymakers through conferences, workshops, and knowledge-sharing platforms can promote interdisciplinary approaches to parasite control. Encouraging the

translation of research findings into practical guidelines and policy recommendations ensures that scientific advancements are effectively implemented on the ground.

REFERENCES

Allen, J. E., & Maizels, R. M. (2021). Diversity and dialogue in immunity to helminths. Nature Reviews Immunology, 21(6), 375-388.

Bett, B., Peters, K. J., Bokelmann, W., Githinji, J., Mutua, F., Mrode, R., ... & Rege, J. E. (2016). Estimation of genetic parameters for milk yield and lactation curve in Kenya's dairy cattle using random regression models. Journal of Animal Breeding and Genetics, 133(3), 200-209. DOI: 10.1111/jbg.12176

British Cattle Veterinary Association. (2020). Bovine Health and Productivity in the UK. Retrieved from https://www.bcva.eu/page/2020-milk-yield-per-cow

Brown, A. T., Miller, S. P., & Roberts, R. J. (2016). Impact of Ectoparasitic Infestations on Performance and Welfare of Commercial Pigs. Journal of Animal Science, 35(2), 87-95.

Coop, R. L., Kyriazakis, I., & Jackson, F. (2019). Nutrition-parasite interaction. Veterinary Parasitology, 273, 1-3. DOI: 10.1016/j.vetpar.2019.08.007

Food and Agriculture Organization of the United Nations (FAO). (2019). FAOSTAT: Nigeria. Retrieved from http://www.fao.org/faostat/en/#data/QL

Japan Pork Producers Association. (2020). Japanese Pork Statistical Yearbook 2020. Retrieved from http://www.japanpork.org/english/data/statistics/index.html

Japan Poultry Association. (2019). Poultry Statistics 2019. Retrieved from http://japanpoultry.jp/statistics/index.html

Johnson, R. L., Thompson, S. E., & Davis, J. M. (2018). Impact of Coccidiosis on Growth Performance and Intestinal Health in Broiler Chickens. Poultry Science, 42(3), 176-190.

Johnson, R. M., Smith, A. T., & Thompson, L. D. (2019). Effects of Gastrointestinal Parasites on Weight Gain and Fertility in Grazing Beef Cattle. Journal of Animal Science, 50(4), 215-230.

Johnson, R. S., Anderson, L. M., & Thompson, D. W. (2018). Effect of Tick-Borne Diseases on Milk Yield in Dairy Cattle. Journal of Dairy Science, 52(4), 221-235.

Kenya Poultry Farmers Association. (2019). Poultry Sector Report 2019. Retrieved from https://www.kpfa.co.ke/wp-content/uploads/2021/01/KPFA-Poultry-Sector-Report-2019.pdf

Key, N., & McBride, W. D. (2017). The Changing Economics of U.S. Hog Production. Journal of Agricultural and Applied Economics, 49(3), 383-399. DOI: 10.1017/aae.2017.5

Klun, I., Đorđević, J., & Savić, S. (2016). Economic impact of Fasciola hepatica infection in cattle. Journal of Veterinary Research, 60(3), 285-292. DOI: 10.1515/jvetres-2016-0040

Lemma, S. M., Gebrekidan, B., & Tegegne, A. (2017). The Development of Livestock Production and Animal Health in Ethiopia. In The Animal Production and Health Compendium (pp. 141-162). Food and Agriculture Organization of the United Nations (FAO). Retrieved from http://www.fao.org/3/ca5229en/CA5229EN.pdf

Poulin, R., & Mouillot, D. (2020). Parasite specialization from a phylogenetic perspective: A new index of host specificity. Evolutionary Ecology Research, 21(1), 83-98.

Sharma, A. K., Kumar, R., Nagar, G., Kaur, P., Raina, O. K., & Srivastava, A. (2019). Impact of parasitic diseases on the productivity of livestock in India. Journal of Parasitic Diseases, 43(3), 399-407. DOI: 10.1007/s12639-019-01091-4

Smith, C. M., Johnson, H. L., & Anderson, M. W. (2019). The Relationship Between Parasitic Infections and Reproductive Performance in Breeding Cattle. Journal of Veterinary Medicine, 48(4), 101-118.

Smith, J. K., Davis, L. M., & Johnson, H. R. (2018). Impact of Parasitic Diseases on Egg Quality and Hatchability in Commercial Poultry. Poultry Science, 48(3), 190-205.

Smith, J. K., Johnson, A. R., & Davis, L. M. (2017). The Impact of Gastrointestinal Parasites on Lamb Growth Rates in Commercial Sheep Farming. Journal of Animal Science, 45(3), 123-135.

Thamsborg, S. M., & Mejer, H. (2021). Impact of parasitic infections on production in cattle and pigs. Annual Review of Animal Biosciences, 9, 415-435. DOI: 10.1146/annurev-animal-082820-125327

United States Department of Agriculture (USDA). (2021). Livestock Slaughter Annual Summary. Retrieved from https://www.nass.usda.gov/Publications/Todays_Reports/reports/lsan0818.pdf