Review

Applications of Smart Agriculture to Improve Animal Production: Opportunities, Challenges, Solutions, and Benefits

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Abstract: Smart livestock farming leverages technology to boost production and meet food demand sustainably. This study delves into smart technologies in animal production, covering opportunities, challenges, and solutions. Smart agriculture employs modern technology to enhance efficiency, sustainability, and animal welfare in livestock farming. It includes remote monitoring, GPS-based animal care, robotic milking, smart health collars, predictive disease control, and other innovations to achieve these goals. While smart animal production holds great promise, it does face challenges related to cost, data management, and connectivity. To address these challenges, potential solutions include remote sensing, technology integration, and farmer education. Smart agriculture offers opportunities for increased efficiency, improved animal welfare, and enhanced environmental conservation. A well-planned approach is crucial to maximize the benefits of smart livestock production while ensuring its long-term sustainability. This study confirms the growing adoption of smart agriculture in livestock production, with the potential to support sustainable development goals and deliver benefits such as increased productivity and resource efficiency. To fully realize these benefits and ensure the sustainability of livestock farming, it is essential to address cost and education challenges. Therefore, this study recommends promoting a positive outlook among livestock stakeholders and embracing smart agriculture to enhance farm performance.

Keywords: smart livestock farms; applications; opportunities; challenges; solutions; benefits

1. Introduction

Smart agriculture employs technology to enhance livestock productivity and efficiency. It achieves this by enhancing animal health, productivity, feed quality, traceability, and sustainability in meat and dairy production. Additionally, smart agriculture reduces resource consumption, such as water and land, while enhancing environmental quality. As a result, smart agriculture effectively enhances livestock management, leading to higher productivity and efficiency in livestock production, improved animal product quality, and increased environmental sustainability [1]. Smart agriculture has the potential to play a major role in addressing the challenges of feeding a growing global population sustainably.

Smart agriculture blends cutting-edge technology with traditional farming to increase efficiency and productivity in livestock production. It uses remote sensing, artificial intelligence, and data analysis to optimize farm management and maximize production and quality. Smart agriculture employs technologies such as sensors, robots, drones, and artificial intelligence to achieve these goals

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[2, 3, 4]. Smart agriculture is one of the most significant technologies that we have for addressing the challenges of feeding a growing global population sustainably.

Specific applications include monitoring animal health, automating tasks like feeding and watering, collecting data on health and feed consumption, and analyzing it to make informed production and management decisions. Smart agriculture greatly boosts farm efficiency, productivity, and sustainability, ensuring a secure and nutritious supply of animal products for the future [5, 6, 7]. Smart agriculture is the future of farming because it is the only way to meet the growing demand for food sustainably.

Smart agriculture brings multiple benefits to livestock farms, including improved animal health and welfare, increased productivity, and reduced environmental impact. Ongoing technological advancements ensure that smart agriculture will continue to play a crucial role in addressing livestock production challenges and enhancing production quality and efficiency [8, 9, 10]. Smart agriculture is a promising technology with the potential to improve the livestock industry significantly.

Applying Smart Agriculture to Improve Animal Production is crucial, as it harnesses cutting-edge technologies and data-driven methods to revolutionize animal farming. This topic holds significance in advancing animal welfare, resource efficiency, and agricultural sustainability. It provides potential solutions to meet the increasing global demand for food while mitigating environmental impact. Furthermore, it offers opportunities for farmers and industry stakeholders to elevate their practices and adapt to the ever-changing landscape of modern agriculture [11, 12, 13]. Smart agriculture is the future of animal farming, with the potential to transform it into a more sustainable, efficient, humane, and productive industry. It harnesses cutting-edge technologies and data-driven methods to make animal farming more precise and optimized while reducing its environmental impact.

This study aims to improve sustainability and productivity in the animal production sector, benefiting both farmers and the broader agriculture industry; it entails a comprehensive examination of smart technologies in animal production, including an exploration of their opportunities and challenges. The study offers directions for future research and development in this field.

2. Materials and Methods

This research reviews the latest technologies in animal production, highlighting opportunities, challenges, solutions, and benefits. It focuses on smart agriculture and its livestock applications.

2.1. Research Questions

Question 1: What are the applications of smart agriculture in animal production?
Question 2: What are some practical examples of smart livestock production farms?
Question 3: What is the role of Blockchain in livestock production farms?
Question 4: What opportunities, challenges, solutions, and benefits are associated with smart livestock production farms?
Question 5: How can smart agriculture technologies enhance sustainable livestock production?

2.2. Review previous studies on smart animal production

The researchers conducted a thorough literature review using a systematic approach, drawing conclusions from diverse academic sources. They accessed data from research institution websites, government agencies, and journals. Data extraction was precise, and careful attention was given to source information collection. The analysis prioritized findings supported by robust and consistent evidence from previous studies.

Smart livestock production uses technology to improve animal health, nutrition, monitoring, management, and marketing, which has a number of economic and social benefits (Figure 1).

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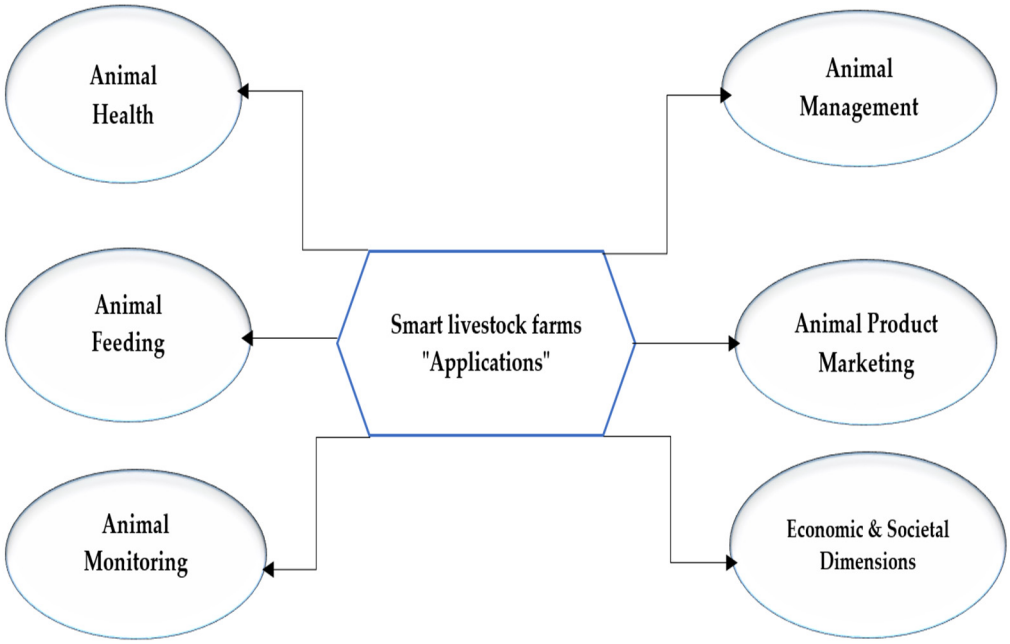

Figure 1. Shows a flowchart of primary smart agricultural applications in livestock production.

3. Results and Discussion

3.1. Applications of Smart Agriculture in Animal Production

3.1.1. Smart Health Care and Safety for Animals

Smart animal healthcare and safety is evolving, using technology to improve animal lives. Smart devices and artificial intelligence improve animal health by monitoring health and identifying patterns and trends. Smart animal healthcare and safety benefits include early disease detection [14, 15]. Biotechnology plays a crucial role in animal health, improving overall animal health. Biotechnology also improves animal health by new vaccines and drugs, and parasite control. Smart systems monitor animal well-being, administer medications, and enhance overall welfare and care [16, 17]. Smart technologies improve farm animal safety and welfare through sensors, artificial intelligence, virtual fencing, robotic milking, and automatic feeding. Smart farm technologies increase productivity, reduce environmental impact, and enhance public perception [18, 19, 20]. Smart technologies will play an increasingly significant role in animal care and health maintenance in the future [21, 22, 23]. Smart technologies improve animal health and welfare.

3.1.2. Smart Feeding Systems in Animal Production Farms

Smart feeding systems are revolutionizing livestock feeding. Sensors, data analysis, and automation power this innovative technology. High-accuracy animal feeding improves health, productivity, and profitability [24, 25]. Smart feeding systems use sensors and data analysis to improve animal feeding programs. They also monitor animals for feeding problems and take action [26, 27]. Smart feeding systems increase productivity and reduce labor costs. Data analysis and machine learning can improve feed composition, increase feed income, and reduce negative environmental impact [28, 29]. Needs-based feeding optimizes animal health, productivity, and environmental impact. Probes and sensors monitor feed and water consumption, ensuring nutritional balance. Feed management and graphical analysis improve feed efficiency by optimizing composition, schedules, and water quality. These efforts enhance resource efficiency [30, 31]. Smart feeding systems improve livestock productivity and profitability by using sensors, data analysis, and automation.

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3.1.3. Smart Monitoring and Control Techniques for Animals

Smart animal monitoring technologies are booming. Smart animal monitoring technologies collect real-time data to monitor and improve animal productivity and the environment. Sensing and tracking technologies revolutionize animal monitoring. Image analysis and remote sensing assess and track animal conditions on farms without breeder intervention, helping to assess their welfare [32, 33, 34]. Intelligent sensing and analysis technologies have the potential to revolutionize animal welfare, benefiting both animal farm management and conservation efforts. Bio-sensing and analysis technologies are advancing rapidly, resulting in innovative applications that can enhance animal production. These applications encompass improvements in animal health and welfare [35, 36, 37]. Smart animal monitoring technologies are revolutionizing animal welfare and benefiting both animal farm management and conservation efforts.

3.1.4. Smart Animal Management and Breeding Techniques

Smart animal management and reproduction technologies seek to improve animal productivity, well-being, and sustainable farming practices. Sensors and data analytics help to improve animal monitoring, breeding, and genomic selection. Robotics and smart technology improve farm efficiency, productivity, and animal welfare [38, 39]. Artificial insemination and selective breeding help to improve animal production, quality, and welfare. Smart chips and electronic tracking improve animal monitoring and herd management [40, 41]. Animal identification systems in livestock production will likely grow, enhancing productivity and quality. Ethical and privacy considerations are important for animal identification systems, ensuring ethical treatment and compliance with local laws [42, 43]. Smart animal management and reproduction technologies improve animal productivity, well-being, and sustainable farming practices by leveraging sensors, data analytics, robotics, and other technologies.

3.1.5. Marketing and Distribution of Smart Animal Production Farm Products

Smart farming applications improve livestock marketing and distribution through tracking, data analysis, remote monitoring, and marketing and branding. Smart farming applications provide real-time information to farmers and retailers about produce, ensuring food safety and traceability. Smart farming applications enhance decision-making, crop planning, livestock management, and logistical operations. Smart farming applications also boost efficiency in the animal production industry, increasing sales and profits [44, 45, 46]. To market smart animal products, emphasize the benefits to animals and owners, making care more convenient. To market smart animal products, run paid ads concentrating on product benefits and visuals. To sell smart animal products, create quality content that educates and attracts customers, and stay updated with industry trends. Effective marketing of smart animal products can increase awareness of their quality [47, 48, 49]. Smart farming applications improve livestock marketing and distribution by providing real-time information and enhancing decision-making.

3.1.6. Economic and Societal Dimensions of Smart Animal Farming

Smart animal production farms use technology to advance agriculture economically and socially. Smart farms use the Internet of Things (IoT), data analytics, and automation to improve operations and animal well-being, saving money and boosting efficiency. Smart farms also improve animal welfare, labor conditions, and sustainability, using technology and data to create a more sustainable and socially responsible future for agriculture [50, 51, 52]. Smart animal production farms use technology to improve agriculture economically, socially, and environmentally.

3.2. Practical examples of smart animal production farms

Smart agriculture technologies for animal production, welfare, and operations:

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3.2.1. Healthcare and Disease Management

Smart healthcare solutions for animals, such as remote monitoring and treatments, can improve timely care and reduce the need for physical veterinary visits, making the process more sustainable and efficient [53]. Smart healthcare solutions for animals are in their early stages of development but have the potential to revolutionize pet care by providing early detection of health problems. Smart healthcare solutions for animals are still in their early stages of development, they have the potential to make a significant positive impact on the lives of pets and their owners.

3.2.2. Animal welfare and nutrition improvements

Implementing facial recognition and machine vision technologies to monitor animal behavior and well-being can help ensure animal welfare, identify nutritional needs and detect potential productivity issues [54, 55]. It is important to note that these technologies should not be used to replace human interaction with animals. Humans should still be involved in the care and monitoring of all animals, even those that are being monitored by these technologies.

3.2.3. Livestock Tracking

Radio-frequency identification (RFID) or The Global Positioning System (GPS) livestock tracking enhances traceability, improving food safety and supporting sustainable practices by enabling precise resource allocation [56, 57]. RFID and GPS livestock tracking are positive developments for the livestock industry. These technologies have the potential to make the industry more efficient, humane, and sustainable.

3.2.4. Automated Milking Systems

Milking machines can improve efficiency, milk quality, and sustainability by milking cows at a predetermined time each day, saving energy [58]. Milking machines are a valuable tool for dairy farmers, improving efficiency, milk quality, and sustainability.

3.2.5. Smart Monitoring Systems

Smart livestock collars monitor activity levels, body temperature, and signs of illness or distress for animal well-being [59]. Smart livestock collars have the potential to play a significant role in improving animal well-being. By providing farmers and ranchers with real-time data about the health and behavior of their animals, smart livestock collars can help to identify and address potential problems early on, before they become more serious.

3.2.6. Animal Management Platforms

Farmers track animal veterinary history, growth rates, and performance metrics to make data-driven decisions for improved animal health and productivity [60]. Tracking and analyzing data can help farmers make better decisions about animal care, leading to healthier and more productive animals, reduced costs, and a more sustainable agricultural system.

3.2.7. Predictive Analytics

Data analytics and machine learning algorithms help farmers reduce resource wastage, optimize breeding, and promote sustainable animal husbandry practices by predicting diseases and developing breeding strategies [61]. Data analytics and machine learning can revolutionize agriculture, making it more sustainable, ethical, and profitable for farmers.

3.2.8. Smart Fencing and Containment

Smart fencing solutions can remotely or independently control animal movement, enhancing animal management and promoting resource conservation [62, 63]. Smart fencing solutions have the potential to revolutionize animal farming, making it more sustainable and profitable.

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3.3. Blockchain in Animal Production Farms

Blockchain technology can potentially revolutionize the livestock sector by offering a wide range of opportunities and benefits for farmers, consumers, and other stakeholders. However, it is important to be aware of the challenges associated with Blockchain technology, such as high initial investment costs, cybersecurity risks, lack of skilled labor, and regulatory challenges [64]. It is important to invest in research and development to address the challenges and to work together to create a supportive environment for the adoption of Blockchain technology. As the technology develops and matures, these challenges will be addressed likely, paving the way for Blockchain to play a transformative role in the livestock sector. The potential benefits of Blockchain technology for the livestock sector far outweigh the challenges [65, 66].

Blockchain has the potential to revolutionize the livestock sector, enhancing its efficiency, transparency, and sustainability. In the future, we can anticipate further innovative and impactful applications of blockchain in this sector, encompassing areas like traceability, food safety, sustainability, and food waste reduction. This technological advancement stands to offer significant advantages to both producers and consumers, fundamentally transforming the way we produce and consume food.

3.4. Opportunities, and Challenges for Smart Animal Production Farms

3.4.1. Opportunities

Smart animal production farms are on the rise, promising increased efficiency, higher yields, and reduced waste [67, 68]. They also improve animal welfare through data-driven monitoring and management and contribute to environmental conservation through sustainable farming practices [69, 70]. Technology integration in agriculture creates jobs in tech development, maintenance, and farm management, improving local economies. Big data from smart farms enables informed decisions and optimal resource allocation [71, 72, 73]. Automation and technology improve farm labor conditions. Smart farms can improve quality and traceability, catering to food safety-conscious consumers. They also foster research and innovation, bridging agriculture and tech [74, 75, 76]. By highlighting their environmentally friendly and socially responsible practices, farms can become sustainable and responsible brands, appealing to conscious consumers. Governments and regulatory bodies may offer incentives and support for smart farming, driving growth and shaping the future of agriculture [77, 78]. Smart livestock production farms offer opportunities to improve efficiency, sustainability, and ethical standards of animal agriculture. They also improve animal welfare and address major agricultural problems in the 21st century. Overall, opportunities can help farmers to improve animal welfare, increase productivity, and reduce environmental impact.

3.4.2. Challenges

Smart agriculture techniques can boost animal production, but face challenges. Advanced technology can be a valuable tool for smallholder farmers, but its high cost can be a barrier to adoption. Data management and privacy challenges in smart agriculture have been documented [79, 80, 81]. Communication and infrastructure gaps in remote or underdeveloped areas hamper tech adoption. Education and training for farmers is critical, but limited in areas with low literacy or resources [82, 83]. Integrating and matching smart farming tools to existing systems is complex and requires planning. Smart agriculture must be environmentally sustainable and ethical [84, 85]. Smart livestock farming faces regulatory, data, and integration challenges. Standard regulations should be established, data ownership rules should be clarified, and farmers should be facilitated to adopt smart practices [86, 87]. Adaptation to environmental variability, including climate change, is critical. Successfully addressing smart agriculture's multifaceted challenges is key to realizing its benefits for animal production, sustainability, ethics, and equitable access [88, 89, 90]. A holistic and well-planned approach is needed to implement smart animal production farms, addressing economic,

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technological, educational, and ethical considerations. Generally, challenges include cost, difficulty to use, and data privacy and security.

Smart technologies in animal production offer opportunities for operational efficiency, animal welfare, environmental impact, economics, employment, and decision-making, but there are also challenges related to cost, data, privacy, connectivity, infrastructure, and education. The benefits of smart technologies in animal production include increased profitability, sustainability, and animal welfare while reducing environmental damage (Figure 2).

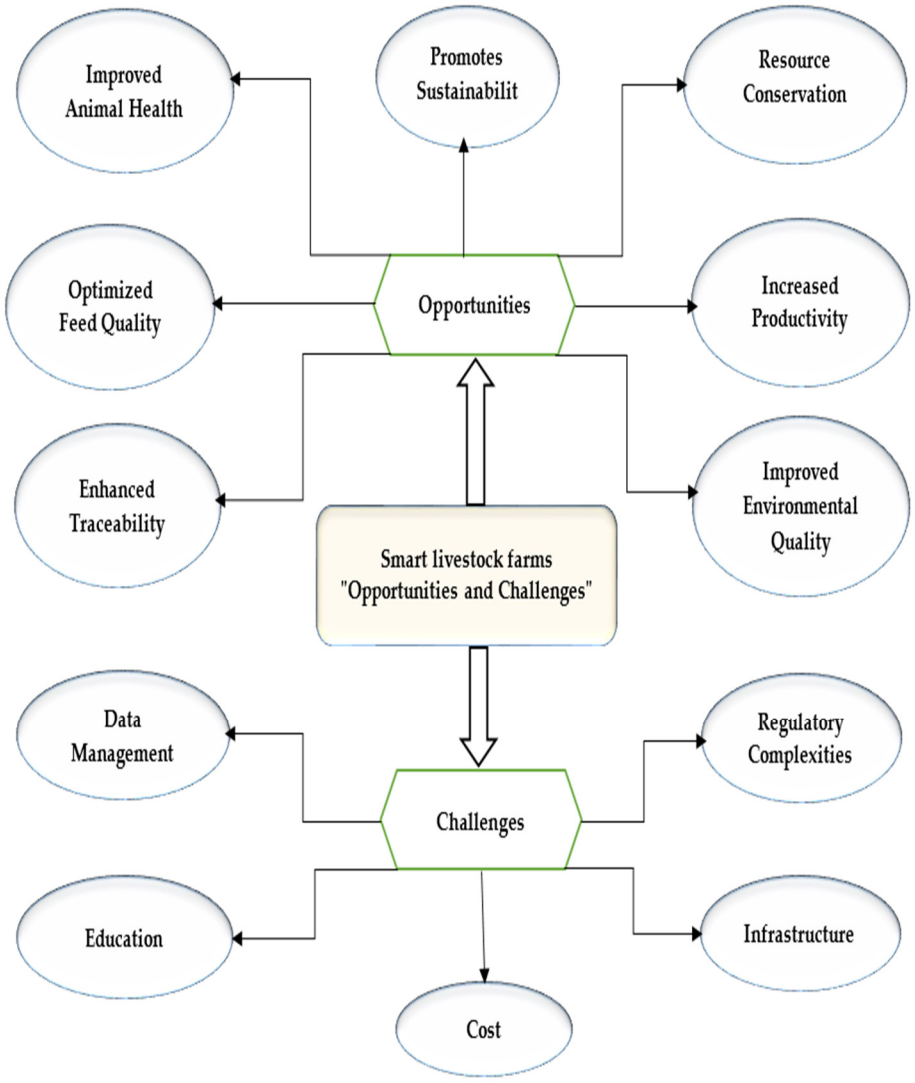

Figure 2. Shows a flowchart of opportunities, and challenges for smart livestock production farms.

3.5. Solutions and Benefits for Smart Animal Production Farms

Remote sensing and analysis, farm management systems, and technology can improve livestock productivity. Smart nutrition and artificial intelligence can also help, but farmer training is crucial [91]. Additionally, smart technologies in animal production offer benefits for profitability, sustainability, animal welfare, and the environment, but ethical considerations must be weighed [92]. Mostly, solutions can be made to address the challenges associated with smart agriculture in animal production. These include making smart farming technologies more affordable and providing training and support, developing data privacy and security standards.

Smart livestock farms use technology to monitor and manage livestock remotely, providing farmers with a number of benefits, including improved animal health and welfare, increased productivity, reduced costs, improved sustainability, and increased profits [93]. In addition, smart

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livestock farms can help to improve food safety, increase transparency, and create jobs. Smart livestock farm applications offer a variety of solutions to improve the efficiency, sustainability, and welfare of livestock operations. By using these applications, farmers can make better decisions about their operations and produce more food with fewer resources.

Smart livestock technology can be beneficial to increase farm efficiency and sustainability. Smart livestock farms use technology for solutions to remotely monitor, enhance animal welfare, increase productivity, improve cost efficiency, enhance sustainability, and increase profits. In addition, this technology enhances food safety, transparency, and employment opportunities (Figure 3).

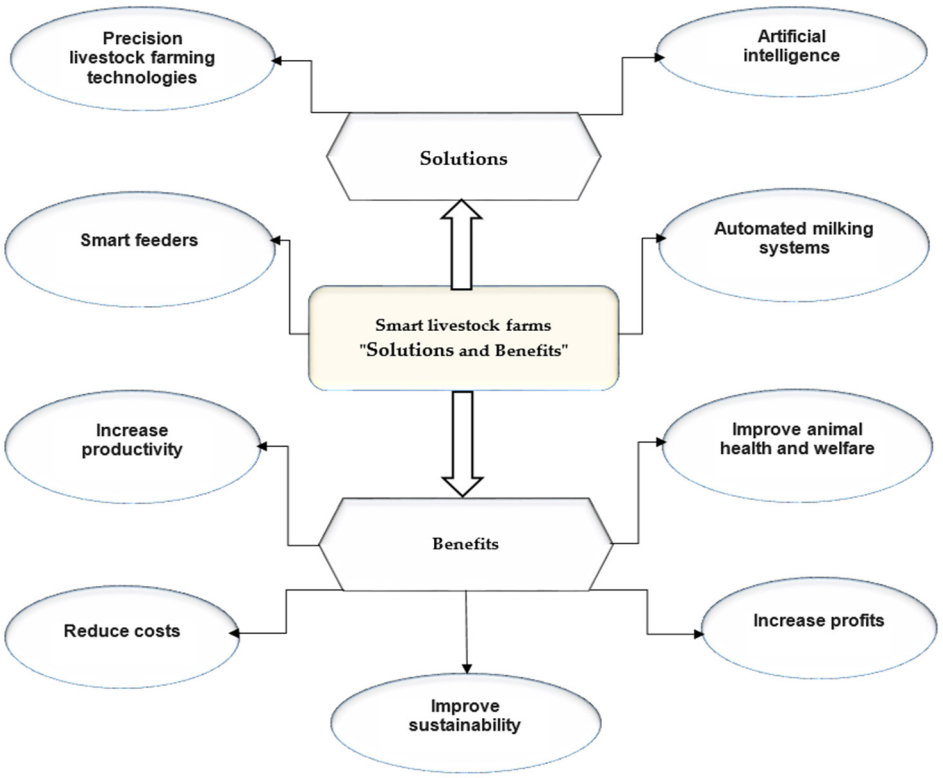

Figure 3. Shows a flowchart of solutions, and benefits for smart livestock production farms.

3.6. Directions for Future Research and Development in Smart Livestock Farms

The future of smart livestock farming is being shaped by a continued focus on innovation and the development of new technologies that enable farmers to enhance animal welfare, increase productivity, and adopt sustainable practices. Key directions for future research and development include precision livestock farming, artificial intelligence, robotics, and automation, as well as sustainable practices [94, 95]. Furthermore, further research and development are necessary for the integration of various smart agriculture technologies. This will help breeders optimize their investments in smart farming technologies, thus creating smooth and efficient smart livestock farms and enhancing the sustainability of smart livestock production systems.

4. Conclusions

Smart agriculture is a rapidly growing field with great potential to boost livestock production and achieve sustainable development goals. Smart agriculture can increase livestock production, improve resource efficiency, and enhance animal welfare. Addressing cost, education, and policy challenges is critical for the success of smart agriculture and sustainable livestock. Smart agriculture can revolutionize livestock by using technology to collect, transmit, store, and analyze data, generate

insights, provide real-time information, control conditions, and automate tasks. This can improve animal welfare, increase productivity, and reduce costs. As the technology continues to develop and become more widely adopted, we can expect to see even more innovative and transformative applications in the years to come.

Smart agriculture technologies have the potential to revolutionize livestock production, making it more sustainable, efficient, and profitable. However, these technologies are still in their early stages of development and face some challenges, such as cost and training. Nevertheless, the potential benefits are significant, and smart agriculture technologies will likely play an increasingly important role in livestock production in the future. Smart livestock farming is a promising new approach that can help us meet the challenges of feeding a growing population sustainably. This research holds a positive outlook regarding its capacity to transform the livestock sector and play a substantial role in enhancing food security.

5. Recommendations

Stakeholders interested in livestock production should have a positive outlook when implementing smart agriculture. Integrating smart technologies with the animal production sector can enhance the performance of animal production farms. Therefore, this research recommends that breeders adopt smart technology in livestock farms.

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