Compendium of Agronomy
ISSN Print: 3079-5486
ISSN Online: 3079-5494
https://doi.org/10.63313/AGR.4001

Research Progress and Prospect of Automation and Intelligent Technology in Beef Cattle Breeding Equipment

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How to cite this paper: Wang, X., & Yang, F. Z. (2025). Research Progress and Prospect of Automation and Intelligent Technology in Beef Cattle Breeding Equipment. Compendium of Agronomy, 1(1), 1-8. ISSN Print: 3079-5486, ISSN Online: 3079-5494. https://doi.org/10.63313/AGR.4001
Published: 2025-09-26

Abstract

With the rapid development of modern technology, the application of automation and intelligent technologies in the beef cattle breeding industry has become increasingly widespread. This paper provides a detailed overview of the current status of the beef cattle breeding industry and conducts an in-depth exploration of technological advancements in areas such as intelligent detection of beef cattle physical signs. The intelligent physical sign detection technology is conducive to real-time monitoring of the health status of beef cattle and enables early warning of diseases. Meanwhile, it looks ahead to the future development trends of automation and intelligent technologies for beef cattle breeding equipment, aiming to provide a reference for promoting the modernization and transformation and upgrading of China's beef cattle breeding industry, as well as facilitating the sustainable development of the beef cattle breeding sector.

Keywords

Beef cattle breeding; Automation; Intelligentization; Physical sign detection

1. Introduction

As a crucial component of the animal husbandry industry, the beef cattle breeding sector plays a key role in ensuring meat supply, boosting farmers' income, and driving rural economic development. In recent years, with the improvement of people's living standards, the demand for beef has continued to grow, which has put forward higher requirements for the scale and quality of the beef cattle breeding industry[1].The traditional beef cattle breeding model relies mainly on manual experience and suffers from numerous drawbacks, such as high labor intensity, low production efficiency, severe resource waste, and difficulty in achieving precise management. These issues have made it no longer able to meet the development needs of modern animal husbandry.The rapid advancement of automation and intelligent technologies has brought new opportunities to the beef cattle breeding industry[2].

By introducing advanced equipment and technologies into the breeding process, it is possible to achieve precise control and intelligent management of breeding links, effectively improving production efficiency, reducing costs, enhancing beef quality, and minimizing environmental impact.Intelligent feeding equipment can accurately adjust feed formulas and perform automated feeding based on factors such as the beef cattle's growth stage, weight, and health status, thereby avoiding feed waste and improving feed conversion rates[3]. Intelligent feed pushing equipment can automatically complete the work of pushing forage, reducing manual operations, improving work efficiency, and ensuring that beef cattle have access to sufficient feed at all times.Relying on various sensors and intelligent algorithms, the intelligent physical sign detection technology monitors the physiological indicators of beef cattle in real time—including body temperature, heart rate, respiratory rate, and activity level. It promptly identifies and issues early warnings about the cattle's health problems, providing strong support for disease prevention and control[4].

Currently, significant achievements have been made in automation and intelligent technologies for beef cattle breeding overseas, and these technologies have been widely applied in large-scale breeding farms. In contrast, although China has also made certain progress in this field, the overall application level remains relatively low. There are several prominent issues, such as lagging technological R&D, high equipment costs, and weak informatization infrastructure in breeding farms.Therefore, conducting in-depth research on automation and intelligent technologies for beef cattle breeding equipment, and accelerating their application in China's beef cattle breeding industry, hold important practical significance for enhancing the competitiveness of China's beef cattle breeding sector and realizing the sustainable development of the industry[5].

2. Current Status of the Beef Cattle Breeding Industry

2.1. Industry Scale and Development Trends

In recent years, the scale of the global beef cattle breeding industry has maintained a steady growth momentum. With the increase in population and the continuous improvement of residents' living standards, the consumer demand for beef has been rising steadily, which has, to a certain extent, driven the development of the beef cattle breeding industry. Among the major beef cattle breeding countries, the United States, Brazil, and China rank among the top in the world in terms of beef production. Beef cattle are mainly distributed in Asia (accounting for 39%), India (30.3%), South America (30.1%), and Brazil (26.1%)[6].

The United States has long maintained a leading position in beef production, thanks to its vast pasture resources and advanced breeding technologies. Brazil's beef cattle breeding industry has developed rapidly; relying on its abundant land resources and low breeding costs, it holds an important share in the international beef market. As a country with a large population, China has an enormous demand for beef. Although

the scale of its beef cattle breeding industry has been expanding continuously, it still cannot fully meet the entire demand of the domestic market, and a certain amount of beef needs to be imported from abroad every year.

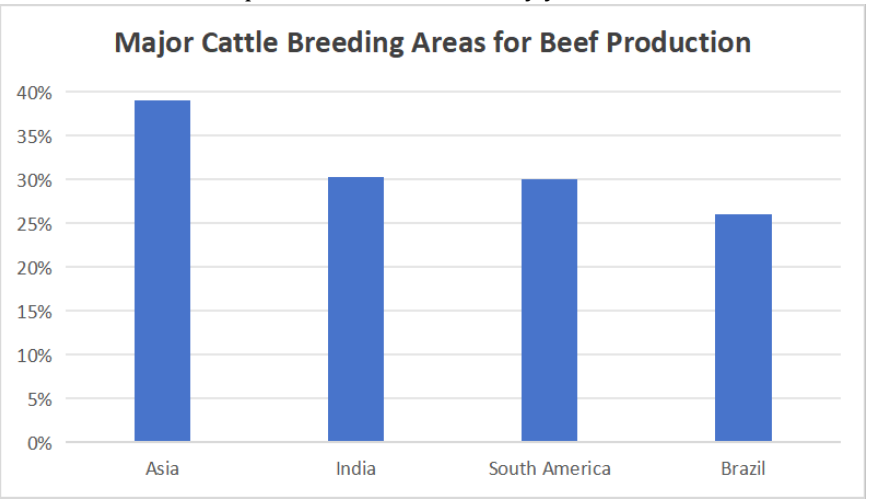

Figure 1. Major Cattle Breeding Areas for Beef Production

From the perspective of development trends, the beef cattle breeding industry is moving toward large-scale, intensive, and intelligent development.Large-scale breeding can give full play to the advantages of resource integration, improve production efficiency, reduce production costs, and enhance market competitiveness. Intensive breeding focuses more on the efficient use of resources and environmental protection[7]; through scientific feeding management and the application of advanced technologies, it achieves the sustainable development of beef cattle breeding. Intelligent breeding, which leverages modern information technologies and automated equipment to conduct precise control and intelligent management of the breeding process, improves breeding efficiency and product quality—it is an important direction for the future development of the beef cattle breeding industry.

2.2. Drawbacks of Traditional Breeding Models

In certain regions of China, the traditional beef cattle breeding model is still in use. This model relies primarily on manual experience for feeding and management, and is associated with numerous drawbacks.It is difficult to achieve precise control over feed rations through manual feeding, which easily leads to either feed waste or insufficient feeding. According to surveys, the feed waste rate under the traditional breeding model is as high as 15%-20%[8]. This not only increases breeding costs, but also causes certain pollution to the environment.The growth environment of beef cattle under the traditional breeding model cannot be effectively controlled. Conditions such as temperature, humidity, and ventilation in cattle sheds often fail to meet the growth needs of beef cattle, which makes the cattle prone to diseases and adversely affects their growth rate and health status.The manual monitoring of

beef cattle's health conditions and growth performance is inefficient and limited in accuracy. It is difficult to promptly detect potential disease risks in beef cattle, resulting in delayed disease treatment and economic losses.

The traditional breeding model involves high labor intensity and a high degree of dependence on the labor force. With the transfer of rural labor, the problem of labor shortage has become increasingly prominent, which restricts the development of the beef cattle breeding industry.

2.3. The Demand for Automated and Intelligent Breeding

Facing the various drawbacks of the traditional breeding model and the higher requirements of the market for beef quality and quantity, the beef cattle breeding industry has an increasingly urgent need for automated and intelligent technologies. Automated and intelligent breeding can effectively solve the problems existing in the traditional breeding model, achieving precise feeding and management, improving feed utilization, and reducing breeding costs. Through the intelligent environment control system, the environmental parameters of the cattle shed can be monitored and adjusted in real-time, providing a comfortable growth environment for beef cattle and reducing the occurrence of diseases[9]. The intelligent detection technology of physical signs can grasp the health status of beef cattle in real-time, promptly detect diseases and issue warnings, providing a scientific basis for disease prevention and control, and improving the survival rate and growth performance of beef cattle[10]. Therefore, accelerating the application of automated and intelligent technologies in beef cattle breeding is an inevitable choice for the transformation, upgrading, and sustainable development of China's beef cattle breeding industry.

3. Intelligent Equipment for Beef Cattle Breeding

3.1. Sensor-Based Monitoring of Beef Cattle Physiological Parameters

Sensor-based monitoring of beef cattle physiological parameters serves as a critical means to realize intelligent detection of beef cattle physical signs. By attaching various types of sensors to beef cattle or installing environmental sensors inside cattle sheds, real-time collection of data can be achieved—this includes not only the physiological parameters of beef cattle (such as body temperature, heart rate, respiratory rate, activity level, and rumination behavior) but also the environmental parameters within cattle sheds, such as temperature, humidity, and ammonia concentration. Body temperature is one of the key indicators reflecting the health status of beef cattle. Currently, commonly used sensors for body temperature monitoring include thermistor sensors and infrared sensors[11]. Thermistor sensors typically require implantation into the beef cattle's body or measurement through contact with the body surface; while they deliver relatively accurate results, their operation is comparatively complex. In contrast, infrared sensors belong to non-contact

measurement tools: they obtain body temperature data by detecting infrared radiation from the beef cattle's body surface, and possess advantages such as convenient operation and minimal stress imposed on the cattle.For the monitoring of heart rate and respiratory rate, electrocardiographic (ECG) sensors and respiratory sensors are generally employed. ECG sensors can collect electrocardiographic signals via electrode pads attached to the beef cattle's body surface, which are then used to calculate the heart rate. Respiratory sensors, on the other hand, can measure respiratory rate by detecting chest fluctuations or changes in air flow of the beef cattle.

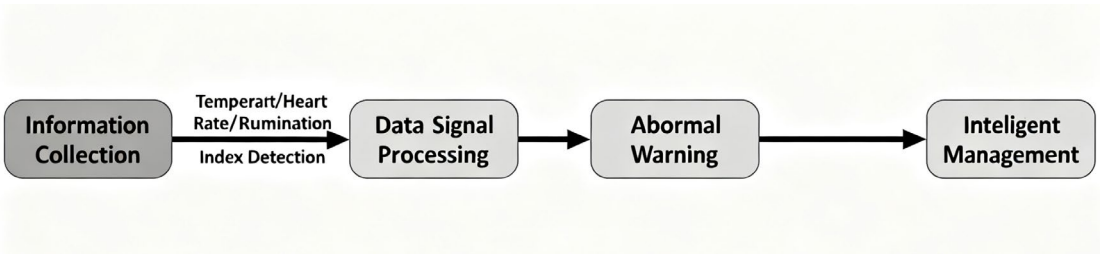

Figure 2. Beef Cattle Physiological Sign Monitoring Chart

Monitoring of activity levels is primarily achieved through accelerometers. These sensors can be installed on parts of beef cattle such as the neck or legs to monitor their movement status and activity intensity in real-time.Rumination behavior is a crucial part of the digestive process in beef cattle. Monitoring rumination behavior helps understand the health status of beef cattle and the digestion of feed. Currently, commonly used rumination monitoring methods include microphone-based acoustic monitoring and sensor-based chewing motion monitoring. The microphone-based acoustic monitoring method judges rumination behavior by collecting sound signals emitted during rumination, while the sensor-based chewing motion monitoring method realizes rumination monitoring by detecting the chewing movements of beef cattle through sensors installed on their ears or necks.Through real-time monitoring and analysis of these physiological parameters, health problems and abnormal behaviors of beef cattle can be detected in a timely manner, providing a scientific basis for disease prevention and control as well as feeding management.

3.2. Intelligent Feeding Pushing Equipment for Beef Cattle

The automatic feeding pusher robot is a new type of intelligent feeding pushing equipment for beef cattle developed in recent years. Its design aims to simulate the movement of manual feeding pushing, realize the automatic pushing of forage, and improve work efficiency. Generally, the automatic feeding pusher robot is composed of a mobile chassis, a feeding pushing device, a control system, sensors and other components. The mobile chassis adopts a wheeled or crawler-type structure, which has good mobility and stability and can travel freely in the cattle shed. Installed at

the front end of the mobile chassis, the feeding pushing device is usually driven by hydraulic pressure or electricity, and can automatically adjust the pushing force and angle according to the accumulation of forage.

The working process of the automatic feeding pusher robot is as follows: First, sensors (such as lidar, cameras, etc.) installed on the robot perceive the environment inside the cattle shed and identify the position and accumulation state of the forage. Then, the control system plans the robot's driving path and feeding pushing actions based on the information fed back by the sensors. The robot moves to the forage accumulation area along the planned path, and starts the feeding pushing device to push the forage to a position where beef cattle can easily access the feed. During the feeding pushing process, the sensors monitor the working state of the feeding pushing device and the position of the robot in real time to ensure the accuracy and safety of the feeding pushing action. After completing the feeding pushing task in one area, the robot automatically travels to the next area that needs feeding pushing and continues its work.

Figure 3. Intelligent Feeding Pusher Robot

To achieve the intelligent operation of feeding pushing equipment, advanced control technologies are required. Currently, commonly used intelligent control technologies include sensor-based feedback control, path planning and navigation technology, and artificial intelligence algorithms.Sensor-based feedback control involves installing various sensors on the feeding pushing equipment, such as pressure sensors, position sensors, and speed sensors, to monitor the equipment's operating status and working parameters in real time and feed this information back to the control system[12]. The control system adjusts and optimizes the equipment's operation based on the feedback information, ensuring that the feeding pushing equipment works in accordance with predetermined requirements. For instance, pressure sen-

sors are used to monitor the force exerted by the feeding pushing device during the pushing process; when significant resistance is encountered, the control system automatically adjusts the driving force of the feeding pushing device to prevent equipment damage.

Path planning and navigation technology enables the feeding pushing equipment to independently plan driving paths in complex cattle shed environments and accurately navigate to target locations[13]. Commonly used path planning algorithms include the A* algorithm and Dijkstra's algorithm. These algorithms can calculate the optimal path from the starting point to the destination based on the cattle shed's map information and obstacle distribution. Navigation technology mainly relies on the Global Positioning System (GPS), inertial navigation systems, and visual navigation systems to realize the positioning and navigation of the feeding pushing equipment. For example, a visual navigation system collects image information inside the cattle shed through a camera and uses image processing algorithms to identify feature points and landmarks in the cattle shed, thereby determining the position and driving direction of the feeding pushing equipment.

4. Conclusion

This paper presents a comprehensive review of the automation and intelligent technologies for beef cattle breeding equipment, covering aspects such as the current status of the beef cattle breeding industry, intelligent feeding pushing equipment, and intelligent physical sign detection.Regarding the industry status, it is clarified that the global beef cattle breeding industry is experiencing scale expansion and evolving toward large-scale, intensive, and intelligent development. Meanwhile, it is pointed out that the traditional breeding model in China has numerous drawbacks, leading to an urgent demand for automated and intelligent breeding practices.

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