TRANSFORMING ANIMAL AGRICULTURE:

CULTURAL VALUES, SUSTAINABLE SYSTEMS, AND ECOLOGICAL SOLUTIONS

ISBN: 978-625-92209-8

TRANSFORMING ANIMAL AGRICULTURE: CULTURAL VALUES, SUSTAINABLE SYSTEMS, AND ECOLOGICAL SOLUTIONS- 2026

ISBN: 978-625-92209-8

DOI: 10.5281/zenodo.20138590

May / 2026

Ankara / Türkiye

(The Licence Number of Publicator: 2014/31220)

E mail: info@ispecbooks.com

www.ispecbooks.com

It is responsibility of the author to abide by the publishing ethics rules.

ISPEC Publishing House – 2026©

ISBN: 978-625-92209-8

May / 2026

Ankara / Türkiye

TRANSFORMING ANIMAL AGRICULTURE: CULTURAL VALUES, SUSTAINABLE SYSTEMS, AND ECOLOGICAL SOLUTIONS

AUTHORS
Kibrat Masalon BARAHAMA
Muhammad ATHIF
Ainun ROIFA
Stephen Nnaemeka OKEY
Ogochukwu Nwamaka OKEY

TABLE OF CONTENTS

PREFACE.....i

CHAPTER 1
IMPLEMENTATION OF ISLAMIC DEVELOPMENT ECONOMIC PRINCIPLES IN VETERINARY PRACTICE IN THE HALAL LIVESTOCK INDUSTRY
Kibrat Masalon BARAHAMA 1

CHAPTER 2
OPTIMIZING SHARIA-BASED MAQASHID VETERINARY SERVICES ON DAIRY FARMS: EFFORTS TO IMPROVE FOOD SECURITY AND ENHANCE THE WELFARE OF LOCAL FARMERS
Muhammad ATHIF
Ainun ROIFA.....20

CHAPTER 3
THE USE OF ACTIVATED CHARCOAL (BIOCHAR) IN THE MITIGATION OF GREENHOUSE GASES AND MANAGEMENT OF ODOUR EMISSIONS IN POULTRY AND LIVESTOCK FARMS: A REVIEW
Stephen Nnaemeka OKEY
Ogochukwu Nwamaka OKEY 39

PREFACE

The sustainability of livestock production systems has become an increasingly important concern in the context of global food security, environmental responsibility, and ethical agricultural practices. Contemporary veterinary and animal production systems are now expected to address not only productivity and economic efficiency, but also social welfare, ecological sustainability, and culturally informed management approaches.

The chapters in this volume explore these multidimensional aspects of livestock systems from interdisciplinary perspectives. The discussion on Islamic economic principles in veterinary practice highlights the integration of ethical and value-based frameworks within halal livestock industries. The examination of Sharia-based veterinary services for dairy farming emphasizes the relationship between animal welfare, farmer wellbeing, and sustainable food production. In addition, the evaluation of biochar applications in poultry and livestock farms demonstrates innovative environmental management strategies aimed at reducing greenhouse gas emissions and improving farm sustainability.

By integrating perspectives from veterinary sciences, livestock management, environmental sustainability, and ethical agricultural systems, this volume contributes to ongoing academic discussions surrounding responsible and adaptive animal production practices. It also offers practical insights for researchers, veterinarians, policymakers, and agricultural practitioners engaged in sustainable livestock development.

It is hoped that this book will serve as a valuable resource for scholars and professionals interested in veterinary systems, ethical livestock management, and sustainable agricultural practices, while encouraging further interdisciplinary research in these evolving fields.

Editorial Team
May, 2026
Türkiye

CHAPTER 1
IMPLEMENTATION OF ISLAMIC DEVELOPMENT ECONOMIC PRINCIPLES IN VETERINARY PRACTICE IN THE HALAL LIVESTOCK INDUSTRY

[1]Kibrat Masalon BARAHAMA

[1]Universitas Islam Negeri K.H. Abdurrahman Wahid Pekalongan, Indonesia, kibratbarahama13@gmail.com, ORCID ID: 0009-0006-8926-71836

INTRODUCTION

The halal livestock industry is a strategic sector of the global and national economy because it not only provides a safe and healthy source of animal protein but also meets the spiritual and Sharia needs of Muslims. In recent decades, demand for halal products has increased significantly worldwide, driven by the growth of the Muslim population and greater consumer awareness of food safety, health, and ethical values in animal consumption. This growth creates significant economic opportunities for producing countries, including Indonesia, Malaysia, and the Philippines, which have large Muslim populations. However, the success of this industry depends heavily on veterinary practices that ensure every animal raised and processed meets halal, healthy, and sustainable standards. Veterinary practice is not only a technical affair of animal health, but also ethical and Sharia, because every stage of production must comply with halal principles, from maintenance, feed, the environment, to the slaughter of animals. Therefore, integrating Islamic development economic principles into veterinary practices is crucial to creating a sustainable, fair, and productive halal livestock industry. (Farouk & Pufpaff, 2010) (Al-Qaradawi, 2007).

Islamic development economics emphasizes balanced development between material and spiritual aspects. In this perspective, economic growth is not measured solely by increases in Gross Domestic Product or financial income, but also by improvements in society's overall quality of life, including equitable distribution of welfare, social justice, and environmental conservation. This differs from conventional economic approaches that often emphasize financial efficiency at the expense of moral or Sharia values. In the context of the halal livestock industry, this principle requires that every aspect of production, from animal husbandry to product distribution, be carried out fairly, transparently, and in accordance with Sharia. In addition, this principle emphasizes that economic profits should be shared equally, so that small and medium-sized farmers benefit proportionately from industry growth, rather than large companies or traders who control the supply chain. Thus, Islamic development economics serves as a moral and ethical framework that guides the practice of the halal industry to be not only financially profitable, but also socially beneficial. (Chapra, 2000)(Mawardi & Insani, 2025).

Veterinary practices in the halal livestock industry play a central role in ensuring the quality and safety of animal products. Veterinarians are not only responsible for animal health. However, they must also ensure that the entire production process complies with halal principles, including animal husbandry, disease prevention and treatment, the selection of halal and healthy feed, and slaughter techniques that minimize animal suffering. Thus, the role of a veterinarian is not only technical, but also ethical and Sharia. This is in line with the concept of maqasid al-shariah, which emphasizes the preservation of life (hifz al-nafs), reason (hifz al-'aql), property (hifz al-mal), heredity (hifz al-nasl), and religion (hifz al-din). The application of this principle in veterinary practice enables the halal livestock industry to produce products that are safe, high-quality, and in accordance with Sharia, while supporting community welfare and social justice. (Farouk & Pufpaff, 2010) (Kamali, 2008).

The halal livestock industry has a dual role in the development of the Islamic economy. First, this sector drives economic growth through job creation, increased production, and the export of high-value halal products to the global market. Second, this sector serves as a social instrument to ensure the welfare of the community, especially small farmers, and to protect animal rights. With proper veterinary practices, halal farming not only produces healthy and edible animals but also promotes a fair distribution of profits throughout the supply chain. Sustainable growth can only be achieved if veterinary practices are integrated with sharia principles and international animal health standards, so that the industry can compete globally without sacrificing moral, ethical, and environmental sustainability values. (Mawardi & Insani, 2025).

Veterinary practice encompasses a range of activities, from maintaining animal health and preventing and treating disease to supervising the slaughter of animals in accordance with halal law. Animal welfare is a major focus, encompassing a decent living environment, healthy feed, and slaughter techniques that reduce animal suffering. Veterinary acts as a link between Sharia principles and industrial practices, so that each stage of production reflects fairness, transparency, and compliance with Islamic law.

In addition, the veterinary sector plays a strategic role in ensuring that international standards set by the World Organization for Animal Health (OIE) are applied alongside halal principles, so that halal products from producing countries can be accepted globally. (Farouk & Pufpaff, 2010).

The principles of justice (al-'adl) and balance (al-tawazun) in Islamic development economics emphasize the fair and proportionate distribution of profits throughout the halal industry supply chain. Veterinary plays an important role in ensuring quality and compliance with halal standards, which directly impacts the market value of products and the welfare of small and medium farmers. Implementing proper maintenance and cutting procedures increases consumer confidence in halal products and encourages transparency and ethical business practices. Thus, the halal livestock industry not only generates economic benefits but also contributes to social development and justice. (Chapra, 2000).

Another important aspect of the principle of Islamic development. Veterinary practices must address the environmental impacts of livestock activities, including waste management, water use, and the preservation of local ecosystems. The concept of maslahah in Islamic fiqh emphasizes protecting the public interest and preventing harm, which is relevant to the planning and management of halal farming. Veterinarians serve as consultants to ensure environmentally friendly, healthy, and halal production practices, so that the goals of Islamic economic development are achieved comprehensively, not only in terms of financial benefits but also in community welfare and environmental sustainability. (Kamali, 2008).

In the Philippines, especially in Mindanao, the halal livestock industry is experiencing rapid growth as demand for local and export halal products increases. However, the sector faces challenges related to sharia-compliant veterinary practices, low farmers' understanding of halal standards, and a lack of regulations that support sharia compliance. Therefore, implementing the economic principles of Islamic development through veterinary practices is crucial to ensure that industrial growth is not only economic but also ethical, fair, and beneficial to all parties, from farmers to end consumers.

Education and training for veterinarians in halal principles, animal welfare, and Islamic development economics are important instruments to overcome these constraints and build sustainable local capacity.(Mawardi & Insani, 2025).

Veterinary practices integrated with Islamic development economic principles enable the halal livestock industry to produce safe, halal, high-quality, and sustainable products. With the simultaneous application of maqasid al-shariah principles, technological innovation, international standards, and sharia compliance, the industry not only meets the demands of the global market but also builds consumer trust, improves economic welfare, and ensures fair and sustainable growth (Al-Qaradawi, 2007; Chapra, 2000; Farouk & Pufpaff, 2010; Mawardi & Insani, 2025). Thus, the study on the implementation of Islamic development economic principles in veterinary practices within the halal livestock industry is highly relevant to ensure productive, ethical practices in line with Islamic values.

1. APPLICATION OF SHARIA PRINCIPLES IN HALAL LIVESTOCK MANAGEMENT

The application of sharia principles in the management of halal livestock is not only a religious guide but also a business strategy that supports sustainability, productivity, and industry reputation. Islamic economic principles emphasize a balance between worldly and ukhrawi goals, so that every management decision must consider financial benefits, morality, social justice, and environmental preservation. In practice, the application of this principle covers the entire production cycle, from animal selection and feed to maintenance, slaughter, distribution, and quality management, so that every product produced can be accounted for in accordance with Sharia and professionally. This approach creates a harmonious, ethical, and efficient industrial ecosystem while increasing market competitiveness. (Chapra, 2000).

The selection of livestock is a crucial initial stage in halal management. The animals used must be healthy, disease-free, not defective, and obtained from a sharia-lawed source. This selection not only emphasizes physical quality but also ensures that the animals are sourced from suppliers that adhere to halal principles.

Veterinarians play an important role in this process by conducting thorough health checks, quarantining new animals, and ensuring that animals do not experience stress or conditions that can cause suffering. Strict standard operating procedures (SOPs) and complete documentation are management tools to ensure compliance with Sharia principles. For example, some modern farms use a barcode system for each animal to record health history, feed, and vaccinations digitally, making monitoring more efficient and accurate. (Farouk & Pufpaff, 2010).

The feeding stage must also comply with Sharia principles. The feed used must be sourced from halal ingredients, free of haram ingredients, and free of any ingredients that could harm animal health. The feed supply chain monitoring system includes supplier verification, feed quality audits, and distribution monitoring to the cage. In modern practice, some farms have used smart feeding system technology that automatically adjusts the amount and quality of feed to the animals' condition, ensuring optimal animal growth and minimal risk of human error. The application of sharia principles at this stage not only ensures the halal status of products but also enhances the productivity and quality of meat and other livestock products.(Mawardi & Insani, 2025).

Cage management and animal welfare are the main concerns in halal farming practices. Islam emphasizes that animals are creatures created by Allah who have the right to be treated well. Animal welfare practices include providing a clean environment, adequate ventilation, adequate space for movement, timely provision of water and feed, and routine health maintenance. Practices that cause stress or suffering, such as intensive maintenance or abuse, should be avoided. Some modern farms also use sensors and cameras to monitor animal behavior, so management can immediately identify signs of stress or disease. This approach is not only sharia-compliant but also directly impacts product quality and value, extending shelf life and increasing consumer confidence. (Farouk & Pufpaff, 2010).

The slaughter procedure is the most crucial stage in ensuring the product's halal status. Cutting must be carried out by trained personnel according to Islamic law, namely calling the name of Allah, using sharp tools to make the process fast, and ensuring that the blood comes out perfectly.

Modern halal slaughter practices implement complete SOPs, regular training for cutters, and periodic internal audits. Technology is also used to ensure efficiency and accuracy, for example, by using mechanical cutting tools with sensors to minimize human error. With proper procedures, meat quality is improved, non-halal risks are minimized, and management can account for the entire production process to consumers and halal auditors. (Al-Qaradawi, 2007).

Transparency and documentation are key in halal livestock management. Islamic economic principles emphasize justice, accountability, and responsibility. All livestock activities, from maintenance, feeding, slaughtering, to distribution, must be recorded and documented. This system facilitates internal and external audits, minimizes the risk of non-compliance, and increases consumer trust. For example, cloud-based livestock management software enables farmers to record data in real time, monitor animal health, and generate audit-ready reports. This transparency also supports international halal certification, opens up export opportunities, and enhances the industry's reputation. (Chapra, 2000).

Risk management is also an integral part of applying Sharia principles. The livestock industry faces biological, economic, and operational risks. Biological risks include animal diseases, while economic risks include fluctuations in feed prices and operational costs. Operational risks can arise from human negligence or distribution disruptions. The sharia-based risk management system includes biological mitigation through vaccination and quarantine, economic mitigation through halal financial planning, and operational mitigation through strict SOPs and human resource training. Effective risk management not only maintains business continuity but is also aligned with the principles of justice and social responsibility. (Farouk & Pufpaff, 2010).

Human resource development is an important strategy in halal livestock management. Halal farming requires a competent workforce that understands sharia principles and can operate modern technology. Regular training on animal welfare, business ethics, slaughter procedures, and documentation is part of the management strategy. Trained human resources improve efficiency, reduce errors, and maintain product quality.

Workers' motivation and loyalty also increase when they understand that the ultimate goal of the entire production process is kindness, justice, and compliance with Sharia. (Al-Qaradawi, 2007).

The aspect of environmental sustainability also received serious attention. Islam teaches humans to be caliphs on earth, so the practice of animal husbandry must consider the preservation of natural resources. Waste management, the use of environmentally friendly energy, the treatment of livestock manure for fertilizer, and habitat protection are the main strategies. Sustainable halal farming not only meets sharia guidelines but also attracts consumers who care about the environment, improves the industry's image, and maintains long-term business sustainability. The integration of this sustainability principle is a concrete example of the application of modern Islamic economics, which prioritizes human and environmental welfare. (Chapra, 2000).

The application of Sharia principles also has a significant impact on the global market. Halal products that meet sharia standards are highly competitive in countries with large Muslim populations and in international markets that demand halal certification. Transparent management, complete documentation, and compliance with halal principles are attractive added values for global consumers. In addition, the application of sharia principles supports local economic growth by creating jobs, strengthening supply chains, and improving production quality. Thus, applying sharia principles not only fulfills religious obligations but also serves as a sustainable business strategy that increases profits and reputation.(Mawardi & Insani, 2025).

The application of sharia principles in halal livestock management covers all aspects of production, from animal selection, feed, maintenance, slaughter, documentation, risk management, human resource development, and environmental sustainability. This practice not only aligns with religious guidance but also enhances professionalism, transparency, efficiency, sustainability, and market competitiveness. The integration of Islamic economic principles shows that sharia compliance and economic growth reinforce each other. With consistent, innovative implementation, the halal livestock industry can serve as an example of ethical, sustainable, and environmentally friendly economic development. (Farouk & Pufpaff, 2010).

2. THE ROLE OF VETERINARY PRACTICES IN ENSURING THE HEALTH AND HALAL OF PRODUCTS

The application of Islamic development economics principles in the halal livestock industry is an important foundation for ensuring business sustainability. Islamic economics emphasizes a balance between economic growth, equitable distribution of people's welfare, social justice, and ecological responsibility. In the context of halal farming, this principle regulates the entire production process from capital, operational management, resource management, to product distribution, to be in line with Sharia and sustainable economic development goals. The application of this principle is not only normative but also practical, as it directs every step of management to create an efficient, productive, ethical, and competitive industry in the global market. (Chapra, 2000).

One of the main principles of Islamic development economics is justice and equal distribution of welfare. In the halal livestock industry, this is implemented through a fair share of profits between business owners, workers, suppliers, and the surrounding community. Farms that pay attention to the welfare of workers through living wages, health facilities, and human resource training not only comply with sharia principles but also increase employee productivity and loyalty. In addition, empowering the surrounding community, for example, through partnerships to provide feed or process livestock waste into fertilizer, is a tangible form of social responsibility that aligns with the concept of Islamic economics, which emphasizes collective welfare.(Mawardi & Insani, 2025).

Another principle is the efficient management of capital and resources. In Islamic economics, capital should not be used extravagantly or speculatively to the detriment of others. Halal farms that apply this principle will manage capital for productive investments, such as cage construction, animal purchases, quality feed, and technology development. The use of natural resources, including water, land, and energy, is carried out efficiently and responsibly. For example, livestock waste is processed into organic fertilizer or biogas, thus not only reducing pollution but also adding additional economic value to the farm. This approach ensures long-term business continuity while maintaining environmental sustainability. (Chapra, 2000).

Efficiency and productivity are the next focus. Islamic economics encourages the efficient use of resources to produce maximum value while upholding the principles of justice and welfare. In halal farming practices, this means that every element of production—animals, feed, labor, and technology—is managed to produce maximum output with minimal inputs. Modern technologies, such as digital monitoring, automated feeding systems, and veterinarians' early disease detection, help increase efficiency, minimize losses, and ensure product quality in accordance with halal standards. This efficiency not only supports economic sustainability but also ensures Sharia compliance and consistent product quality (Farouk & Pufpaff, 2010).

Innovation and technology are important for applying Islamic development economic principles to sustain the halal livestock industry. The integration of technology in animal health management, cage maintenance, slaughter, and distribution helps reduce the risk of human error, increase productivity, and ensure Sharia compliance. For example, the use of sensors to monitor animal behavior enables early detection of stress or disease, enabling timely interventions. Software-based management systems help record data on health, feed, and slaughter procedures, supporting halal audits and certifications. This innovation aligns with Islamic principles that encourage efficiency, social responsibility, and the use of technology for the good of humanity. (Chapra, 2000).

Risk management is a crucial component in the sustainability of the halal industry. Farms face biological, economic, and operational risks that can threaten animal health and product quality. The application of Islamic economic principles emphasizes the need for fair and responsible risk mitigation. Veterinarians play a role in preventing biological risks through vaccinations, quarantines, and routine health surveillance. Economic risks, such as fluctuations in feed prices or operational costs, can be managed through Islamic financial planning and transparent supplier contracts. Operational risks are minimized through strict SOPs, HR training, and technology monitoring. Effective risk management reflects the principles of justice and social responsibility in Islamic economics.(Mawardi & Insani, 2025). The environment is an important aspect that cannot be separated from the economic principles of Islamic development.

Islam emphasizes humans as caliphs on earth, so every economic activity must consider ecological impacts. In halal farming, environmentally friendly practices include livestock waste management, the use of renewable energy, maintenance of soil and water quality, and pollution reduction. For example, livestock manure is processed into biogas or organic fertilizer, while water and feed use are adjusted to the animals' actual needs. This practice not only supports environmental sustainability but also improves the industry's image and the attractiveness of halal products in the global market. (Chapra, 2000).

(Al-Qaradawi, 2007) Human resource development (HR) is also an integral part of the application of Islamic development economic principles. Human resources who are competent, trained, and understand Sharia principles can manage livestock efficiently, professionally, and ethically. Regular training on animal welfare, modern technology, slaughter procedures, and Islamic economic principles helps workers improve skills and productivity. Increasing the capacity of the human resources supports business sustainability because a trained workforce can address operational challenges, adapt to new technologies, and ensure that every aspect of production remains sharia-compliant.

(Mawardi & Insani, 2025) The impact of applying Islamic development economic principles on local and global markets is significant. Halal livestock products produced with sustainable, ethical, and Sharia-compliant practices are highly competitive. Local consumers receive quality assurance and halal certification, while the international market is open to exports. Transparency, documentation, and halal certification are added values that enhance the company's reputation. In addition, adherence to Islamic economic principles supports local economic development by creating jobs, strengthening supply chains, and improving the welfare of the surrounding community. Thus, the economic principles of Islamic development become a sustainable strategy that integrates economic, social, and environmental goals.

The application of Islamic development economic principles in the halal livestock industry includes capital and resource management, efficiency and productivity, innovation and technology, risk management, environmental sustainability, human resource development, and market impact.

This principle ensures that the industry not only generates financial gains but also meets social and moral goals in accordance with Sharia guidelines. The integration of Islamic economic principles with modern livestock practices results in a sustainable, ethical, and competitive system that safeguards the welfare of animals, workers, and the wider community. The sustainability of the halal industry, grounded in this principle, is a concrete example of how the sharia economy can be practically applied to build a resilient, ethical, and future-oriented industry.(Mawardi & Insani, 2025).

3. RISK MANAGEMENT STRATEGIES IN HALAL FARMING BASED ON ISLAMIC ECONOMICS

The halal livestock industry is a strategic sector of the global economy because it focuses not only on financial benefits but also on compliance with sharia principles and the welfare of the community as a whole. From an Islamic economic perspective, every economic activity must always uphold the principles of justice, equity, and environmental sustainability, ensuring that economic growth is not only material but also ethical. In practice, halal farming faces various challenges related to production factors, animal health, feed quality, distribution, and market fluctuations. Therefore, risk management cannot be ignored, as unmanaged risks can cause financial, reputational, and broader social impacts. Risk management in the halal livestock industry based on Islamic economics is not only about mitigating financial risks but also about integrating sharia values into every decision-making process. This concept emphasizes a balance between worldly gain and adherence to halal-haram principles, where tolerated risks must always align with sharia principles and Islamic business ethics. Within this framework, risk management strategies should include comprehensive risk identification, impact assessment, and the implementation of effective and sustainable mitigation measures. Halal farming practitioners need to understand that risks are not only external, such as market price fluctuations or natural disasters, but also internal risks, including operational errors, animal health, and non-compliance with halal standards. With this understanding, risk management strategies can be designed proactively in line with Islamic economic principles that emphasize sustainability, justice, and the well-being of society as a whole (Chapra, 2000).

Risks in halal farming can be grouped into several main categories, each with a different impact on business sustainability. The first is production risk, which includes feed quality, animal genetics, and livestock productivity. In the context of Islamic economics, production is assessed not only quantitatively but also against halal and animal welfare standards. For example, the use of feed containing haram ingredients or breeding practices that hurt animals can pose legal and reputational risks, in addition to impacting the quality of the final product. The second is the health risks to animals, including infectious diseases, suboptimal environmental conditions, and nutritional deficiencies. This risk can interfere with production continuity and incur additional costs for treatment and prevention. The third is market and price risk, arising from fluctuations in the prices of meat, milk, or derivative products in domestic and international markets. Changes in demand and supply can lead to income instability for farmers.

The fourth is financial risk, which is related to business liquidity, capital investment, and sharia financing. In the framework of Islamic economics, financial risk is also related to the principle of profit sharing (mudharabah) or other forms of sharia financing, which emphasize transparency, justice, and shared responsibility. Fifth, regulatory and compliance risks arising from changes in government regulations or international halal standards require business actors to continually update their operational procedures to remain in compliance with Sharia and applicable laws. Systematic risk classification helps halal farmers develop a structured risk management strategy in line with Islamic economic principles (Al-Qaradawi, 2007).

From an Islamic economic perspective, the principle of risk management emphasizes tawazun, or a balance between profit opportunities and potential losses, while maintaining sharia ethics and compliance. In contrast to conventional approaches that tend to focus only on financial aspects, Islamic economics-based risk management also considers the social, moral, and environmental impacts of every business decision. This principle is reflected in the concept of maslahah, which aims to achieve benefits for the wider community while avoiding mafsadah, or harms that can cause injustice.

In the context of halal farming, this means that any risk mitigation strategy must consider animal welfare, product halalness, and compliance with sharia standards, while maintaining business profitability. For example, investing in modern technology to monitor livestock health and feed quality not only reduces the risk of disease-related losses but also ensures that livestock rearing practices meet halal and ethical principles. This approach, based on Islamic economics, encourages farmers to view risk holistically, integrating economic, social, and moral goals into every operational policy. Thus, risk management is not only a protective tool, but also a means of increasing business added value and business reputation sustainably (Chapra, 2000; Farouk & Pufpaff, 2010).

One key strategy in production risk management is the application of precision farming technologies and practices to improve the efficiency and quality of livestock products. This technology includes an automatic feed monitoring system, optimal cage temperature settings, and the use of digital devices to detect animal diseases early. This approach aligns with the principle of istiqamah in Islamic economics, which emphasizes maintaining consistency in applying halal and high-quality practices. In addition, livestock genetic management is also an important risk mitigation strategy. Selecting healthy, productive, superior seeds can improve meat or milk quality, reduce the risk of livestock deaths, and maintain production continuity. The implementation of halal standards must also be integrated at every stage of production, from feed and cage environments to slaughter procedures, to minimize the risk of non-compliance with Sharia. The integration of technology, ethical practices, and Sharia compliance not only reduces operational risks but also increases the economic and social value of the halal farming business. This aligns with the principles of Islamic economics, which emphasize a balance among profit, sharia compliance, and the welfare of society.(Mawardi & Insani, 2025) (Al-Qaradawi, 2007).

Animal health risks require special attention because they can have far-reaching impacts on production, finances, and business reputation. Health risk mitigation strategies include implementing regular vaccination programs, using digital systems for animal health monitoring, and managing hygienic cage environments.

In the framework of Islamic economics, animal welfare is part of the principle of rahmah, or compassion for living beings, and aligns with Sharia and halal business ethics. Maintenance practices that emphasize animal welfare also improve the quality of the final product and consumer confidence in the halal label. In addition, collaboration with veterinary and research institutions enables farmers to access the latest information on livestock diseases and prevention innovations, helping them proactively minimize the risk of losses. The Islamic economy-based approach emphasizes that the management of animal health is not only a technical but also a moral and social affair, in which any risk mitigation measures must safeguard the welfare of the wider community and the ecological balance. (Farouk & Pufpaff, 2010) (Chapra, 2000).

Market and price risks are always present in the halal farming industry. Changes in consumer demand, seasonal factors, or global economic conditions can cause fluctuations in the prices of livestock products. Market risk mitigation strategies include product diversification, such as processing meat into ready-to-eat preparations, milk production and its derivative products, and developing export markets to reach global consumers. This diversification is in line with the Islamic economic principles of tawazun and ikhtiar, which call for making optimal efforts to maintain business stability and sustainability. In addition, implementing sharia-based contract systems, such as muzara'ah or musyarakah, can help farmers manage risks with business partners and reduce income uncertainty. Digital marketing strategies and halal branding are also key to maintaining consumer trust, thereby minimizing reputational risks and Sharia non-compliance. By proactively managing market risks, halal farmers can maintain business sustainability while maximizing the economic and social value of the products produced (Mawardi & Insani, 2025) (Al-Qaradawi, 2007)

In the context of financial risk, Islamic economics offers sharia-compliant financing mechanisms, such as mudharabah, musyarakah, and ijarah, which emphasize the principles of profit-sharing, transparency, and shared responsibility. The implementation of sharia financing not only reduces the risk of interest-bearing debt but also encourages farmers to manage capital and investments more ethically and sustainably.

Financial risk mitigation strategies include careful financial planning, the use of sharia-compliant insurance to protect livestock assets, and flexible liquidity management to address emergencies. The integration of Islamic economic principles into financial risk management enables farmers to maintain business sustainability, minimize potential losses, and remain compliant with halal principles. In addition, periodic evaluation of financial performance, revenue projections, and sensitivity analysis to market changes are important strategies in anticipating financial risks. This approach emphasizes the principles of justice, balance, and sustainability, which are at the core of Islamic economics. (Chapra, 2000) (Farouk & Pufpaff, 2010).

In addition to internal risks, halal regulatory compliance and standards are important aspects that require specific mitigation strategies. Changes in government regulations, international halal certification standards, or export requirements may pose operational and reputational risks. The mitigation strategy includes employee training on halal standards, regular internal and external audits, and transparent documentation to ensure that each production stage complies with sharia regulations. This approach aligns with the principle of trust, a moral and ethical responsibility in running a business that emphasizes legal and Sharia compliance. The implementation of a halal-based quality management system can strengthen consumer trust, maintain business reputation, and minimize the risk of non-compliance with financial and social impacts. By consistently implementing this strategy, halal farmers can face regulatory changes and global market competition with greater confidence and sustainability. Therefore, risk management in halal farming based on Islamic economics emphasizes the integration between ethical principles, sharia compliance, sustainability, and profitability. Effective risk mitigation strategies include the application of modern technology, animal health management, market diversification, sharia financing, and compliance with halal regulations. This approach encourages farmers to think holistically, considering risks not only from a financial perspective but also from social, moral, and environmental perspectives. By adopting Islamic economic principles, risk management becomes a strategic tool for achieving business sustainability, improving product quality, and providing broader societal benefits.

The implementation of this strategy requires a high level of commitment from all stakeholders, including farmers, the government, religious institutions, and consumers, to ensure the halal livestock industry grows sustainably, fairly, and beneficially for all parties involved. In the long term, integrating risk management principles based on Islamic economics enables the halal livestock industry to become an ethical, globally competitive business model. (Al-Qaradawi, 2007) (Farouk & Pufpaff, 2010)(Chapra, 2000) (Farouk & Pufpaff, 2010) (Mawardi & Insani, 2025) (Al-Qaradawi, 2007)

CONCLUSION

The implementation of Islamic development economic principles in veterinary practice in the halal livestock industry emphasizes the balance between economic growth, sharia compliance, and community welfare. Every stage of veterinary practice, from seed selection and feeding to health monitoring and slaughter procedures, must comply with halal principles and Islamic ethics. This approach not only improves productivity and product quality but also minimizes risks associated with animal health, market fluctuations, and non-compliance with Sharia standards. The integration of modern technologies, such as livestock health monitoring systems, digital recording of feed and vaccinations, and hygienic cage management, enhances operational efficiency and product quality. In addition, halal-based veterinary practices affirm the importance of animal welfare as part of moral responsibility, an ethical foundation of Islamic economics. Thus, good veterinary practices not only support business sustainability and profitability but also build consumer trust in the safety, quality, and halal nature of livestock products.

Furthermore, the principles of Islamic development economics encourage the application of sharia-based risk management to address uncertainty in the livestock industry, across biological, financial, and market dimensions. This strategy includes diversifying livestock products, managing finances in accordance with the principle of profit-sharing, and complying with halal regulations and international standards.

This approach ensures that every business decision remains within the ethical, transparent, and fair corridor, in line with the principles of maslahah (public good) and tawazun (balance) in the Islamic economy. By applying these principles, the halal livestock industry can grow sustainably, create a positive social impact, protect animal welfare, and increase global competitiveness. All of these efforts show that the success of veterinary practices is not only measured in terms of economy, but also in moral, social, and environmental contributions, so that the halal livestock industry becomes an ethical, sustainable, and beneficial business model for all stakeholders, including farmers, consumers, and the wider community.

REFERENCES

Al-Qaradawi, Y. (2007). The Lawful and the Prohibited in Islam (Al-Halal wal Haram fil Islam). Cairo: Islamic Book Trust.

Al-Qurashi, A., & Siddiqi, R. (2018). Halal Supply Chain Management: Principles and Practices. Journal of Islamic Marketing, 9(4), 1023–1040. https://doi.org/10.1108/JIMA-03-2017-0036

Chapra, M. U. (2000). The Future of Economics: An Islamic Perspective. Leicester: The Islamic Foundation.

Esposito, J. L., & DeLong-Bas, N. J. (2001). Women in Muslim Family Law. Syracuse: Syracuse University Press.

Farouk, M. M., & Pufpaff, K. M. (2010). Halal meat production and animal welfare: A review. Meat Science, 86(2), 303–309. https://doi.org/10.1016/j.meatsci.2010.05.011

Hassan, M. K., & Lewis, M. K. (2007). Handbook of Islamic Banking. Cheltenham: Edward Elgar Publishing.

Khan, M. F. (2015). Islamic Finance and Halal Industry Development. Kuala Lumpur: IIUM Press.

Mawardi, M., & Insani, N. (2025). Islamic development economics and its implementation in the halal industry. (Article/Scientific journal).

Kamali, M. H. (2008). Shari'ah Law: An Introduction. Oxford: Oneworld Publications. https://www.perlego.com/book/950357

Rahman, F. (2002). Islam and Modernity: Transformation of an Intellectual Tradition. Chicago: University of Chicago Press.

CHAPTER 2
OPTIMIZING SHARIA-BASED MAQASHID VETERINARY SERVICES ON DAIRY FARMS: EFFORTS TO IMPROVE FOOD SECURITY AND ENHANCE THE WELFARE OF LOCAL FARMERS

[1]Muhammad ATHIF
[2]Ainun ROIFA

[1]Universitas Islam Negeri K.H. Abdurrahman Wahid Pekalongan, Indonesia, muhammad.athif@mhs.uingusdur.ac.id, ORCID ID: 0009-0000-3974-9543
[2]Universitas Islam Negeri K.H. Abdurrahman Wahid Pekalongan, Indonesia

INTRODUCTION

The global Islamic economic ecosystem is currently experiencing massive expansion, transitioning from a mere concept of sharia compliance to a major pillar in sustainable economic development. In the State of the Global Islamic Economy (SGIE) report, Indonesia consistently occupies a strategic position, ranking third globally in overall Islamic economic indicators in 2023, with the halal food and beverage sector as one of its main driving forces (DinarStandard, 2023). However, the narrative and policy of the development of the halal food industry in Indonesia often still experience structural inequality. The focus of halal industry discourse and certification rests more on the downstream sector, namely on the slaughtering process (for broiling), processing, packaging, and distribution. On the other hand, monitoring in the upstream sector, especially in livestock-level animal welfare management, still lacks comprehensive interventions (Nakyinsige et al., 2012).

In fact, the halal paradigm in Islam cannot be separated from the principle of thayyib (good, safe, and healthy). The concept of halalan thayyiban implies that the validity of an animal food product is not only determined in the slaughterhouse but also starts with how the animal is treated, given good feed, and guaranteed health during life (Al-Qaradawi, 2013). In this context, the existence and optimization of veterinary services (animal health) are absolute prerequisites inseparable from the halal industry supply chain.

Specifically, the dairy farming subsector in Indonesia presents a complex economic reality that is crucial for national food security. Milk is a strategic commodity for animal protein providers, essential to preventing stunting and improving the quality of human resources. However, data from the Central Statistics Agency indicates that domestic fresh milk production (SSDN) in 2023 will only meet around 20% to 22% of total national milk needs, while the rest remains highly dependent on imports (Central Statistics Agency [BPS], 2023). This gap between supply and demand is exacerbated by the demographic structure of dairy farmers in Indonesia, where small-scale smallholder farmers dominate more than 90% of the dairy population with an average ownership of only 2 to 4 heads per farmer (Ministry of Agriculture of the Republic of Indonesia, 2022).

These small-scale farmers face very high economic vulnerability. Dairy cattle are not just a means of production, but a biological asset and the family's main savings. When there is a shock, such as a disease outbreak, such as the Foot and Mouth Disease (FMD) epidemic that spread widely in Indonesia in 2022, the impact is highly destructive. FMD outbreaks not only cause livestock morbidity and mortality, but also drastically reduce milk production by 30-50% in various dairy farming centers on the island of Java (Prabowo et al., 2023). Livestock deaths or reduced productivity due to disease directly result in asset depletion (wealth depreciation), dragging local farmers into the abyss of structural poverty.

This is where the main problem lies: local farmers' access to quality veterinary services is still very limited. The ratio of veterinarians and veterinary paramedics to the livestock population and the size of the production center area in Indonesia is not balanced (P. D. H. Indonesia, 2023). In addition, farmers' literacy about the importance of biosecurity and preventive medical measures remains low. Small farmers often see the cost of veterinary services as an additional burden (sunk cost) that erodes their already thin profit margins, rather than as an investment in biological asset protection. This systemic failure in the provision of inclusive veterinary services is contrary to the principles of equitable economic development.

1. PHILOSOPHICAL AND THEORETICAL FOUNDATIONS: VETERINARY SERVICES IN THE PERSPECTIVE OF ISLAMIC DEVELOPMENT ECONOMICS

In conventional discourse, the economic development of the livestock subsector is often constrained by a capitalist paradigm that prioritizes instrumental rationality. Animals are reduced solely to "biological machines" of meat or milk printers to maximize Output and Profit (Advantage) (Masri, 2007). As a result, medical interventions or veterinary services are often counted solely as operational costs. If the cost of treatment exceeds the value of the livestock farm, leaving sick animals is often an economically rational choice. However, Islamic Development Economics has very different ontological and epistemological foundations.

Development in Islam is not only oriented towards material growth, but also ecological balance and adherence to the sharia values that prosper all of God's creations (Chapra, 2008). Therefore, the institutionalization and optimization of veterinary services must be reconstructed not just as a technical-medical instrument, but as a manifestation of Islamic worship and economic ethics.

The most basic foundation in viewing the position of animals in Islam is the principle of Rifq (affection/tenderness). The Prophet Muhammad (PBUH) explicitly provided ethical guidance regarding the treatment of animals, ranging from the prohibition of burdening animals beyond their capacity, the prohibition of abandoning animals until starvation, to the recommendation to sharpen knives during slaughter so that animals would not be tortured (Al-Qaradawi, 2013). In the modern context, Rifq's principle resonates with the concept of Animal Welfare promoted by the World Organization for Animal Health (WOAH).

WOAH sets the standard of Five Freedoms for animals, namely: 1) freedom from hunger and thirst; 2) free from discomfort; 3) free from pain, wounds, and diseases; 4) free to express normal behavior; and 5) free from fear and distress (Health, 2021). In the Islamic eye, the fulfillment of these five freedoms, especially "freedom from pain, wounds, and disease", is fardu kifayah (collective obligation) for humanity to benefit from these animals.

This is where veterinary services find their theological legitimacy. Veterinarians and paramedics are Rifq's implementing agents. Without an established animal health system, starting from the availability of vaccines, medicines, and medical personnel, the principle of freedom from pain will only become empty jargon. In dairy farms, for example, mastitis (inflammation of the udder), which often affects dairy cows, not only reduces milk quantity and quality but also causes tremendous pain to livestock. Allowing dairy cows to suffer from mastitis without proper medical intervention is a form of ecological tyranny that tarnishes the halal production process (Nakyinsige et al., 2012). Therefore, the integration of veterinary services is an ethical prerequisite for livestock products to be labeled halal.

To analyze veterinary services as part of an instrument of economic development, the Maqashid Syariah approach (sharia goals) formulated by Imam Ash-Shaytibi offers a highly relevant framework. Maqashid Syariah aims to realize the benefit (goodness/welfare) of humans in this world and the hereafter through the protection of five basic elements: religion (Din), soul (Nafs), intellect (Aql), heredity (Nasl), and property (Mal) (Ash-Syatibi, 1997). In the context of animal health and dairy farming, veterinary services intersect directly with the protection of the soul (Hifz al-Nafs) and property (Hifz al-Mal).

- Life Protection (Hifz al-Nafs) through Zoonotic Prevention and Food Safety. Animal health is directly proportional to human Health (One health). Many deadly infectious diseases are zoonotic (transmitted from animals to humans), such as Anthrax, Brucellosis, and Bovine Tuberculosis. Fresh milk produced by cows infected with Brucellosis, if not properly pasteurized, can transmit the disease to humans (Farma, 2022).

  In addition, the practice of self-medication by farmers without veterinary supervision often leads to the misuse of antibiotics (antimicrobials). This leads to high levels of antibiotic residues in meat and milk, which trigger antimicrobial resistance (AMR) in human consumers. The WHO now recognizes AMR as one of the biggest global health threats (Organization, 2021). Through the lens of Hifz al-Nafs, the existence of professional veterinary services is a mandatory instrument to prevent harm (danger) that threatens human life. Veterinary services are responsible for controlling the spread of disease, supervising the rational use of hard drugs, and ensuring that animal-derived products are safe for consumption (embodying the thayyib aspect).
- Property Protection (Hifz al-Mal) and Resilience of Biological Assets. In the review of Islamic accounting and economics, livestock such as dairy cows are classified as productive assets (I. A. Indonesia, 2018). For small-scale farmers in rural Indonesia, dairy cows are capital-intensive investments and future savings that reflect most, if not all, of their wealth (small).

Islamic economics prohibits the destruction or neglect of property (ida'atul mal). When livestock are left dead or permanently disabled due to the lack of access to medicine, it is a form of neglect or the destruction of the wealth of the people. The empirical analysis that occurred in Indonesia in 2022 provides a very clear picture of this. The re-emergence of the Foot and Mouth Disease (FMD) outbreak after Indonesia was declared FMD-free in 1990 has destroyed thousands of farmers' biological assets. BPS noted a drastic decline in milk production and dairy cow population in production centers such as East Java and West Java during that period (Statistics, 2023).

Research conducted by Prabowo et al. (2023) in Central Java shows that FMD causes the average smallholder dairy farmer to lose potential income of up to Rp 2,500,000 per head per month due to a decline in milk production, plus swollen recovery costs. The absence of early veterinary risk mitigation has triggered mass decapitalization. Through the framework of Hifz al-Mal, veterinary services, especially preventive measures such as mass vaccination programs and biosecurity education, are economic defensive strategies to protect people's wealth from biological shocks.

Furthermore, the theory of Islamic Development Economics places distributive justice ('Adl) as an indicator of development success (Auda, 2008). Development is not judged simply by the aggregate Gross Domestic Product (GDP) of farms, but by the extent to which resources, including public services such as access to animal health, are distributed equally to the most vulnerable.

Empirical evidence on livestock governance in Indonesia shows a wide gap between corporate and smallholder farmers. Dairy farms with mega-farm status (corporation) have in-house veterinarians, strict biosecurity management, and unlimited access to the latest medicines and diagnostic technologies. On the contrary, more than 90% of dairy cows in Indonesia are owned by small farmers who are members of Village Unit Cooperatives (KUDs), with ownership of 2-4 heads. For them, the cost of calling a veterinarian is often beyond financial reach, and the ratio of paramedics provided by local services is inadequate to reach remote areas (K. P. R. Indonesia, 2022a). This structural inequality violates the principle of Islamic economic justice.

The inability to access veterinary services traps small farmers in a vicious circle of poverty: livestock become sick, unable to pay for treatment; productivity drops; or livestock die; income plummets; and they are increasingly unable to raise livestock properly (Chapra, 2008).

Therefore, the provision of veterinary services should not be left entirely to a capitalist free-market mechanism, where services are provided only to those who can afford to pay. The state, along with Islamic financial instruments such as Ziswaf (Zakat, Infaq, Alms, and Waqf), and philanthropic institutions, must intervene to ensure justice. Building animal clinics in community livestock centers or cross-subsidizing veterinary service costs is an implementation step of the principle of equity in Islamic Development Economics.

Based on the above review, the integration of veterinary services into the halal livestock industry is not a stand-alone entity outside the religious corridor, but an integral part of implementing Sharia. Philosophically, it is the embodiment of affection (Rifq). Technically, it is a bulwark of defense for human safety (Hifz al-Nafs) and the financial wealth of breeders (Hifz al-Mal). Ignoring equitable access to veterinary services is tantamount to preserving structural injustice, which is directly contrary to the noble goal of creating welfare (Falah) in the Islamic Development Economics paradigm.

2. REALITY, PROBLEMS, AND ANALYSIS OF VETERINARY ECONOMICS IN INDONESIA

The economic development of the livestock subsector in Indonesia is faced with an unequal structural reality, where the governance and distribution of animal health services have not reflected the principles of justice ('Adl) as mandated in the Islamic Development Economics. Most livestock populations, particularly dairy cows, which account for more than 90%, are managed by small-scale smallholder farmers in rural areas (K. P. R. Indonesia, 2022a). However, the distribution of veterinary medical resources is concentrated in urban areas or absorbed by the large-scale livestock industry (corporations).

Based on data from the Indonesian Veterinary Association (PDHI), the ratio of veterinarians to the livestock population in Indonesia remains far from ideal.

Until 2023, the availability of large-animal practitioners operating in community livestock center areas remained very limited, creating a large gap or unserved area (P. D. H. Indonesia, 2023). From the perspective of conventional economics, this scarcity is explained by market mechanisms; veterinarians tend to practice in sectors that offer higher economic incentives (such as urban pets or corporate farms) than in low-purchasing-power sectors of smallholder farming.

However, from the perspective of Islamic Development Economics, the handover of access to animal health services solely to the free market mechanism is a form of market failure that gives birth to structural tyranny. Islamic economics requires equity and distributive justice ('Adl) for access to resources that concern the livelihood of the many. Ibn Taymiyah in Al-Hisbah emphasizes the obligation of public authorities to intervene when the essential needs of the community, in this case, the protection of their productive assets, are not met by market mechanisms (Islahi, 1988). Veterinary services for smallholder farmers should not be classified as pure private goods subject to corporate demand and supply laws, but as public goods or at least merit goods whose provision must be subsidized or facilitated through state instruments or socio-religious funds (Ziswaf).

This lack of access forces local farmers to undertake medical measures independently, without an adequate scientific basis, such as haphazard antibiotic injections. This practice is not only economically ineffective, but also endangers the halal supply chain as a whole, as drug residues in milk or meat violate the principle of thayyib (safe and healthy) and threaten the lives of human consumers (Hifz al-Nafs) (Nakyinsige et al., 2012).

The problem of the lack of defensive (preventive) and curative veterinary services reaches its culmination point when there is a shock of a strategic infectious animal disease outbreak. The most tangible empirical evidence is the re-emergence of the Foot and Mouth Disease (FMD) outbreak in Indonesia during the 2022-2023 period. The shock of this epizootic is not just an animal health crisis, but a massive-scale development economic crisis that hits the pillars of Maqashid Shariah, specifically in the dimension of property protection (Hifz al-Mal).

Dairy cows are biological commodities that are highly sensitive to environmental stress and disease. Empirical studies conducted at various dairy cow milk centers in Central Java show that FMD outbreaks directly undermine farmers' economic stability (Prabowo et al., 2023). The morbidity rate due to FMD in smallholder farms in some areas reaches more than 80%. The direct economic loss experienced by farmers includes: 1) a sharp decrease in fresh milk production of up to 30%-50% due to damage to the udder tissue (secondary mastitis); 2) weight loss of livestock; 3) abortion in pregnant cows; and 4) sudden death in calves (FMD Handling Task Force, 2022).

At the macro level, the Central Statistics Agency (BPS) confirmed a significant decline in the aggregate domestic fresh milk production. If in 2021 milk production reached around 946 thousand tons, then after the outbreak peak in 2023, recovery has been slow and has not returned to the starting point (Statistics, 2023). For small farmers, losing 1 to 2 cows that die or are forced to retire early at a very low price (distress sale) is equivalent to losing lifetime savings.

Within the framework of Islamic Development Economics, the loss of productive biological assets due to the absence of early detection systems and veterinary services is a prohibited form of ida'atul mal (waste of property). Wealth (Mal) in Islam must always be maintained in productivity so that it can continue to circulate and provide circular benefits (تداول, tadawul) for the community (Chapra, 2008). The FMD shock shows how fragile the economic resilience system of local farmers is. In the absence of a solid safety net of the veterinary ecosystem, a single outbreak is enough to drag farmers from the lower-middle class into the abyss of extreme poverty. This fundamentally thwarts the achievement of Falah (prosperity and victory), which is the ultimate goal of Islamic economic development (Auda, 2008).

Another problem, no less crucial, due to the weak veterinary economy at the upstream level (livestock), is the disconnection of the traceability system for animal products. In the modern halal industry, with international standards, halal guarantees are no longer evaluated only at the time of slaughter in sharia-certified slaughterhouses (RPH), but must be traceable back to the origin of livestock on farms (from farm to table) (Tieman, 2011).

This traceability requires accurate veterinary medical records. The halal industry must ensure that dairy cows are never fed najis feed (the concept of Jallalah in fiqh), are not treated with medicines containing haram elements without a sharia emergency, and are maintained in accordance with animal welfare standards (Masri, 2007). Unfortunately, the reality on the ground shows that adoption of medical recording and tagging on small-scale farms remains very low. The national animal health information system has not been fully integrated with the Halal Product Assurance System managed by the Halal Product Assurance Agency (BPJPH).

This weakness in animal medical records creates an information asymmetry between farmers (producers of raw materials) and the dairy industry (industrial consumers). Information asymmetry is a form of Gharar (uncertainty) in economic transactions that is prohibited in Islam. When a halal milk processing plant receives a supply of fresh milk from a cooperative, the lack of a veterinary track record makes it impossible for the factory to fully guarantee that the milk is free of any medical intervention that violates the law or that it comes from unjustly treated livestock.

Economically, this lack of traceability reduces the competitiveness of local dairy products against imported products that have strict traceability certification. In turn, this contributes to the stagnation of milk prices at the local farmer level. Industries will reduce purchase prices due to the risk of biological contamination that they must mitigate independently (K. P. R. Indonesia, 2022a). Thus, losses are not only experienced in the aspect of Sharia compliance, but also give birth to low economic efficiency (inefficiency) in the supply chain.

Examining this problem through Islamic development theory requires a paradigm shift. So far, the economic rationality of farmers and related authorities has leaned more towards a curative approach: calling a veterinarian or buying medicine only when the cow is already lying sick. Preventive costs, such as improving cage sanitation, purchasing disinfectants (biosecurity), providing vitamins, and routine vaccinations, are considered expenses that burden the already very limited monthly cash flow. However, economic calculations that ignore preventive measures are, in fact, a miscalculation within the framework of wealth management (Hifz al-Mal).

Ibn Khaldun in Muqaddimah implies that negligence in maintaining the foundations of production (in this case, the physical health of livestock) will lead to the collapse of economic activity itself (Ibn Khaldun, 2006). The recovery cost of a cow affected by severe mastitis far exceeds the total cost of routine sanitation for months. In addition to medical losses (the purchase of medicines), farmers must dispose of milk containing antibiotic residues (which cannot be sold), experience post-disease production stagnation, and risk infertility (cow sterility) due to untreated systemic infections.

Empirical evidence from rural dairy farming centers shows that short-term economic rationality (avoiding preventive costs) has trumped long-term economic rationality (asset sustainability). This is where Islamic Development Economics comes in, offering institutional interventions. People's economic institutions, both in the form of breeder-based sharia cooperatives and philanthropic fund management institutions (Baitul Maal), must take a central role in changing this cost structure. By intervening in preventive financing, such as the provision of community veterinarians paid through the sharia micro insurance scheme (Ta'min), collectively, risk mitigation costs previously borne by individual farmers can be absorbed and spread communally (risk-sharing).

An analysis of this series of empirical problems shows that neglecting to integrate veterinary services into dairy farm structures is not just a medical or technical issue in agriculture. It is a fundamental macroeconomic issue that is closely related to economic justice ('Adl), the protection of welfare and life (Maqashid Syariah), and the future of the sovereignty of the halal food industry in Indonesia.

3. ISLAMIC DEVELOPMENT ECONOMIC INTEGRATION MODEL

The analysis of the empirical problems in the previous sub-chapter shows that the lack of access to veterinary services for smallholder dairy farmers is not solely a clinical problem but a systemic failure that creates structural injustice. In response to this, Islamic Development Economics does not stop at moral appeals (such as the recommendation to practice Rifq, or love for animals), but rather offers solutions through institutional engineering and financing instruments.

Economic development in Islam requires institutions that can bridge the gap between available resources and those who need them most, in order to realize Falah (holistic welfare) and 'Adl (distributive justice) (Chapra, 2008). Therefore, this section will outline in depth three models for integrating sharia-based veterinary financing and governance solutions, along with recommendations for cross-sectoral actions to strengthen the resilience of the halal livestock industry in Indonesia.

The most basic instrument in Islamic Development Economics to overcome access disparities is wealth redistribution, namely Zakat, Infaq, Alms, and Waqf (Ziswaf). So far, the paradigm of distributing Ziswaf in Indonesia is still dominated by short-term charitable programs (fulfilling mustahik consumptive needs). In fact, the optimization of productive Ziswaf funds has massive potential to build animal health infrastructure in people's livestock centers.

The concept of waqf is not limited to immovable assets such as land for mosques or madrasas. In modern Islamic economic jurisprudence, a money waqf can be collected collectively to finance the procurement of productive public assets (Kahf, 1998). A model that can be applied is the establishment of "Waqf-Based Community Animal Clinics" in pockets of dairy farms (such as in Lembang, Boyolali, or Pujon). Waqf funds from the community (waqf) are managed by professional Nazhir (waqf managers) and invested in sukuk instruments or sharia mutual funds. The principal value of the waqf remains intact, while the investment returns subsidize the clinic's operating costs, purchase essential medicines (vaccines, measurable antibiotics, vitamins), and pay permanent veterinarians and paramedics.

On the other hand, productive zakat funds can be distributed specifically to dairy farmers who are included in the asnaf of Fakir, Miskin, or Gharimin (people who are entangled in debt due to epidemic losses). This distribution is not in cash but in veterinary preventive service packages. For example, the National Amil Zakat Agency (BAZNAS), through its "Livestock Center" program, has pioneered a model of farmer mentoring. However, this needs to be improved by including Key Performance Indicators (KPIs) for "Zero Zoonosis" and "Zero Mortality" through routine medical interventions.

This approach is a direct manifestation of Hifz al-Mal (guarding mustahik wealth so that it does not shrink) and preventing the recurrence of the cycle of poverty (Beik & Arsyianti, 2016).

The vulnerability of small-scale farmers to disease shocks (such as FMD or Bovine Ephemeral Fever) requires more structured risk mitigation mechanisms. The Indonesian government, through the Ministry of Agriculture, actually has a Cattle Business Insurance (AUTS) program. However, AUTS still uses the principle of conventional insurance (risk transfer), and its claims focus only on mortality events (animal deaths) or losses due to theft (K. P. R. Indonesia, 2022b). Conventional AUTS does not provide financing incentives for preventive measures or treatment when the cow is still sick.

Islamic Development Economics offers a more comprehensive and equitable alternative, namely Sharia Micro Insurance (Micro-Takaful), specifically for livestock. The basic principles of Takaful are Ta'awun (help) and Takaful (mutual support), where farmers collect Tabarru' (grant) funds to help other members affected by disasters (Billah, 2003).

The advantage of this Veterinary Micro-Takaful design is its expanded coverage. Tabarru's funds are not only disbursed when a cow dies. However, they can also be claimed (or used cashless through community clinics) for the cost of veterinarian emergency calls, cesarean sections for cows that have difficulty giving birth (dystocia), and mastitis treatment. By covering the cost of clinical treatment, Micro-Takaful prevents livestock from dying prematurely (reducing deadweight loss), which substantially preserves members' assets. In addition, because it follows the principle of togetherness, the underwriting surplus (the remaining Tabarru' funds after claims are deducted) can be returned to participants or used for the annual mass vaccination program, creating a sustainable economic cycle for asset preservation.

Farmers on a small scale (1-3 cows) will not be able to achieve economies of scale if they move independently, both in accessing veterinary services and when selling milk. In Islam, the form of corporate cooperation that is highly recommended is Syirkah (business partnership). The institutions of dairy cooperatives operating in Java need to be revitalized and transformed into Baitul Maal wat Tamwil (BMT) or Sharia Cooperatives, which oversee two functions at once: social (Maal) and commercial (Tamwil) (Ascarya, 2017).

As commercial aggregators, Sharia Cooperatives act as quality assurance guarantors (Quality Assurance). This cooperative employs in-house veterinarians (internal veterinarians of the cooperative) who are responsible for overseeing the health of all its members' cows. These vet costs can be included proportionally into profit sharing (Ratio) or milk sales margins to the processing industry. With this system, surveillance of antibiotic residues and animal health status can be ensured.

In its social function (Maal), Sharia Cooperatives can provide Qardh al-Hasan (interest-free, benevolent loan) facilities. When farmers need urgent funds to renovate cages to meet animal welfare standards (e.g., improving ventilation, cage floors, etc.), they can use Qardh al-Hasan funds. This loan is paid through the gradual deduction of milk deposit yields without burdening farmers (free of Riba). This approach breaks farmers' dependence on middlemen or rural loan sharks, who often exploit them during a biological asset crisis.

The above financing model will not run optimally without a cross-sectoral policy framework. The veterinary service ecosystem in the halal supply chain is complex and requires a Pentahelix approach involving the Government, Academia, Industry, Community (Cooperative), and the Media.

Synchronization of Halal Product Assurance and Animal Health Regulations: Until now, BPJPH's halal certification process has focused more on downstream processes. The essential policy recommendation is to integrate the Ministry of Agriculture's national animal health database (iSIKHNAS) with BPJPH's SIHALAL (Farma, 2022). Every liter of milk deposited by Sharia Cooperatives to the Dairy Processing Industry (IPS) must have a "Digital Veterinary Passport". This passport contains the cow's medical history, vaccinations received, and proof that the cow was not treated with non-halal ingredients. This traceability not only guarantees the absolute status of Halalan Thayyiban, but also increases the bargaining value (price) of local milk because it is free from Gharar (quality uncertainty) (Tieman, 2011)

Strengthening the Role of Higher Education (Academics): The Faculty of Veterinary Medicine (FKH) and the State Islamic University (UIN), which have study programs related to the halal industry, must collaborate.

UIN can prepare guidelines for veterinary fiqh (Fiqh al-Baitarah), while FKH provides integrated community services by sending young veterinarians to high-risk farm pockets. This integration equips animal health practitioners with the worldview of Islamic Economics, so that they realize that the task of injecting and treating animals is not just a biological act, but part of worship in maintaining a halal ecosystem.

Dairy Industry Inclusive Partnership (IPS): Large industries should not only act as buyers, but must be responsible partners (Corporate Social Responsibility). Based on the principle of 'Adl (distributive justice), corporations must subsidize veterinary diagnostic infrastructure (e.g., antibiotic residue detection devices or portable ultrasound) for their partner Sharia Cooperatives. This core-plasma partnership must be based on the contract of Shirkah Muwafadah or equality, not a subordinate relationship.

The integration model offered in this paper reaffirms the initial thesis: that veterinary services are a fundamental pillar, not just a complement, in the economic development of the upstream halal industry. Through social institutional engineering (Ziswaf, Community Clinic Waqf), risk-mitigation instrument engineering (Micro-Takaful), and sociocultural empowerment through Sharia Cooperatives, the problem of scarcity and the high cost of veterinary medical services for small farmers can be overcome.

This multidimensional intervention represents the essential application of Maqashid Sharia. Maintaining the health of dairy cows with easily accessible veterinary services means maintaining the purity and safety of food for the ummah (Hifz al-Nafs). At the same time, it is the most rational fortress of defense to save the wealth assets (Hifz al-Mal) of millions of local farmers from the threat of an impoverishing disease outbreak. In the end, when livestock prosper from medical treatment, the quality of halal commodities improves, and farmers are freed from structural poverty, the great goal of Islamic Development Economics, in the form of Falah (welfare in this world and the hereafter), will be realized in Indonesia's livestock ecosystem.

CONCLUSION

The research and discussion in this book chapter emphasize that the optimization of veterinary services in smallholder dairy farms is not solely a technical, clinical, and agricultural issue, but a fundamental issue within the paradigm of Islamic Development Economics. So far, animal health governance remains trapped in conventional economic rationality, which positions medical services as an additional operational burden (a sunk cost) and leaves their distribution solely to the free market mechanism. As a result, there are structural injustices that violate the principle of 'Adl, where small-scale dairy farmers who control more than 90% of the national livestock population struggle to access decent veterinary services. This scarcity of access has a destructive impact when there are epizootic shocks such as Foot and Mouth Disease (FMD), which triggers a massive depletion of biological assets and drags local farmers into the abyss of structural poverty.

Through the lens of Maqashid Syariah, the provision of veterinary services embodies economic ethics and ecological worship. The fulfillment of animal welfare rights (Rifq bil Hayawan) is an absolute prerequisite before animal food products can be labeled halalan thayyiban. The presence of veterinary medical personnel and a systematic disease prevention system is an important pillar to ensure the safety of human life from zoonotic threats and antimicrobial resistance (Hifz al-Nafs), as well as the protection of the productive wealth assets of the people so that they do not perish in vain (Hifz al-Mal).

As a solution to these systemic failures, this paper recommends institutional engineering and integrated financing based on Islamic Development Economics. The proposed policy recommendations include three tactical pillars. First, the integration of Islamic philanthropic social funds (Ziswaf) through the cash waqf scheme to establish Community Animal Clinics, as well as the use of productive zakat to fund biosecurity programs for vulnerable farmers. Second, the implementation of veterinary Sharia Micro Insurance (Micro-Takaful), which prioritizes the principle of Ta'awun (help-help) to cover not only the risk of livestock death, but also subsidize the cost of preventive and curative medical measures.

Third, strengthening the institutionalization of Sharia Cooperatives (BMT) as commercial and social aggregators that oversee dairy farmers, provide in-house veterinary services collectively, and fund improvements in cage sanitation through charitable instruments (Qardh al-Hasan).

At the macro level, this implementation demands strong Pentahelix synergy between governments, academics, dairy industry corporations, Islamic financial institutions, and the farming community. One of the most crucial steps is to integrate the national animal health information system (such as iSIKHNAS) with the halal product assurance system (SIHALAL) to create end-to-end traceability. Ultimately, making veterinary services inclusive and certified is not just an administrative burden but a long-term strategic investment. This is believed to help save local farmers' economies, maintain the integrity of the halal food industry supply chain, and achieve true welfare (Falah) within the framework of Indonesia's food security development.

REFERENCES

Al-Qaradawi, Y. (2013). The lawful and the prohibited in Islam (Al-halal wal haram fil Islam). The Other Press.

Ascarya. (2017). Baitul Maal wat Tamwil (BMT): An alternative model of Islamic microfinance in Indonesia. International Journal of Islamic and Middle Eastern Finance and Management.

Auda, J. (2008). Maqasid Al-Shariah as philosophy of Islamic law: A systems approach. International Institute of Islamic Thought (IIIT).

Beik, I. S., & Arsyianti, L. D. (2016). Economics of Sharia Development. Rajawali Press.

Billah, M. M. (2003). Islamic and modern insurance: Principles and practices. Scientific Publishers.

Chapra, M. U. (2008). The Islamic vision of development in the light of Maqasid al-Shariah. International Institute of Islamic Thought (IIIT).

DinarStandard. (2023). State of the global Islamic economy report 2023/24. DinarStandard.

Farma, P. V. (2022). One Health-based zoonotic disease control guidelines. Ministry of Agriculture.

Health, W. O. and A. (2021). Terrestrial animal health code: Animal welfare. WOAH.

Ibn Khaldun, A. R. (2006). Muqaddimah Ibn Khaldun. Al-Kautsar Library.

Indonesia, I. A. (2018). Financial Accounting Standards Statement (PSAK) 69: Agriculture. IAI Financial Accounting Standards Board.

Indonesia, K. P. R. (2022a). Performance report of the Directorate General of Livestock and Animal Health in 2022. Ministry of Agriculture of the Republic of Indonesia.

Indonesia, K. P. R. (2022b). Guidelines for the implementation of Cattle Business Insurance (AUTS). Directorate General of Agricultural Infrastructure and Facilities.

Indonesia, P. D. H. (2023). Annual report on the availability and distribution of veterinarians in Indonesia. PB PDHI.

Islahi, A. A. (1988). Economic concepts of Ibn Taimiyah. The Islamic Foundation.

Kahf, M. (1998). Financing the development of Awqaf property. American Journal of Islamic Social Sciences, 15(4), 39–67.

Masri, B. A. (2007). Animal welfare in Islam. The Islamic Foundation.

Nakyinsige, K., Man, Y. B. C., & Sazili, A. Q. (2012). Halal authenticity issues in meat and meat products. Meat Science, 91(3), 207–214.

Organization, W. H. (2021). Global action plan on antimicrobial resistance. WHO Press.

Prabowo, A., Susanti, I., & Rahman, F. (2023). The economic impact of the Foot and Mouth Disease (FMD) outbreak on dairy farmers in Central Java. Journal of Agricultural Economics and Agribusiness, 7(2), 145–156.

Statistics, B. P. (2023). Livestock and animal health statistics 2023. BPS RI.

Tieman, M. (2011). The application of Halal in supply chain management: In-depth interviews. Journal of Islamic Marketing, 2(2), 186–195.

CHAPTER 3
THE USE OF ACTIVATED CHARCOAL (BIOCHAR) IN THE MITIGATION OF GREENHOUSE GASES AND MANAGEMENT OF ODOUR EMISSIONS IN POULTRY AND LIVESTOCK FARMS: A REVIEW

[1]Stephen Nnaemeka OKEY
[2]Ogochukwu Nwamaka OKEY

[1]Department of Veterinary Biochemistry and Animal Production, College of Veterinary Medicine, Michael Okpara University of Agriculture Umudike, Nigeria, nnamuokey@gmail.com
[2]Department of Theriogenology, College of Veterinary Medicine, Michael Okpara University of Agriculture Umudike, Nigeria

INTRODUCTION

Poultry and pig farms generate volatile organic compounds (VOCs), greenhouse gases (GHGs) and nitrogenous compounds such as ammonia and nitrous oxide responsible for the odour emissions (Basmin-Grave et al., 2019). The odour emission is attributed to a complex biological, physical and anaerobic microbial activity in the litter which lead to the decomposition of the organic matter which brings about the offensive odour and gases (Kalu et al., 2015). Exposure to these gases and volatile organic compounds causes health problems such as chronic respiratory diseases in poultry (Abdullahi et al., 2017). The poultry and livestock dung or wastes generated from these farms have resulted in increased complaints from local residents (Nwagwu et al., 2012; Kalu et al., 2015), due to bad odour and nuisance flies. The economic losses associated with poor litter in farms include foot and leg problems, respiratory infection, poor weight gain and inferior feed conversion (Charles, 2005; Sashikala et al., 2012; Kalu et al., 2015).

The odour emitted from intensive pig production system is a very serious nuisance to people living in the vicinity of pig farms and has led to health problems. Some of these odorous compounds are capable of affecting both the health and production efficiency of animals. The odour which is mainly formed from the microbial conversion of organic compounds in manure is emitted into the air from building or external manure storage sites (Lee et al., 2005). Besides the foul odour, the hydrogen sulphide, ammonia and other gases emitted by pig manure can diminish air quality. This can lead to tension and complaints between pig farmers and their neighbours which in some cases can result to litigations and risk of possible closure of farms.

The challenges of handling pig dung are recognized as a major issue in sustaining the growth of pig and poultry industry in Nigeria (Okoli et al., 2019). Livestock waste is a biomass that changes rapidly from the time of excretion thereby creating a serious pollution problem. It is more offensive to the human environment than any other animal waste (Iregbu et al., 2014; Okoli et al., 2019) with the chemical composition of pig manure dependent on several factors like age, water intake, digestibility of the ration, housing environment and waste management practices.

This paper is aimed at reviewing the use of activated charcoal as dietary intervention in the management of odour emission in poultry and livestock farms.

1. MANAGING ODOUR AND GAS EMISSIONS IN POULTRY AND PIG FARMS

Basically, there are two strategies that can be used in the management of odour and gas emissions in poultry and pig farms.

- Controlling the production of gases through proper dietary management such as the inclusion of activated charcoal (AC) at appropriate inclusion level in feed (Bist et al., 2023).
- Trapping of the already produced gaseous volatile compound by the use of bio-filters, air scrubbers and neutralizing agents (Ma et al., 2021).

Biochar or activated charcoal (AC) is a black carbonaceous material produced from carbon-containing material and agricultural wastes using pyrolytic carbonization or decomposition (AAFCO, 2012). They are processed carbon materials that are capable of adsorbing various substances because of their highly developed pore structure and large internal surface area (Abdul and Aberuagba, 2005). It is differentiated from the elemental carbon by its high surface area and the oxidation of carbon atoms found at both its outer and inner surfaces (Al-Qodah and Shawabkah, 2009; Khah and Ansari, 2009). The surface chemistry of activated charcoal confers on it the ability to absorb many gases, aqueous liquids and poisons (Al-Qodah and Shawabkah, 2009). Activated carbon produced from agro-residue are extremely porous and excellent natural filter with a huge internal adsorption capacity for water, ammonia, ions, and other irritants than any other organic material (Sashikala et al., 2012).

It is this high adsorption property that makes it useable in water purification and in the removal of undesirable odours and impurities from food (Al-Qodah and Shawabkah, 2009). Bad odours caused by skin ulcers have been eliminated by placing charcoal-filled cloth over plastic cast on the sore. It has also been effectively used to adsorb wound secretions, bacteria and toxins (Burdock, 1997).

Activated charcoal is required by law to be part of the standard equipment in many ambulances as first aid against poisoning (Burdock, 1997). In addition to enhancing nutrient uptake from feed raw materials, AC is proposed as an effective litter moisture and odour control in livestock and poultry farms (Sashikala et al., 2012). Sashikala et al. (2012) compared the odour abatement of poultry litter using three odour control products (activated charcoal, silica gel and zeolite) under controlled environmental conditions and demonstrated that AC and silica gel exhibited prominent adsorption or reduction in litter volatiles.

The application of activated charcoal in poultry feed improved digestion, nutrient absorption and improved get health through modification of intestinal microbiota (Rattanawut, 2021). This improved digestibility and nutrient absorption of feed in poultry results in manure or litter with lower content of undigested nutrient thereby reducing the production of these odorous gases upon anaerobic fermentation (Sigh and Kim, 2021). This reduction in the release of harmful gas and VOCs, from manure into the environment bring about lower environmental impact on poultry production (Adegbeye et al., 2019).

Kalus et al. (2019) reported a significant decrease in nitrogen excretion (4-20%) on including 1-2% bench-wood biochar in the diet of laying chickens. Okey (2025) reported that activated charcoal supplementation resulted to improved laying performance and shell thickness. More so, the inclusion of bench-wood biochar (2-4%) in broiler feed was reported to have lowered nitrogen volatilization in broiler chickens (Kalus et al., 2019) with 17% reduction in ammonia emission. This could also be as a result of the absorption of the gases by biochar and its activity on the gut microflora (Kalus et al., 2020).

2. GREENHOUSE GASES, NITROGENOUS AND VOLATILE ORGANIC COMPOUNDS IN POULTRY AND PIG FARMS

The manure decomposition results in the production of several odorous compounds such as ammonia, hydrogen sulphide, skatole, indole, mercaptan and ketones (Sharma et al., 2017). Janocha et al. (2022) reported that the highest odour emission arise from poultry followed by pig and cattle.

Regarding GHG gas emissions, the ruminant sector contributed 41% which is far less the contribution from poultry (Akamati et al., 2023). The contribution of the poultry sector to greenhouse gas emission (GHGs) compared to other animals is due to their high number coupled with intensity of production with about 50% contributed by the egg production sector (Akamati et al., 2023).

2.1 Ammonia

Ammonia has a strong irrigating odour and is very harmful at a level above 22-50ppm. It will cause lowered immunity, ocular damage, damage to respiratory system and low production parameters (Piorkowska et al., 2016). In a level above l00ppm, ammonia will cause decrease in feed intake, daily weight gain, egg weight and meat quality in poultry (Piorkowska et al., 2016). The average daily emission of ammonia is observed to be 130mg per bird. More so, poultry manure is rich in nitrogenous compounds out of which 20-30% of it are uric acid and traces of creatinine. The microbial decomposition of uric acid by Bacillus pasteuri leads to production of ammonia. Ammonia emission from poultry is 1.9 – 2.4 times higher than that of pig manure and 6.6 – 17.4 times higher than cattle manure (Wang et al., 2019).

2.2 Hydrogen Sulphide (H2S)

Hydrogen sulphide at high concentration of 10ppm will be harmful to the environment, and the health of birds and farm attendants (Saksrithal and King, 2018). The exposure of 14th day old chickens to 30ppm H2S gas for 2 weeks was observed to induce inflammatory responses, metabolic dysfunctions and oxidative stress (Chi et al., 2018). In monogastrics, the odour is generated from anaerobic fermentation of sulphur-containing amino acids or the reduction of sulphate ions by microbes in manure (Basic et al., 2017; Chi et al., 2018).

2.3 Volatile Organic Compounds (VOCs)

In poultry waste, various VOCs are produced such as alcohol, esters, ketones, alkanes, aromatic and halogen compounds, phenol, nitrogen and sulphur containing compounds.

They have varying odour perception in humans such as pungent odours from alcohol and acetone odour from ketones, burnt sugar odour from aldehydes, sour odour from carboxylic acid, faecal odour from indole and skatole, garlic odour from sulphur-containing compounds and paint odour from toluene (Patil et al., 2019). These compounds irritate the mucous membrane of the throat and nose and adversely affect liver and the functioning of the nervous system (Patil et al., 2019). The higher carbon and moisture content in poultry waste favours the production of VOCs under anaerobic conditions. Poultry manure has high nitrogen content, lower carbon to nitrogen ratio, thereby favouring the increased formation of VOCs and ammonia emissions.

3. REDUCTION OF ODOUROUS GASES USING ACTIVATED CHARCOAL IN POULTRY AND PIG FARMS

Intensive poultry and pig production practice with nutrient-condensed feed brings about higher nitrogen loss in the manure thereby increasing ammonia and odour emissions (Bist, 2023). Proper feed management and inclusion of activated charcoal could lower the excretion of undigested nutrients in the faecal output. Biochar will consequently reduce the available organic substrate for the growth microbes and the production of these odorous compounds (Charma et al., 2017).

Biochar can significantly reduce greenhouse gas (GHG) emission from poultry manure particularly when used in composting and soil application contexts.

Researchers have shown that biochar captures 63% of ammonia and other gases such as methane, nitrous oxide, hydrogen sulphide, urea, organic acids, ketones, volatile vapours and noxious liquids found in animal manures (David, 2015). The effects are achieved when 5-20% of biochar is blended with conventional litter and spread on the floor as an air purifier. Lowering of the build-up of odourless gases and improvement in air quality and livestock health has also been reported by Durunna et al. (2018) when graded levels of AC were incorporated in to the diets of broilers. Lower moisture content and ammonia levels curtail risk of footpad diseases, skin lesions and respiratory diseases which will ultimately improve vitality, egg production and weight gain.

Depending on the type of litter, biochar can be mixed at the rate of 5-10% by volume with litter, with the effects being strong at 5% biochar but reaching saturation beyond 15%. Biochar can also be added and mixed when making silage to conserve moisture, buffer pH, retain cation and anions and provide stable environment for fermenting organisms.

3.1 Greenhouse Gases reduction by Biochar

Methane (CH4)

The percentage reduction of methane by biochar typically range from 10.10% to over 80% particularly during composting studies and between 66-78% when used as feed additive to mitigate odour effects.

Nitrous Oxide (N2O)

The reduction of this gas by biochar generally falls between (13.10% and approximately 50% especially when applied to soil with nitrogen fertilizer or during composting and 20-53% when used as feed additive.

Carbondioxide (CO2)

The effect of carbondioxide is variable or minimal with some reports of slight increase or no significant change. This could be because biochar can enhance carbon mineralization or microbial activity.

Ammonia (NH¬3)

Ammonia is not primarily a greenhouse gas but it is a major air pollutant in nitrogen loss pathway. Biochar reduces ammonia volatilization by 40-77% during composting. Finally, manure or soil conditions like pH, temperature carbon to nitrogen ratio (C: N) ratio of the manure or soil influence the microbial processes that produce or consume (GHGs) emissions. According to work done by Selvarajh et al. (2020), rice husk biochar (T1-T5) readily adsorb NH4 and NO-3 to its surface due to abundance of negatively charged sites when compared with the control (T0).

Table 1. Rice husk biochar effectiveness in adsorption NH+4 and NO-3 to its surface

Treatment	NH_4 (ppm)	NO_{-3} (ppm)
T0	100.67±12.01^{a}	14.67± 5.49^{a}
T1	256.67±29.63^{b}	56.00± 4.62^{c}
T2	447.67±3.33^{cd}	33.33± 2.33^{b}
T3	464.33±26.30^{d}	39.67± 2.33^{bc}
T4	383.33±31.80^{cd}	44.33± 6.17^{bc}
T5	335.00±27.84^{bc}	50.00± 4.93^{bc}

Results are mean ± SD; a, b: means on the same row with different superscripts are significantly different ($P \leq 0.05$). Source: Selvarajh et al. (2020)

3.2 Factors Affecting The Reduction of Odorous Gases by Activated Charcoal

The effectiveness of activated charcoal in the reduction of these odorous gases varies widely depending on the type of biochar, application rate and specific management techniques (Kalus et al., 2019). Another important factor is the adsorption capacity of the AC which is dependent on the specific surface area, surface charge, pore size distribution, nature of agricultural waste materials, activating agent and pyrolytic temperatures (Verheijen et al., 2010).

Type of Biochar

Biochar type is another factor influencing the reduction of the odorous gases. Biochar made from certain feedstock (e.g. poultry manure derived biochar or sawdust derived biochar) can be more effective than others (Verheijen et al., 2010). This is because of the specific properties such as high porosity and surface area which are important parameter in absorption of greenhouse gases (GHGs).

Several studies have shown that one of the most important factors that affect the texture of AC is the nature of the starting material (Verheijen et al., 2010). Different agricultural bio-waste would produce AC having different texture characteristics even with the same method of treatment or activation method.

Khali et al. (2013), prepared activated carbon from three different biomasses: oil palm empty fruit bunch (EFB), bamboo stem and coconut shell using potassium hydroxide as activating agent under atmospheric nitrogen and reported irregular cavities or pores that differed from each other. Also, Martinez et al. (2006), observed that the texture of the carbon yield as well as development of pores is strongly affected by the nature of precursor material. They investigated two biomass materials, walnut shells and olive pits and showed that the former has a homogenous structure of carbon, while the later develops rough texture of carbon with heterogeneous surface under different concentration of the activating agent (KOH).

Another critical determinants of AC quality associated with precursor include level of non-starch polysaccharides (NSPs) namely, hemicelluloses, cellulose and lignin; pore structure, level of volatile and non-volatile fractions, carbon and ash contents (Olivares, 2006; Dhyani and Bhaskar, 2017). Woody biomass (Baski et al., 2006; Madu and Ladije, 2013), palm fruit fibre and palm kernel shell yield good AC due to high content of NSPs and good pore structure. The level of volatile and non-volatile fractions can be determined by chemical analysis. These parameters influence the heating value (HV) of precursors and AC quality.

Pore Structure and Surface Area of Activated Charcoal

Activated charcoal has a negatively charged porous surface that attracts positively charged toxins or poison resulting in their binding and subsequent elimination through the entire length of the digestive tract out of the body (Davis, 2005). This binding or adsorption is made possible by lots of pores on the AC particles that increase the surface area and available binding sites. Pore structure of AC are typically classified into micropore (1 nm), mesopore (1-25 nm), and macropore (25 nm and above) based on the pore radius (Lowell and Shields, 1998; Gerd and Tondeur, 2001).

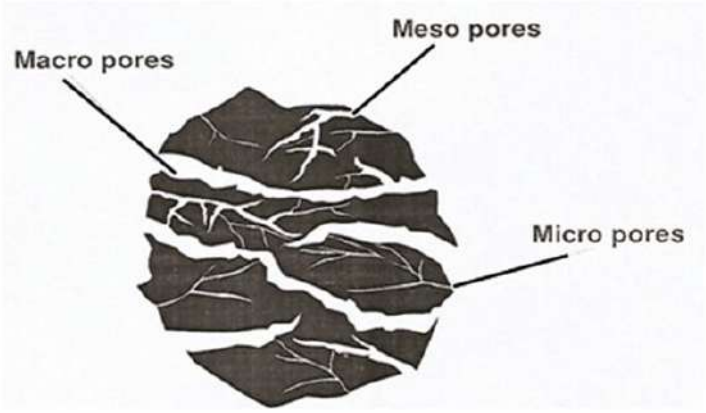

Figure 1. Schematic diagram of the pore structure of activated charcoal. Sources: Gerd and Tondeur (2001)

Application Rate

On application rate, a biochar dosage of 10-20% by dry weight during composting is often recommended for optimal co-mitigation of multiple gases. This means that lower or higher application rates may be less effective.

Management Technique

Another important factor is the overall management of the farm. Adding biochar to manure during storage or composting are common practices that would mitigate these gases and the odour they emit (Kalus et al., 2019). Bi-weekly re-application of the biochar will maintain and improve mitigation effect over time compared to when a single application is made. Incorporating biochar application into poultry or piggery manure management is a promising strategy for climate change mitigation, primarily by reducing potent methane (CH4) and nitrous oxide (N20) emissions (Bist et al., 2023).

4. PRODUCTION OF ACTIVATED CHARCOAL AND ITS USE IN REMOVAL OF ODOUR IN WATER AND FISH POND

4.1 Production Processes of Activated Charcoal

The most frequently used method of preparation of AC is the carbonization of the precursors at high temperature in an inert atmosphere followed by activation process (Allwar, 2012). The activation process could be achieved through physical and chemical methods. Physical activation involves treatment of char obtained from carbonization with oxidizing gases using steam or carbon dioxide at high temperature (400-10000C), depending on the type of precursor (Matali et al., 2013).

4.2 Chemical Activation

In chemical activation, the starting material is mixed with activating reagent and the mixture heated in an inert atmosphere (Ioannidou and Zabaniotou, 2005; Allwar, 2012). This process is usually done at a lower temperature and shorter activation time, and it produces higher surface area and better pores when compared to physical activation. Several studies have shown that chemical activation is better than physical activation in terms of lower temperature, higher yield and larger surface area (Tsai et al., 2007; Zhu et al., 2008). On the other hand, there are some disadvantages associated with chemical activation such as washing that is required to remove impurities arising from activating reagents due to their corrosive actions. A flow chart of the chemical activation process is shown in figure 2.

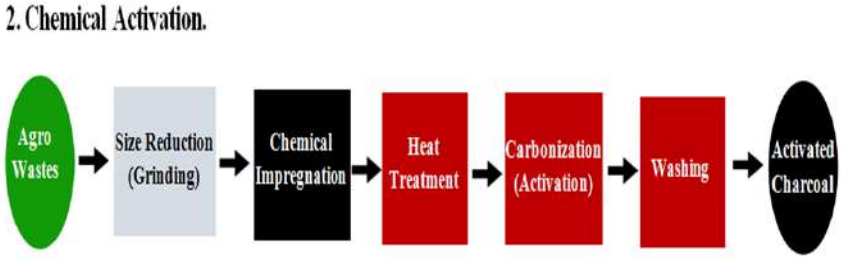

Figure 2. A flow chart for chemical activation in preparation of activated charcoal. Source: Ioannidou and Zabaniotou (2005)

The nature of the starting material plays a vital role in determining the quality, characteristics and properties of the resulting activated charcoal (Cagnon et al., 2009; Camphell et al., 2012; Abechi et al., 2013). The properties of the activated charcoal produced can also be influenced by the type of activating reagents, time of activation, impregnation condition and carbonization temperature (HirunPraditkoon et al., 2011).

4.3 Physical Activation

Physical activation follows thermal decomposition or carbonization of the precursor, and it is achieved by controlled gasification or activation of the crude char (Schimdt et al., 2019). Carbonization temperature ranges from 400 to 8000C, while activation temperature is around 6000C. During carbonization, most of the non-carbon elements such as oxygen, hydrogen, nitrogen and sulphur are eliminated as volatile gaseous products as the material is decomposed to carbon skeleton with graphite-like pore structure (HirunPraditkoon et al., 2011). The low molecular weight volatiles are the first to be released followed by light aromatics and hydrogen gas, resulting in a fixed carbonaceous char which will undergo activation. During activation process, there is entrance of the oxidizing gases (carbon dioxide or steam or a mixture of both) into the char thereby generating pores.

The main aim of activation is to transform the carbon structure into a highly porous solid called activated charcoal. An automated procedure is presented in Figures 2 and 3 according to Okey (2023).

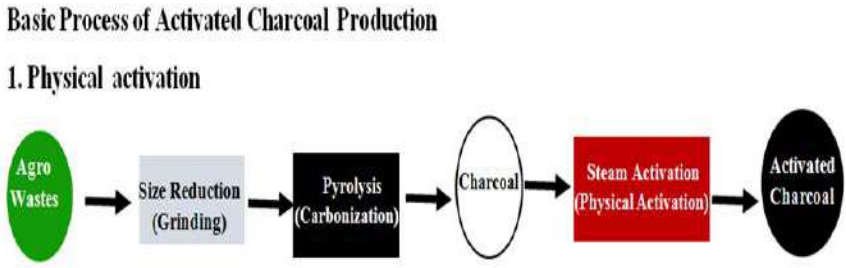

Figure 3. Flow chart for carbonization and physical activation in preparation of activated charcoal. Source: Okey, 2023

The most frequently used method of preparation of AC is the carbonization of the precursors at high temperature in an inert atmosphere followed by activation process (Allwar, 2012). The activation process could be achieved through physical and chemical methods. Physical activation involves treatment of char obtained from carbonization with oxidizing gases using steam or carbon dioxide at high temperature (400-10000C), depending on the type of precursor (Matali et al., 2013).

In chemical activation, the starting material is mixed with activating reagent and the mixture heated in an inert atmosphere (Ioannidou and Zabaniotou, 2005; Allwar, 2012). This process is usually done at a lower temperature and shorter activation time, and it produces higher surface area and better pores when compared to physical activation. Several studies have shown that chemical activation is better than physical activation in terms of lower temperature, higher yield and larger surface area (Tsai et al., 2007; Zhu et al., 2008). On the other hand, there are some disadvantages associated with chemical activation such as washing that is required to remove impurities arising from activating reagents due to their corrosive actions. The nature of the starting material plays a vital role in determining the quality, characteristics and properties of the resulting activated charcoal (Cagnon et al., 2009; Camphell et al., 2012; Abechi et al., 2013). The properties of the activated charcoal produced can also be influenced by the type of activating reagents, time of activation, impregnation condition and carbonization temperature (HirunPraditkoon et al., 2011).

4.4 Use of Activated Charcoal in odour in Water and Fish Pond

During the 20th century, powdered AC was used in the United States of America to control taste and odours in drinking water (Boonanuntanasarn et al., 2014). Studies by Etuk et al. (2014 and 2016) have specifically shown that such water sources commonly used in animal feeding have negative effects on the physiological performances of broilers. One of the major ways of cleaning contaminated water is by the use of activated carbon in the adsorption of metallic ions and bacterial toxins from waste water (Schmidt et al., 2019).

The earthy odours of organic compounds namely geosmin and 2 methylisoborne (MIB) have been a problem in pond-based fish farming (Boonanuntanasarn et al., 2014). These are metabolic products of some blue-green algae and bacteria which fish absorb from the surrounding water through their gills and intestines on ingestion thereby contributing to disease outbreaks and fluctuations in water quality and productivity (Boonanuntanasarn et al., 2014). Activated charcoal including granular and powdered AC have been demonstrated to be suitable for the removal of geosmin and MIB from drinking water.

CONCLUSION

Activated charcoal (AC) is a solid, porous, tasteless and black carbonaceous material prepared from a variety of carbon containing materials, including agricultural wastes. The surface chemistry of activated charcoal confers on it the ability to absorb many gases, aqueous liquids and poisons. The use of activated charcoal in animal farming reduces the harmful effect of ammonia and has the potential of reducing the greenhouse such as methane, hydrogen sulphide and nitrous oxide. In addition to enhancing nutrient uptake from feed raw materials, activated charcoal is proposed as an effective litter moisture and odour control in livestock and poultry farms. It is also widely used as feed additive, water purification and in odor control in poultry and fish production. Researchers have also shown that biochar captures 63% of ammonia and other gases such as methane, nitrous oxide, hydrogen sulphide, urea, organic acids, ketones, volatile vapours and noxious liquids found in animal manures. The effects are achieved when 5-20% of activated charcoal is blended with conventional litter and spread on the floor as an air purifier.

REFERENCES

AAFCO (2012). Official publication. Association of American Feed Control Officials. USA.

Abechi, S.E., Gimba, C.E., Uzairu, A. and Dalltu, Y.A. (2013). Preparation and characterization of activated carbon from palm kernel shell by chemical activation. Resource Journal of Chemical Science, 3(7): 54-61.

Adbullah, A. H., S. A. Shukor, M. S. Kamis, A. Y. M. Shakaff, A. Zakaria, N. A. Rahim, S. M. Mamduh, K. Kamarudin, F. S. A. Saad, M. J. Masnan, and H. Mustafa. 2017. "Calibration of an electronic nose for poultry farm". AIP Conference Proceedings.

Addul, A. and Aberuagba, F. (2005). Comparative study of the adsorption of phosphate by activated carbon from corncobs, groundnut shell and rice husk. AUJ Journal, 9(1): 59-63.

Adegbeye, M. J., M. M. M. Y. Elghandour, J. C. Monroy, T. O. Abegunde, A. Z. M. Salem, A. B. Barbabosa-Pliego, and T. O. Faniyi. 2019. "Potential Influence of Yucca Extract as Feed Additive on Greenhouse Gases Emission for a Cleaner Livestock and Aquaculture Farming – A Review."Journal of Cleaner Production 239:118074. https://doi.org/10.1016/j.jclepro.2019.118074.

Akamati, K. G. P. Laliotis, and I. Bizelis. 2023. "Greenhouse Gas Emissions of the Poultry Sector in Greece and Mitigation Potential Strategies." Gases 3 (1): 47-56. https://doi.org/10.3390/gases3010003.

Allwar, A. (2012). Characteristics of microporous and mesoporous structure and surface chemistry of activated carbon produced from oil palm shell. Presented at International Conference on Chemical, Ecology and Environmental Science (ICEES), Bangkok, 2012.

Al-Qodah, Z. and Shawabkah, R. (2009). Production and characterization of granular activated carbon from activated sludge. Brazilian Journal of Chemical Engineering, 26(1): 127-136.

Anukam, K. U. (2013). Development of simple technologies for the control of odours from pig dung. Department of Animal Science and Technology, Federal University of Technology Owerri, Nigeria.

Basic, A., Blomqvist, M., Dahlen, M.G. and Syensater, G. (2017). The Proteins of Fusobacterium Spp. involved in Hydrogen Sulphide production from

L-Cysteine. BMC Microbiology, 17: (1). https://doi.org/10.1186/s12866-017-0967-9.

Baski, S., Soumitra, B. and Mahajan, S. (2006). Activated carbon from bamboo technology development towards commercialization.

Baskin-Graves, L., Mullen, H., Aber, A., Sinisterra, J., Ayub, K., Amaya-Fuentes, R. and Wilson, S. (2019) Rapid health impact assessment of a proposed poultry processing plant in Millsboro, Delaware. International Journal of Environmental Research and Public Health 16 (18): 3429. https://doi.org/10.3390/ijerph16183429.

Bist, R. B., Subedi, S., Chai, L. and Yang, X. (2023). Ammonia emissions, impacts, and mitigation strategies for poultry production: A critical review. The Journal of Environmental Management, 328:116919. https://doi.org/10.1016/J.JENVMAN.2022.116919.

Boonanuntanasarn, S., Khaomek, P., Pitasong, T. and Hua, Y. (2014). The effects of the supplementation of activated charcoal on growth, health status and fillet composition-odor of Nile Tilapia (Oreochromis Niloticus) before and after harvesting. Aquaculture International, 22: 1417 – 1436.

Burdock, G.A. (1997). Encyclopedia of food and color additives. CRC Press, Boca Raton, USA.

Cagnon, B., Py, X., Guillot, A., Stoecidi, F. and Chambar, G. (2009). Contribution of hemicelluloses and lignin to the mass and the porous properties of chars and steam activated carbons from various lignocellulosic precursors. Bioresource Technology, 100(1): 292-298.

Campbell, Q.P., Bunt, J.R., Kasaini, H. and Kruger, D.J. (2012). The preparation of activated carbon from South Africa coal. Journal of Science African Institute Min. Metal, 112: 37-44.

Charles, E.B. (2005). Litter management for confined turkeys. Poultry Science and Technical Guide, No. 41, The North Carolina Agricultural Extension Service Bulletin. Pp. 3-7.

Chi, Q., Chi, X., Hu, C.X., Wang, S., Zhang, S.H. and Li, S. (2018). The Effects of atmospheric Hydrogen Sulphide on peripheral blood lymphocytes of chickens: Perspectives on inflammation, oxidative stress and energy metabolism." Environmental Research 167:1-6.

David, Y. (2015). Terra, 573-818-4148.www.dyarrow.org/carbonsmart.

Davis. (2005). Atherosclerosis an inflammatory process. Journal of Insur Medicine, (37): 72.

Dhyani, V. and Bhaskar, T. (2017). A comprehensive review on the pyrolysis of linocellulosic biomass. Renewable Energy, 35: 1-22.

Durunna, C.S., Abatai, U.G and Uchegbu, C. (2018). Performance evaluation of broiler chickens fed varying levels of raw african velvet tamarind, Icheku (Dialium guineense) wood charcoal as feed additive. Proceedings of 43rdAnnual Conference of the Nigerian Society for Animal Production, March 18th -22nd 2018 Owerri, Imo State, Nigeria. Pp: 514 -516.

Etuk, I. F., Ogbuewu, I. P., Iwuji, T. C., Okoli, I. C., Aladi, N. O., Williams, E. and Unamba-Opara, C. I. (2016). Physiological responses of broilers to drinking water from different sources in eastern Nigeria. International Journal of Agriculture and Rural Development, 19(1): 2422-2426.

Etuk, I. F., Ogbuewu, I. P., Iwuji, T. C., Okoli, I. C., Aladi, N. O., Williams, E. and Unamba-Opara, C. I. (2016). Physiological responses of broilers to drinking water from different sources in eastern Nigeria. International Journal of Agriculture and Rural Development, 19(1): 2422-2426.

Etuk, I. F., Ogbuewu, I. P., Okoli, I. C., Etuk, E. B., Iwuji, T. C., Obikoonu, H. O., Opara, M. N. and Odoemelam, V. U. (2014). Quality of different water sources used in poultry and piggery farms in southeastern Nigeria. International Journal of Agriculture and Rural Development, 17(2): 1847-1852.

Etuk, I. F., Ogbuewu, I. P., Okoli, I. C., Etuk, E. B., Iwuji, T. C., Obikoonu, H. O., Opara, M. N. and Odoemelam, V. U. (2014). Quality of different water sources used in poultry and piggery farms in southeastern Nigeria. International Journal of Agriculture and Rural Development, 17(2): 1847-1852.

Gerd, D. L. and Tondeur, W. (2001). Crucial role for training in manure management. Pig Progress, 17 (16): 20-22.

Hirunpraditkoon, S., Tunthong, N., Ruangchai, A. and Nuithitku, K. (2011). Adsoption capacities of activated carbons prepared from bamboo by

KOH activation. World Academy of Science, Engineering and Technology, 78: 711-715.

Ioaninidou, O. and Zabaniotu, A. (2005). Agricultural residues as precursors for activated carbon production. A review. Renewable and Sustainable Energy Reviews, 11: 1996-2005.

Iregbu, G. U., Kubkomawa, I. H., Okoli, C. G., Ogundu, E. C., Uchegbu, M. C. and Okoli, I. C. (2014). Environmental concerns of pig waste production and its potentials as bio-fuel Source. Journal of Animal and Veterinary Sciences, (3): 17-24.

Janocha, A., A. Milczarek, M. Kosmalski, P. Gajownik-Mu, and D. Radzimkowski. 2022. "Effect of Feed Additives Supplementation on the Growth Performance, Gastrointestinal Tract Characteristics, and Carcass Composition in Turkey Hens." Animals 12 (24): 3464. https://doi.org/10.3390/ani2243464.

Kalu, E., Ajaruonye, A.N. and Okwara, N. (2015). Waste Management Practices in selected poultry farms in Umuahia, Abia State. Journal of Veterinary Advances, 6(a): 1310 – 1316.

Kalus, K., Konkol, D., Korczynski, M., Koziel, J.A. and S. Opalinski, (2020). Effect of biochar diet supplementation on chicken broilers performance, NH3 and odor emissions and meat consumer acceptance." Animals, 10 (9): 1-13. https://doi.org/10:3390/ani10091539.

Kalus, K., Koziel, J. and S. Opalinski. (2019). A review of biochar properties and their utilization in crop agriculture and livestock production. Applied Sciences, 9 (17): 3494. https://doi.org/10.3390/app9173494.

Khali, H.P.S.A., Jawaid, M., Firozian, P., Rashid, U., Isalm, A. and Akil, H.M. (2013). Activated carbon from various agricultural wastes by chemical activation with KOH preparation and characterization. Journal of Bimobased Material Bioenergy, 7: 1-7.

Khan, A.M. and Ansari, R. (2009). Activated carbon preparation, characterization and applications: A review article. International Journal of Chemical Technology Resource, 1(4): 859-864.

Lee, P. D., Aarnink, A. J. A., Ogink, N. W. M. and Vertegen, A. M. W. A. (2005). Effects of environmental factors on odour emission from pig manure. American Society for Agricultural Engineers, 48 (2): 757-765.

Lowel, S. and Shields, J.E. (1998). Powder surface area and porosity. Springer Journal, Volume 2.

Ma, H., Li, F., Niyitanga, E., Chai, X., Wang, S. and Liu, Y. (2021). The odour release regularity of livestock and poultry manure and the screening of deodorizing strains. Microorganisms (Internet) 9(12): 2488. https://doi.org/10.3390/microorganisms9122488.

Madu, P.C. and Lajide, l. (2013). Physicochemical characteristics of activated charcoal derived from melon seed husk. Journal of Chemical and Pharmaceutical Research, 5(5): 94-98

Martinez, M.L., Torres, M.M., Guzman, C.A. and Maestri, D.M. (2006). Preparation and characterization of activated carbon from olive stones and walnut shells. Industrial Crops Production, 23: 23-28.

Matali, S., khairuddin, A.S., Sharifah, A.K and Hiduyu, A.R. (2013). Removal of selected gaseous effluent using activated carbon derived from oil waste: An overview. IEEE Symposium on Business, Engineering and Industrial Applications, Kuching, Sarawak.

Nwagwu, C., Ede, P.N., Okoli, I. C., Chukwuka, O. K., Okoli, C. G. and Moreki, J. (2012). Effect of environmental factors and structural dimension of aerial pollution gas concentrations in tropical poultry pen in Nigeria. International Journal of Applied Poultry Research, 1(1): 15-20.

Okey S.N. (2023). Assessment of the feeding value of agricultural waste-derived activated charcoal in chicken production. PhD Thesis, Departtment of Veterinary Biochemistry and Animal Production, College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike, Nigeria.

Okey, S. N., Ogbu, C. C., Akomas, S. C., Okoli, I. C. and Akpan, C. A. N. (2025). Egg quality parameters of Isa brown layer chickens fed varying dietary levels of activated charcoal. Journal of Sustainable Veterinary and Allied Sciences. March, 2025, 7(1): 6 – 12.

Okoli, C.G., Edo, F.A., Ogbuewu, I.P., Nwajiobi, V.H.A. and Okoli, I.C. (2019). Biochemical values of pig dung collected from different locations in Imo State, Southeastern, Nigeria. Asian Journal of Biological Sciences, 12(3): 470-476.

Olivares Marin, M., Fernade Z-gonzalez, C., Macias-Garcia, A. and Gonez-Serrano, V. (2006). Activated carbon surface properties. Applied Surface Science, 252: 5967.

Patil, K., Jeon, S., Lim, H., Byun, H.S. and Han, S. (2019). Removal of volatile organic compounds from air using activated carbon impregnated cellulose acetate electro spun mats. Environmental Engineering Research 24 (4): 600-607. https://doi.org/10.4491/eer.2018.336.

Piorkowska, K., Zukowski, K., Nowak, J., Poltowicz, K., Ropka-Molik, K. and Gurgul, A. (2016). "Genome-wide RNA-sequence analysis of breast muscles of two broiler chicken groups differing in shear force. Animal Genetics 47 (1): 68-80. https://doi.org/10.1111/age.12388.

Rattanawut, J., Areerat, A and Wigunda, R. (2021). Supplemental effect of bamboo charcoal and bamboo vinegar, alone or in combination, on laying performance, egg quality, intestinal bacteria populations and alteration of intestinal villi. Italian Journal of Animal Science, 20(1): 2211-2219.

Sashikala, M., Pillai, G. P., Xinguang, R. and Stuetz, M. (2012). Odour abatement of poultry litter using odour control products. A publication of Italian Association of Chemical Engineering, Vol. 30, Onlinewww.acidic.it.cet.

Saksrithal, K. and King, A. J. (2018). Controlling Hydrogen Sulphide emissions during poultry productions. Journal of Animal Research and Nutrition, 3(01). https://doi.org/10.21767/2572-549.100040.

Schmidt, H.P., Hageman, N., Drapper, K. and Kammann, C. (2019). The use of biochar in animal feeding. Peer Journal 7: e7373.

Selvarajh, G., Ch'ng, H.Y. and Zain, N. M. (2020). Effects of rice husk biochar in minimizing ammonia volatilization from urea fertilizer applied under waterlogged condition. AIMS Agriculture and Foods, 6(1): 159-171.

Sharma, N., Chot, K., Chot, M., Wu, S., Swick, R. and A. Swick. (2017). Nutritional effects on odour emissions in broiler production. World's Poultry Science Journal, 73 (2): 257-280.

Singh, A. K., and Kim. W. K. (2021). Effects of dietary Fiber on nutrients utilization and gut health of poultry: A review of challenges and opportunities. Animals, 11(1): 181.

Tsai, W.T., Chang, C.Y. and Lee, S.L. (1998). A low cost adsorbent from agricultural waste corn cob by zinc chloride activation. Bioresource Technology, 64: 211-217.

Verheijen, F., Diafas, I., Jeffery, S., Bastos, A. and Valde, M. V. D. (2010). Biochar application to soils: A critical scientific review of effects on soil properties and functions. European Commission Joint Research Centre, Brussels.

Wang, Y., W. Xue, Z. Zhu, J. Yamg, X. Li, Z. Tian, H. Dong, and G. Zou. 2019. "Mitigating Ammonia Emissions from Typical Broiler and Layer Manure Management – A System Analysis." Waste Management 93:23-33. https://doi.org/10.1016/j.wasman.2019.05.019.

Zhu, Z., Li, A., Xia, M. and Wan, J. (2008). Preparation and characterization of polymer based spherical activated carbons. Chinese Journal of Polymer Science, 26(5): 645-651.

ISBN: 978-625-92209-8