Design and Implementation of Traceability System for Beef Cattle Product Quality and Safety

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Abstract: The demand for high-quality and safe beef products is increasing as consumers prioritize traceability and food safety. However, the beef product market faces challenges in terms of information sharing and traceability, leading to safety concerns. Establishing a comprehensive traceability system for Chinese beef cattle products can address these issues and enhance the modernization of animal husbandry production and international competitiveness. This study presents a four-layer architecture for a beef product quality and safety traceability system, incorporating identification technology, data synchronization, and data management. RFID and QR code technologies are utilized for individual cattle tracking, while data synchronization ensures efficient communication between the backend and frontend. Data management and analysis technologies enable real-time monitoring of breeding, feeding, and slaughtering processes. The system design includes modules for data collection, processing and storage, analysis and application, traceability queries, alarms, and system management. The study emphasizes the importance of implementing a traceability system for Chinese beef cattle products to meet consumer demands, enhance animal husbandry production, and improve international competitiveness. The proposed architecture and system design aim to provide a reliable and efficient solution for ensuring the quality and safety of beef products, benefiting both consumers and regulatory authorities.

1. Introduction

In a broad sense, beef products refer to various food and non-food products obtained from cattle. According to data from the beef supply and demand balance table, in 2022, China's beef production was 6.92 million tons, a year-on-year increase of 1.32%; domestic beef consumption was 10.149 million tons, a year-on-year increase of 3.95%; China's beef imports also grew rapidly, reflecting the overall undersupply of beef in China [1]. With the improvement of people's living standards and the change of consumption concepts, there is an increasing demand for high-quality and safe food, and such products have gradually become consumers' preferred choices. 1489 consumers were surveyed about their purchase of pork, and the results from the mixed logic model and latent class model showed that "products with traceability information covering breeding, slaughter and processing, distribution and sales" are one of the most favored product characteristics by consumers [2].

The beef product market is a global market with fierce competition, but the corresponding management system is not perfect, and there is a lack of information sharing among various links,

which in turn makes it difficult to trace the source of beef products once there is a safety problem. Safety issues related to beef products, such as "mad cow disease" and "horse meat posing as beef", have caused widespread panic. Some scientists attempted to trace the information clues generated along the supply chain and whether they are related to the corresponding carcass and the identity of the live animals from the breeding farm by tracking beef products samples from retail stores. The conclusion was that the supply chain for Malawi local beef and beef sausages was untraceable [3].

To address the safety issues of beef cattle products, production companies should increase their awareness of food safety issues, while regulatory authorities should strictly monitor the production process and establish a traceability system is the most effective, economical, and convenient way to monitor food safety issues [2]. Developed countries are placing increasing emphasis on traceability as an important tool for maintaining food safety [4]. Moreover, due to the relatively mediocre domestic beef cattle production capacity, lack of competitiveness in beef cattle brands, and large domestic supply-demand gap, the quantity of live cattle exports in China's beef cattle industry is extremely low [5]. Therefore, establishing a complete traceability system for Chinese beef cattle products can not only meet the needs of consumers for traceability of safe and high-quality beef, but also significantly improve the modernization level of China's animal husbandry production and the international competitiveness of animal products [6]. The production process of beef cattle products includes breeding, feed production, slaughter, processing, transportation, and other links, which require the coordinated efforts of multiple industry chain links to achieve full traceability, leading to considerable difficulty. Jianying Feng et al. attempted to develop and evaluate a cow/cow meat traceability system integrated with RFID technology, PDA, and barcode printers in 2013, but the system's cost was high, and the efficiency of data input and communication mechanisms was low [7]. In 2015, scientists proposed cattle live 15-bit tracing code to achieve full digital management of beef cattle from breeding, transportation, slaughter, segmentation, storage, processing, and complete entry into the market [6]. This system seeks to establish a comprehensive beef cattle product quality and safety traceability system, which includes basic information, breeding information management, slaughter information management, sales information management, transportation information management, and traceability information management, etc., to facilitate regulators' supervision of beef cattle product quality and safety, and to provide consumers with multi-channel traceability information services such as the Internet.

2. Overall Architecture

The beef product quality and safety traceability system presented in this paper adopts a four-layer architecture, as shown in Figure 1. The underlying data layer uses network services infrastructure and formulates standards and specifications for breeding, slaughtering, sales, and logistics companies to obtain relevant data and store it in the system's central database. The data support layer is responsible for configuring the central database system and operating a series of functions, such as synchronizing, managing, processing and refining the data. The processed data feeds into the application layer where it is classified and managed by module. The system function management includes five modules: basic information, breeding information, slaughtering and processing, Transport and sales, and traceability information. Additionally, the System user management through six modules: user information, system menus, user permissions, system logs, system upgrade maintenance, and system security. Eventually, breeding companies, slaughterhouses, consumers, and others can enter or obtain information through various media such as mobile phones, computers, etc., and achieve complete quality and safety traceability of beef products.
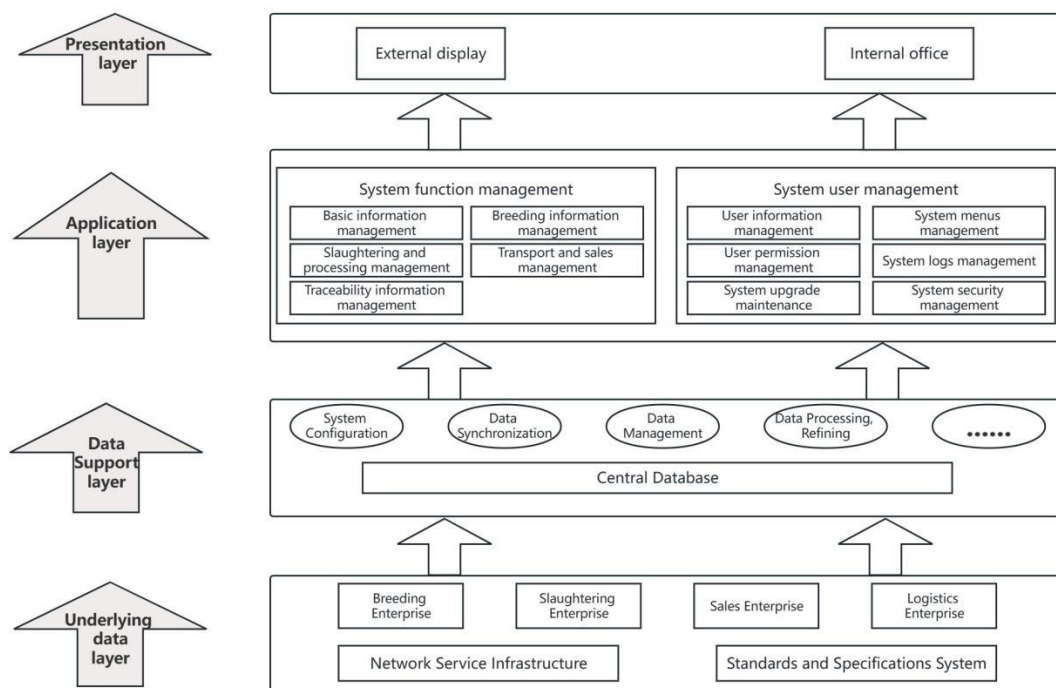
Figure 1: Overall architecture diagram

3. Key Technology Analysis

3.1 Identification Technology

The key to traceability system is uniqueness and coding and standardized management [8]. At present, RFID (Radio Frequency Identification), QR code and other technologies have been widely used. These technologies can record and track individual information, breeding history, feed sources, vaccine use and other data of beef cattle, so as to realize whole-process traceability of beef cattle. The RFID tag is affixed to the ears of beef cattle, and the information on the tag can be read through the RFID reader to track and manage the beef cattle. After the beef cattle out of the cattle pen, the QR code is printed on the body of the beef cattle or on the meat packaging. By scanning the QR code, the relevant information of beef cattle can be queried, including production information, transportation information, processing information and so on. In this traceability system, through the unique card number of RFID, the background database will give the unique identification ID number of beef cattle products. According to the unique identification ID number, the corresponding QR code can be generated by using the QR code generator, which is equivalent to the ID card of the beef cattle products. Finally, the QR code is affixed to each beef cattle product at the point of sale, which records all relevant information of the beef cattle individual [9]. Users can scan the QR code or input the source code below the QR code to obtain the whole process information of beef cattle products from the cattle pen to the point of sale.

3.2 Data Synchronization

The architecture design of beef cattle product quality and safety traceability system adopts B/S architecture to achieve data synchronization between back-end and front-end, improve the work efficiency of beef cattle farmers in the cattle pen and reduce the work intensity. By utilizing the B/S three-layer architecture mode, the reliability of the system and the suitability of the growing

environment for beef cattle in the cowshed can be guaranteed [10]. In this paper, the quality and safety traceability system of beef cattle products synchronizes data through SQL. After receiving the request from the mobile client, the server first accepts the data changes on the mobile device, and then sends the data changes on the server to the mobile client. During the upload process of the mobile client, the upload business of the mobile client is divided according to the basic table, shared table and private table to ensure that the data uploaded by different user roles do not conflict with each other. The data synchronization architecture diagram is shown in Figure 2.
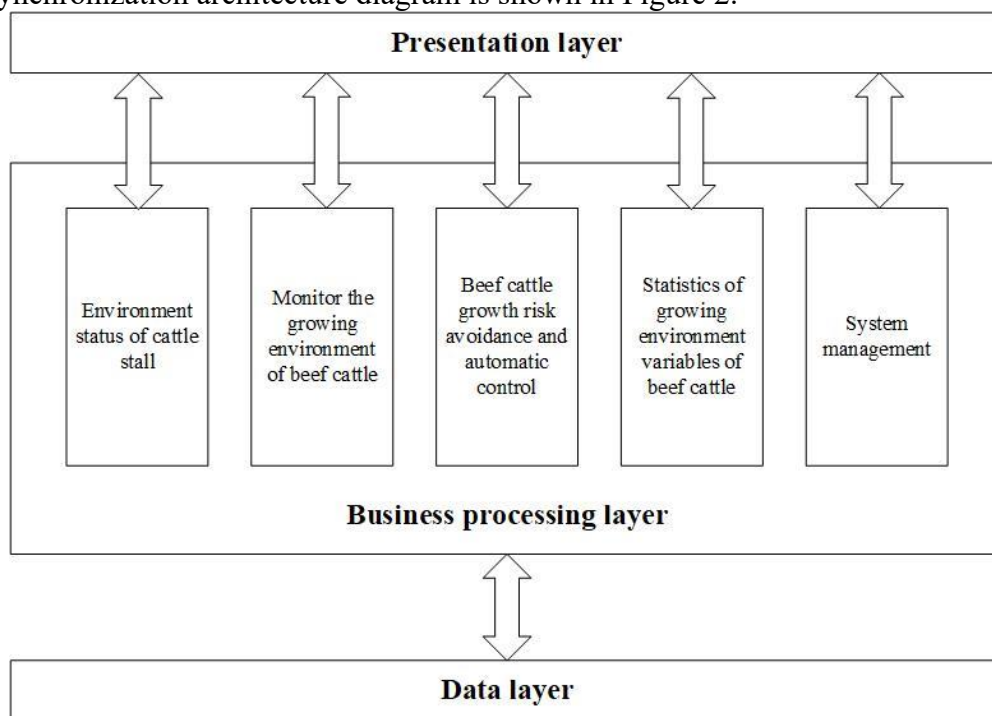

Figure 2: Data synchronization architecture

3.3 Data Management

Data management and analysis technology can monitor and manage the breeding, feeding, slaughtering and processing of beef cattle. These technologies can help farmers and slaughtering and processing enterprises achieve real-time monitoring and traceability of beef cattle data. Information platform technology can integrate identification, sensors, data management and analysis technology to realize the sharing and query of beef cattle traceability information. These technologies can improve the efficiency and accuracy of beef cattle traceability. Blockchain technology can realize decentralized management and sharing of beef cattle traceability data. Through blockchain technology, the traceability data of beef cattle can be better guaranteed for safety and reliability.

4. System Design

4.1 System Function Division

In this paper, the system function division of the beef cattle traceability system mainly includes data collection, data processing and storage, data analysis and application, traceability query, alarm and warning, and system management to realize monitoring, tracing and management of the whole process of beef cattle production and management.

Data collection function: This function mainly monitors and collects data in real time from beef

cattle through the equipment and sensors in the collection layer, including the identity information, feeding management information, drug use information, vaccination information, disease monitoring information, etc. of beef cattle.

Data processing and storage function: This function is mainly for processing, cleaning, integrating and storing the collected beef cattle data to ensure the accuracy and integrity of the data, as well as security measures such as data backup, encryption and permission control.

Data analysis and application function: This function mainly analyzes and applies the processed and stored beef cattle data, generates various indicators and reports of beef cattle production and management through data mining, machine learning, statistical analysis, etc., and provides decision support for beef cattle breeding managers.

Traceability inquiry function: This function is mainly provided for consumers and regulatory authorities to use to inquire about the production and management information of beef cattle through the beef cattle traceability system to ensure the safety and traceability of meat.

Alarm and early warning function: This function mainly monitors and analyzes the collected beef cattle data, and alerts and warns about abnormal events in the process of beef cattle production and management by setting thresholds and rules to improve the efficiency and safety of beef cattle production and management.

System management function: This function mainly manages and maintains the beef cattle traceability system, including system configuration, user rights management, logging, etc.

4.2 System Management Division

According to the actual demand, the beef cattle product quality and safety traceability system in this paper consists of six parts: basic information management module, breeding process management module, slaughtering and processing management module, transportation and sales management module, traceability information management module and system management module. By collecting, storing, analyzing and displaying data information, the beef cattle traceability system helps enterprises carry out production process control, product quality monitoring and risk early warning, improves the quality and safety level of beef cattle products, provides a traceability platform for consumers, and also facilitates the supervision and management of beef cattle product quality and safety by governmental supervision departments. The specific division is shown in Figure 3.
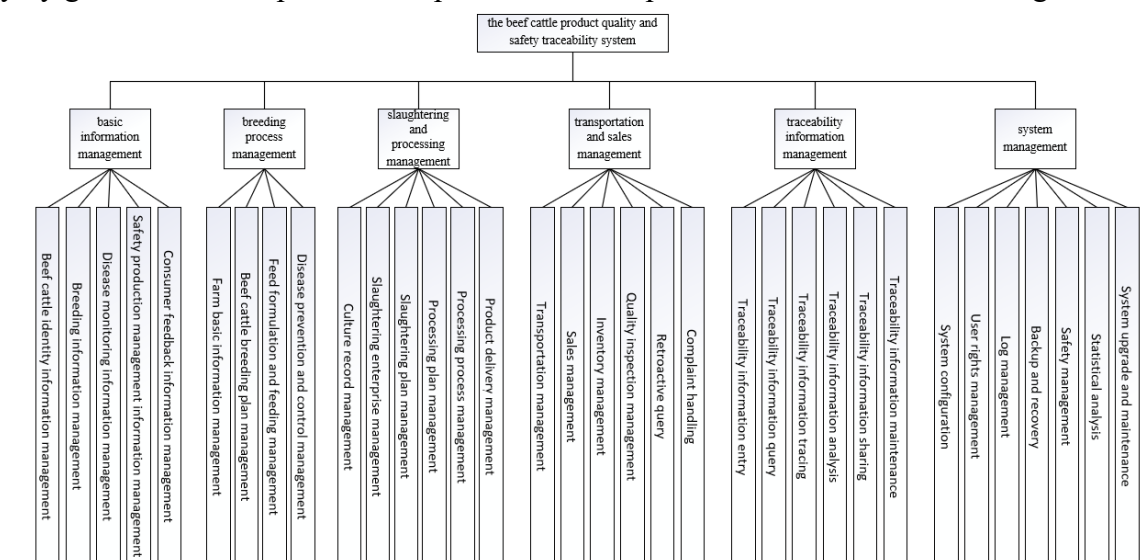

Figure 3: System module division

4.3 System Management Module Detailed Division Design

4.3.1 Basic Information Management

Basic information management mainly includes beef cattle identity information management, feeding management information management, disease monitoring information management, safety production management information management, and consumer feedback information management.

Beef cattle identity information management includes basic information of beef cattle (such as breed, gender, age, weight, color, etc.), ear tag or chip code, parental information, etc. These information will be used as the unique identifier of each beef cow in the beef cattle traceability system for the traceability and tracking of beef cattle.

Feeding management information management includes feed formulation, feeding frequency and quantity, water consumption, vaccination records, and drug usage records. This information will be used to monitor the feeding management of beef cattle as well as to provide quality assurance of meat to consumers.

Disease monitoring information management includes disease detection, treatment records, disease transmission monitoring, etc. This information will be used to monitor the health status of beef cattle, detect and prevent diseases in time, and ensure the health and safety of beef cattle.

Safety production management information management includes beef cattle transportation records, disinfection records, and health monitoring records. This information will be used to monitor the health and safety of the beef cattle production process and ensure that the process meets the relevant safety and health standards.

Consumer feedback information management includes feedback and complaint information from consumers. This information will be used to monitor the quality of beef cattle products and consumer feedback, to adjust and optimize the beef cattle production and management process in time, and to improve the quality of beef cattle products.

4.3.2 Farming Process Management

The beef cattle traceability system can realize the management and monitoring of the whole process of beef cattle breeding and provide effective technical support and decision-making basis for beef cattle production and management, mainly including basic farm information management, beef cattle breeding plan management, feed formula and feeding management, and disease prevention and control management.

Basic farm information management includes farm name, address, person in charge, contact information and other information to provide basic data for the monitoring of the beef cattle production process.

Beef cattle breeding plan management includes beef cattle breeding objectives, planning breeding cycles, breeding numbers and breeds, feeding methods and management plans, etc. This information will be used to guide the specific implementation of beef cattle production and management.

Feed formulation and feeding management include feed type and proportion, feeding frequency and quantity, water consumption, breeding environment control, vaccination plan, etc. This information will be used to implement scientific and rational feeding management to improve the efficiency and quality of beef cattle production.

Disease prevention and control management includes disease control plans, vaccination records, disease detection and treatment records, etc. This information will be used to detect and control beef cattle diseases in a timely manner and improve the safety and quality of beef cattle production.

4.3.3 Slaughter and Processing Management

The slaughtering and processing management module of the beef cattle traceability system is mainly used to record and manage the information related to the slaughtering and processing of beef cattle, including the basic information of the slaughtering enterprise, the time, place, way, slaughterers and slaughtering equipment of beef cattle, and the time, place, way, processors and processing equipment of beef cattle processing. The module mainly contains the following functions. Slaughter enterprise management includes information such as enterprise name, address, contact person and contact phone number. Slaughter plan management includes information such as slaughter time, location, slaughter quantity and slaughter method. Slaughtering process management includes information such as slaughterer, slaughtering equipment, inspection and quarantine to ensure the safety and hygiene of the slaughtering process. Processing plan management includes processing time, location, processing quantity, processing method and other information. Processing process management includes processing personnel, processing equipment, processing raw materials, processing process and other information to ensure the safety and hygiene of the processing process. Product outbound management includes information such as product name, outbound time, outbound quantity, and outbound destination.

4.3.4 Transportation Sales Management

Transportation management mainly records the information related to the transportation of beef cattle, including the transportation date, starting point, ending point, transportation tools, transporters and other information, and tracks the whole transportation process through the traceability code. Sales management is mainly responsible for recording information related to sales of beef cattle, including sales date, sales place, information of seller and buyer, etc., and tracking the source and quality information of beef cattle through traceability code. Inventory management is mainly responsible for tracking the inventory of beef cattle, recording the date of purchase, quantity, source and other information, and classifying and marking the cattle in order to track the whole sales process. Quality testing management carries out quality testing of beef cattle, records information such as testing date, testing organization and testing results, in order to trace the quality information of beef cattle. Traceability inquiry queries the source, production process, and quality information of meat cattle through traceability codes to ensure the safety and traceability of meat products. Complaint processing that is to handle consumer complaints, record information such as complaint date, complaint content, and processing results, and trace and process the corresponding meat cattle to ensure the rights and interests of consumers.

4.3.5 Traceability Information Management

The traceability information management module of the beef cattle traceability system is a crucial part of the whole system and is mainly responsible for the traceability of beef cattle products and the management of traceability information. This module mainly includes the following functions:

Traceability information entry: By scanning or manually inputting the traceability identification code of the beef cattle, the information on the breeding, slaughtering, processing, transportation and sales of the beef cattle is entered, and the traceability file of the beef cattle products is established.

Traceability information query: query the traceability information of beef cattle products through traceability identification code or other keywords, including information on breeding base, feed source, breeding process, slaughtering and processing process, transportation process, sales channel, etc.

Traceability information tracing: In case of food safety incidents or consumer complaints, traceability is carried out through traceability identification codes or other keywords to find

information on the whole process of production, processing, transportation and sales of beef cattle products to determine the causes and responsibilities of food safety problems.

Analysis of traceability information: Statistics and analysis of traceability information are conducted to dig out hidden food safety hazards and quality problems and provide a basis for formulating food safety and quality management measures.

Traceability information sharing: information sharing with government regulatory departments, meat producers, and sales enterprises to improve the efficiency and effectiveness of food safety and quality management.

Traceability information maintenance: maintain and update traceability information, provide timely feedback on new beef cattle product information, and ensure the accuracy and integrity of traceability information.

4.3.6 System Management

The system management module of the beef cattle traceability system refers to the management and operation and maintenance of the whole system, including the functions of system configuration, user rights management, log management, backup and recovery, etc. System configuration includes setting parameters of the system, such as system language, unit, time format, etc. User rights management manages the rights of system users, assigns user roles and rights, and restricts users' operation rights to the system. Log management records the operation log of the system, and records the important operations in the system to facilitate later auditing and problem solving. Backup and recovery means backing up the system data to avoid data loss, and providing data recovery function to guarantee the security and integrity of the system data. Security management that is to strengthen the security of the system, set access control, encrypted transmission and other measures to protect the privacy and security of the system. Statistical analysis that is to carry out statistics and analysis of the data in the system, providing reports and data visualization functions to facilitate managers to understand the operation of the system and data analysis results. System upgrade and maintenance, that is, timely system upgrade and maintenance, to ensure the stability and security of the system and improve the efficiency of the system operation.

4.4 The Whole Process of Beef Production Process

When young cattle enter the farm, first check the health condition of this cattle, after quarantine qualified, this cattle wear RFID tags that store their basic information, the basic information is recorded from the birth of the beef cattle, including breed, sex, age, weight, beef cattle number, origin, date of birth, etc., and create beef cattle breeding files in the system. Thereafter, the breeder records the information in the growth process of the beef cattle through the reading and writing equipment, such as the breeding environment situation, disease situation, vaccination situation, feed consumption situation, etc. Before the slaughter of the beef cattle, it is necessary to ensure that the beef cattle meet the slaughter requirements before they can be slaughtered, and quarantine is required before and after the slaughter, and the quarantine is qualified to enter the next link afterwards, while recording the information related to the slaughter process. After the slaughter, the cattle are processed according to the selling requirements and the relevant information is recorded. Then the beef products are transported and sold, and the relevant information is recorded. Consumers can check the complete information of beef cattle breeding, slaughtering, transportation and sales according to the QR code and traceability code on the package after purchasing beef, and can also give relevant feedback, and regulators and producers can achieve control and monitoring purposes through this system. The business process of the whole process of beef production is shown in Figure 4: is shown in Figure 4.
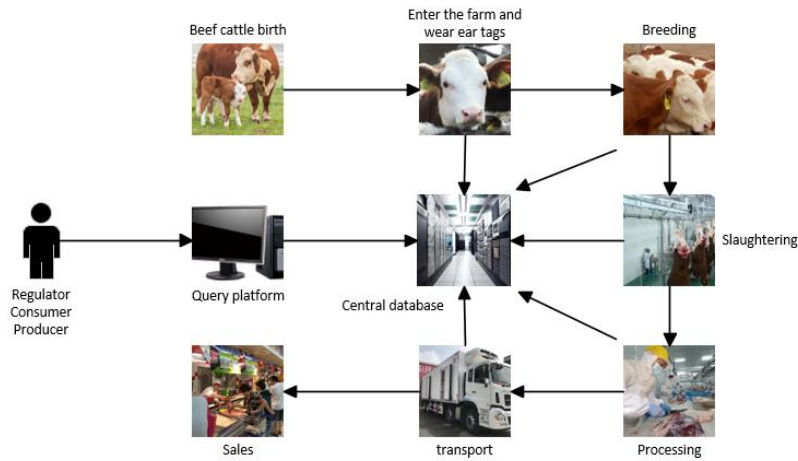
Figure 4: Business Process Flow Diagram

5. System Implementation

Users enter the website through the browser and enter the inquiry interface of the system traceability system. They can enter the traceability code for inquiry. After entering the platform, the home page will display the basic information of the product, you can also choose to query its breeding information, slaughtering and processing information, as well as user personal information. The system query interface is shown in Figure 5, and the system interface is shown in Figure 6.

Figure 5: System query interface

Figure 6: System interface

6. Conclusion

Through the information management and supervision of the whole life cycle of beef cattle, the whole process traceability from the source to the terminal can be realized, and consumers' trust and satisfaction with meat products can be improved. This paper introduces the system architecture, management modules and key technologies of the beef cattle product quality and safety traceability system, and briefly introduces the basic information management, breeding process management, slaughtering and processing management, transportation and sales management and traceability information management, as well as the application of key technologies such as identification technology. The establishment of traceability system of beef cattle product quality and safety can effectively improve the traceability and management level of beef cattle products, improve the quality and safety of meat products, promote the development and upgrading of the meat industry, and provide consumers with safer and more reliable meat products.

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