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Table of Content

Chapter I:

Sustainable Livestock Breeding ……………………………………………….………… 1

Muhammad SAFDAR, Muhammad TANVEER, Mehmet OZASLAN

Chapter II:

Molecular Genetics and their Advances ……………………...…………...……….. 24

Muhammad YOUNUS, Mehwish IQBAL, Nighat MUSHTAQ, Muhammad SAFDAR

Chapter III:

Livestock Breeding Systems and Strategies …………………….…………….…….… 39

Muhammad ASIM, Fakhar-un-Nisa, Faisal RAMZAN

Chapter IV:

Mendelian and Quantitative Genetics in Livestock ……………………….…….……… 51

Muhammad Mujeeb ULLAH

Chapter V:

Bioinformatics and Computational Genomics in Livestock …………..….…….……… 72

Hafiz Ishfaq AHMAD, Javeria AYOUB, Sara BIBI, Maaz ULLAH, Akhtar Rasool ASIF

Chapter VI:

CRISPR Technologies in Livestock …………………………………………….….. 98

Hafiz Ishfaq AHMAD, Sara BIBI , Maaz ULLAH, Javeria AYOUB, Akhtar Rasool ASIF

Chapter VII:

Role of Epigenetics On Gene Expression in Livestock ……………..……….…..….. 124

Huma NAZ, Tanveer AHMED, Ayesha YASEEN, Muhammad Hamza BABAR, Umamah IMRAN, Muhammad JAHANZAIB

Chapter VIII:

Genetics, functional genomics and selective breeding in livestock …………………...147

Fakhar-un-NISA, Muhammad ASIM

Chapter IX:

Communication and Information Technology (CIT) in livestock feeding…...………… 164
Si Ammar KADI, Azeddine MOUHOUS, Zahia DORBANE, Nacima ZIRMI-ZEMBRI, Hocine GUERMAH, Farid DJELLAL, Ali BOUZOURENE, Idir MOUALEK, Rabia CHERFOUH, Dahia SAIDJ

Chapter X:

Epigenetic Modifications in High-Performance Cows ……………………………….... 177
Maria NAZIR, Humera NAZIR, Khadija ZAFAR, Mariam ZAFAR, Mehmet OZASLAN

Chapter XI:

Advances in molecular genetics and selection of DNA markers in livestock ………..... 189
Muhammad MUJEEB ULLAH, Muhammad SAFDAR

Chapter XII:

Genomic Selection and Reproductive Biotechnology in Sheep and Goats ………..…. 209
Muhammad SAFDAR, Muhammad TANVEER, Mehmet OZASLAN

Chapter XIII:

Role of genetics and epigenetics on growth traits in chicken……………………..……232
Muhammad YOUNUS, Jawairia Mehrin NASIR, Muhammad RIZWAN, Muhammad SAFDAR

Chapter XIV:

Mechanisms of CRISPR-Cas systems in livestock ………………………………………250
Aneesa Riaz, Khadima, Maria Bibi, Muhammad Samiullah, Muhammad SAFDAR

Chapter XV:

Role of epigenetics on gene expression in livestock …………………………………..… 268
Muhammad YOUNUS, Aneesa RIAZ, Zulfiqar KHURSHEED, Muhammad SAFDAR

Chapter XVI:

Molecular Biotechnology and Its Pivotal Role in Advancing Animal Genomics ..…... 286
Muhammad TARIQ, Muhammad SAFDAR, Safdar Imran

Chapter XVII:

Microbiome Analysis for Precision Livestock Health Management ………………….. 308
Maria NAZIR, Qais MAHMOOD, Isha ARSHAD, Zubia RASHID, Mehmet OZASLAN

Communication and Information Technology (CIT) in livestock feeding

Si Ammar KADI
Azeddine MOUHOUS
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1. Introduction

The global livestock industry currently faces significant challenges in meeting the expanding demand for animal products, whilst concurrently minimising its environmental impact and optimising its utilisation of resources. This is further compounded by forecasts that the global population will continue to rise and reach 9.7 billion by 2050, resulting in an anticipated increase in demand for animal protein of over 70% (FAO, 2021). This projected increase poses significant challenges for the livestock sector as it is expected to have to address a number of issues, including climate change, the scarcity of resources, environmental degradation. Livestock production has been determined to be a significant source of greenhouse gas emissions, with a contribution of approximately 14.5% to the global emissions inventory (Gerber et al., 2013). Notably, the production of animal feed contributes substantially to this emissions footprint. Additionally, livestock production is under heightened scrutiny regarding its utilisation of water, land, and feed resources, particularly in the context of competing demands for these resources from human food production and other industries.

In the context of modern livestock feeding operations, CIT has emerged (Figure 1) as a transformative force, enabling precise monitoring and automation, and facilitating data-driven decision-making (Meena et al., 2024; Vlaicu et al., 2024). Digital innovations, including intelligent feeding systems, cloud-based platforms, and artificial intelligence-driven analysis, represent a paradigm shift in feeding strategies, thereby enhancing animal health, productivity and overall farm efficiency (Vlaicu et al. 2024). For instance, smart feeding systems equipped with IoT sensors have the capability to monitor feed intake in real time, thereby enabling farmers to adjust rations dynamically based on the needs of individual animals (Akhigbe et al., 2021). In a similar manner, AI-driven analytics have been shown to predict optimal feeding schedules and nutrient requirements, thereby reducing feed wastage and enhancing growth performance (Dayoub et al., 2024). These technologies enhance productivity and contribute to sustainability by minimising resource use and environmental impacts.

Further explanations reveal how the microbiome affects autoimmune diseases: SCFAs are related to the microbial activities and have the ability to exert immunomodulatory effects, influence the regulatory T cell balance (Ratajczak et al., 2019). The autoimmune reactions can also be attributed to the molecular mimicry, where microbial antigens are similar to host antigens. Secondly, if the gut barrier is compromised, it allows luminal microbial components to directly enter the blood stream and potentially worsen systemic inflammation and autoimmune processes (Wells et al., 2017).

This shift in the concept of microbiome, particularly with reference to autoimmune diseases has, significant implication for both fields of study. It offers the chance for a clinical focus in Phillipsburg, to emerge and establish pharmacological strategies based on the disruption of microbiota to correct immunological disorders (Duarte-Chavez et al., 2018). Possible solutions may include use of probiotics as well as prebiotics, diet change and a process called fecal microbiota transplantation (FMT). Subsequently, targeting of biomarkers with links to specific autoimmune diseases would mean early identification and diagnosis of the disease, and elevating the management of autoimmune diseases to the next level: the potential of biomarkers in autoimmune diseases (Giacomelli et al., 2019).

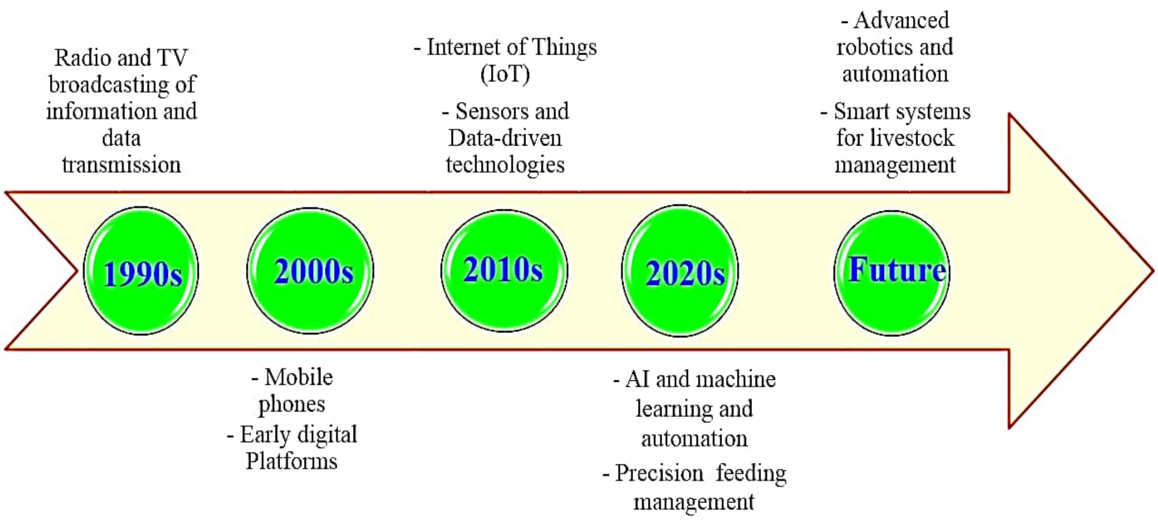

Figure 1. Timeline of CIT Evolution in Livestock Feeding

It is imperative to acknowledge the significance of feed costs in the domain of animal farming. A study conducted by Papadopoulos et al. (2025) has demonstrated that feed costs contribute to more than 60% of the total production costs, thereby underscoring its critical role in the realm of economic sustainability. Inadequate feeding strategies engender elevated costs and result in excessive nutrient excretion, thereby contributing to environmental pollution (Van Zanten et al., 2019). For instance, the presence of nitrogen and phosphorus from animal waste has been demonstrated to contaminate water bodies, resulting in phenomena such as eutrophication and biodiversity loss (Van Zanten et al., 2019). The employment of precision feeding systems, facilitated by CIT, has been identified as a solution to these challenges. These systems enable the delivery of the precise nutrients, in the optimal amounts and at the optimal time. Numerous studies have demonstrated the efficacy of this approach in reducing nitrogen excretion by up to 30%, thereby significantly mitigating environmental impacts (Domingos et al., 2024). Furthermore, these systems enhance feed conversion ratios, ensuring a greater proportion of feed is transformed into animal products rather than waste (Figure 2).

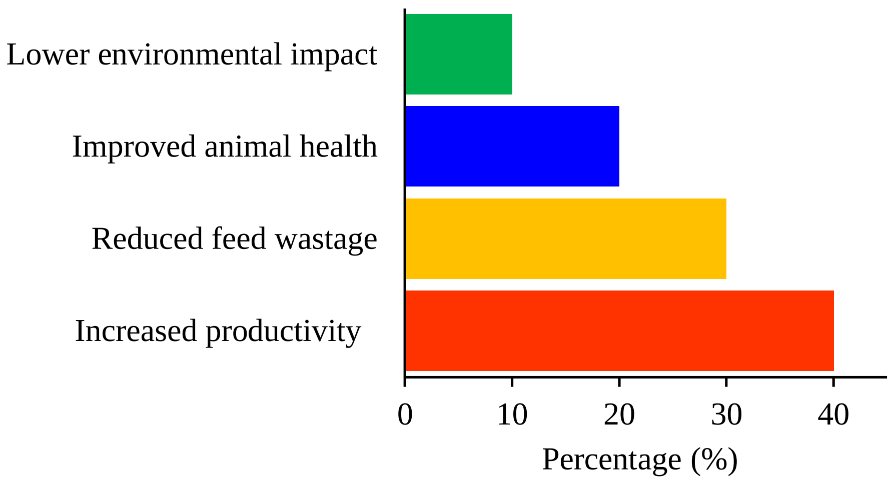

Figure 2. Benefits of CIT in Livestock Feeding

The integration of CIT into livestock feeding has been demonstrated to support animal welfare by facilitating the early detection of health issues and ensuring optimal nutrition is received by animals. Wearable sensors, for example, have been shown to monitor physiological parameters such as heart rate, rumination, and activity levels, thereby providing early warnings of metabolic disorders or stress (Neethirajan, 2020). This proactive approach to animal health has been demonstrated to reduce mortality rates and enhance productivity by maintaining animals in optimal condition. Furthermore, CIT facilitates traceability and transparency in the feed supply chain, ensuring that feed ingredients are safe, sustainable, and ethically sourced (Kamilaris et al., 2019). Blockchain technology, for instance, enables real-time tracking of feed ingredients from farm to fork, enhancing food safety and consumer trust (Neethirajan, 2020).

Notwithstanding the aforementioned advancements, the implementation of CIT in the domain of livestock feeding is confounded by several challenges. The initial costs are high, there is a paucity of technical expertise, and the infrastructure in rural areas is limited, which are significant barriers, particularly for small-scale farmers (Mahmud et al., 2021). Additionally, concerns about data security and privacy pose risks that must be addressed through robust cybersecurity measures and regulatory frameworks (Drape et al., 2021). Nevertheless, it is anticipated that the ongoing development of technology, in conjunction with favourable policies and educational programmes for farmers, will facilitate the overcoming of these obstacles and lead to the widespread adoption of CIT in the livestock feeding sector.

The present chapter offers a comprehensive exploration of the role of CIT in the field of livestock feeding, with a particular focus on recent advancements, prevailing challenges, and future prospects. It delves into the transformative impact of digital technologies, such as precision feeding systems, remote monitoring, decision-support tools, and blockchain, on the domain of livestock nutrition. The chapter further examines the economic, environmental, and social benefits of these technologies, while also addressing the barriers to their adoption. Finally, it outlines future prospects for CIT in livestock feeding, including the potential of emerging technologies such as quantum computing, edge computing, and robotics to further enhance efficiency and sustainability.

2. Precision Feeding and Digital Monitoring

2.1 Precision Feeding Systems

Precision feeding is defined as the process of administering the appropriate nutrients to livestock in the correct amounts and at the optimum times (Jiang et al., 2024; Su et al., 2024). CIT tools, including automatic feeders, smart scales, and real-time sensors, have been developed to ensure that feed composition and quantity are optimised (Wathes et al., 2008). Machine learning algorithms analyse feeding patterns and nutritional requirements, with the aim of reducing waste and improving growth performance (Wathes et al., 2008). Furthermore, precision nutrition minimises nutrient excretion, thereby contributing to environmental sustainability (Van Zanten et al., 2019).

Recent advancements in precision feeding systems have incorporated AI algorithms, which predict individual animal needs on the basis of real-time data (Assimakopoulos et al., 2025). For instance, Akintan et al. (2024) demonstrated the effectiveness of AI in optimising the formulations of animal feed for dairy cows, with results including improved milk yield and reduced feed costs. Furthermore, the integration of IoT devices with precision feeding systems facilitates seamless data collection and analysis, enabling farmers to make informed decisions promptly (Singh and Sharma, 2024).

2.2 Remote Sensing and Wearable Technologies

Advancements in sensor technology and the proliferation of IoT devices have facilitated the remote monitoring of livestock feeding behaviours by farmers. Wearable sensors have been employed to track various biological parameters such as rumination, feed intake, and digestion efficiency, thereby providing critical insights into animal health. These technologies have been shown to facilitate early detection of metabolic disorders and digestive issues, resulting in a reduction in morbidity and mortality rates (Neethirajan, 2020). The implementation of remote monitoring has not only led to a reduction in labour costs but also enhanced early disease detection through automated alerts, consequently leading to improved herd management (Bao and Xie, 2022).

Recent advancements in wearable technologies have given rise to the incorporation of biosensors that are capable of monitoring physiological parameters, including heart rate, body temperature, and stress levels. This development offers farmers a comprehensive view of their livestock's health status, facilitating timely intervention when issues are identified (Folarin et al., 2025). Furthermore, the integration of 5G technology has enhanced the reliability and the speed of data transmission from wearable devices, thereby further enhancing their utility in the field of livestock management (Raja et al., 2024).

A notable example of this is the use of GPS-enabled collars for the monitoring of cattle movements and feeding patterns during grazing in Australian agricultural settings (Menezes et al., 2024). These collars facilitate the analysis of movement and foraging data, which, in turn, provides farmers with the ability to optimise the utilisation of grazing land and to reduce overgrazing. The data collected via these collars is then subjected to analysis using AI algorithms, with the purpose of gaining insights into grazing behaviour patterns and the resulting environmental impacts.

3. Decision-Support Systems and Data Analytics

3.1 Role of Big Data in Livestock Nutrition

The integration of big data analytics into the realm of livestock feeding has empowered farmers to make decisions based on empirical data. The utilisation of cloud-based platforms facilitates the analysis of historical feeding data, the prediction of feed conversion rates, and the optimisation of rations. The employment of AI-powered analytics enhances feed efficiency, thereby promoting the sustainability of livestock production. Recent studies underscore the importance of predictive analytics in anticipating feed shortages and in the optimisation of supply chains (Can, 2024).

Emerging trends in big data analytics, as highlighted in the literature, include the application of machine learning models to predict the impact of climate change on feed availability and quality (Meena et al., 2024). This particular study utilised machine learning to forecast the effects of drought on forage production, thus enabling farmers to adjust their feeding strategies proactively. Furthermore, the employment of blockchain technology, when combined with the analysis of voluminous data, has enhanced transparency and traceability within feed supply chains (Yang et al, 2025). This, in turn, has facilitated the assurance of food safety and quality. A case study undertaken on a poultry farm offers an illustrative example of the merits of big data analytics. Through the analysis of historical feeding data and market trends, it's possible to refine farm's feed formulations, reducing costs and maintaining production levels (Brill et al., 2024). The farm's implementation of blockchain technology for the tracking of feed ingredients serves to ensure compliance with food safety regulations.

3.2 Decision-Support Software for Feed Management

The utilisation of software solutions, such as feed formulation programmes and nutrient optimization models, has been instrumental in aiding farmers in the selection of cost-effective feed ingredients (Brill et al., 2024). The incorporation of real-time market data in such tools has led to a reduction in feed costs while ensuring the maintenance of nutritional equilibrium. Decision-support systems have also been found to facilitate enhanced farm management and strategic planning by integrating data on climatic, economic, and animal performance (Kazembe and Mkandawire, 2024). Furthermore, the implementation of blockchain technology has been shown to enhance feed traceability, thereby ensuring increased transparency and food safety (Kamilaris et al., 2019).

The development of mobile applications that provide farmers with real-time recommendations has also been an area of recent advancement, with these applications enabling farmers to make informed decisions in real-time, and with the potential to improve the efficiency of feed management (Brill et al., 2024). Furthermore, the incorporation of AI algorithms into decision-support software has led to enhanced accuracy of feed formulation models, consequently resulting in improved nutritional outcomes for livestock (Martinez et al., 2024).

4. Challenges and Limitations

4.1 Barriers to Technology Adoption

The utilisation of CIT in livestock feeding systems has been demonstrated to offer numerous benefits. However, the adoption of these technologies is found to be variable, with financial constraints, a paucity of technical expertise, and infrastructural deficiencies being cited as the primary factors hindering their integration into farming practices. This is particularly pronounced among small-scale farmers, who face significant challenges in incorporating advanced feeding technologies into their operations (Table 1).

Table 1. Challenges and Solutions for CIT Adoption in Small-scale and Rural Farms.

Challenges	Solutions
Poor Infrastructure: no internet, unreliable power…	Mobile-Driven Information Systems : SMS-base advisory services, …
High Costs: expensive devices, software, …	Government subsidies and low-cost solutions
Lack of farmer training: low digital literacy, …	Training programs: workshops, online courses,…
Limited access to advanced tools: no access to ToT, AI tools…	Integration with traditional media: radio, TV,…

Studies have underscored the pivotal role of government support and knowledge transfer initiatives in overcoming these barriers. Recent research has emphasised the imperative of collaborative endeavours between governments, technology providers, and farmers in fostering the adoption of CIT in livestock feeding systems. According to Le Hoang Nguyen et al. (2023), farmers' cooperatives and extension services play a crucial role in facilitating the adoption of precision feeding technologies among small-scale farmers. Additionally, Mishra et al. (2022) state that the development of low-cost, user-friendly technologies has the potential to increase adoption rates in resource-limited settings.

4.2 Data Security and Privacy Concerns

Concerns have been raised regarding the use of digital technologies in livestock feeding and the associated risks to data security and privacy (Drape et al., 2021). These risks have been attributed to cyber threats, unauthorised access, and the potential misuse of sensitive farm data. It is imperative that robust cybersecurity measures are implemented to address these issues.In addition, regulatory frameworks must evolve to ensure data protection while enabling innovation in digital livestock management (Akintan et al., 2024). Recent advancements in cybersecurity have included the development of blockchain-based solutions for securing farm data. The decentralised and secure nature of blockchain technology is particularly well suited to the storage and dissemination of data, thus reducing the risk of unauthorised access (Yang et al., 2025). Furthermore, the employment of AI-driven cybersecurity tools has led to improvements in the detection and prevention of cyber threats within digital livestock management systems (Akintan et al., 2024).

5. Future Perspectives

The future of livestock feeding is likely to be shaped by ongoing advancements in computerised information technology (CIT). The development of blockchain technology for feed traceability, artificial intelligence-driven predictive models, and enhanced automation will further optimise feeding efficiency, policy frameworks and farmer education programmes will play a crucial role in overcame adoption barriers and maximising the potential of CIT in livestock nutrition. Additionally, the integration of robotics in feeding operations may further streamline processes and reduce labour requirements (Uzedhe et al., 2023).

The application of emerging technologies, such as quantum and edge computing, holds considerable potential for a paradigm shift in livestock feeding. Quantum computing, notably, is poised to enhance the accuracy of predictive models by processing vast datasets with greater efficiency (Menezes et al., 2024). Furthermore, the integration of edge computing, in conjunction with IoT devices, has the capacity to mitigate latency and enhance the reliability of data transmission, thereby facilitating expedited decision-making processes (Folarin et al., 2025).

6. Conclusion

Recent advancements in communication and information technology have profoundly impacted the realm of livestock feeding, leading to significant improvements in terms of precision, efficiency, and sustainability. While ongoing challenges persist, the continuous development of technological innovations and the establishment of favourable policy frameworks are poised to catalyse sustained progress in this domain. The integration of intelligent feeding systems, data Analytics and automation holds considerable promise for shaping the future of animal agriculture. Consequently, the integration of communication and information technology in the field of livestock feeding is imperative in ensuring the attainment of sustainable and robust food production systems, particularly in the face of prevailing global challenges.

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