International Journal of Computer Science and Information Technology
ISSN: 3005-9682 (Print), ISSN: 3005-7140 (Online) | Volume 3, Number 3, Year 2024
DOI: https://doi.org/10.62051/ijcsit.v3n3.10
Journal homepage: https://wepub.org/index.php/IJCSIT/index

# Traceability System for Segmented Livestock Meat Processing based on Radio Frequency Identification Technology

Haojie Chai, Yanyan Wang

School of Artificial Intelligence, Henan Institute of Science and Technology, Xinxiang 453003, China

## ABSTRACT

Based on radio frequency identification technology, this paper proposes a novel traceability system for the processing of segmented livestock meat, aiming to address the issues of information opacity and tracing difficulties in the existing processes. The system includes functions such as raw material tracing, processing monitoring, and product quality inspection and tracing. It employs a 32f103c8t6 microcontroller and an ESP8266 WiFi remote communication module to establish a connection with the host computer. Communication with the microcontroller is established through serial communication for data reception and transmission. The system also possesses product quality inspection and tracing capabilities, enabling the timely detection of potential quality issues. Testing and evaluation have confirmed that the system performs exceptionally well in practical applications, effectively enhancing processing efficiency and accuracy, reducing food safety risks, and enabling real-time updating and sharing of product information. By providing real-time tracking and monitoring of the processing process, the system enhances production efficiency and accuracy, ensuring food safety.

## KEYWORDS

Radio Frequency Identification technology; Traceability systeml; Meat processing; Food quality and safety.

## 1. INTRODUCTION

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. Use *italic* for emphasizing a word or phrase. Do not use boldface typing or capital letters except for section headings (cf. remarks on section headings, below).

Do not number your paper: All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question.

In China, with the increasingly stringent food safety regulations and the growing consumer demand for food safety, traceability systems for livestock meat processing based on Radio Frequency Identification (RFID) technology have received increasing attention. These systems are primarily used to record and manage the entire process of livestock breeding, slaughter, processing, transportation, and sales, ensuring food safety and traceability [1-3].

Currently, some large meat processing enterprises and research institutions in China have conducted related research and applications. In foreign countries, especially in developed countries such as the European Union and the United States, traceability systems for livestock meat processing based on RFID technology have been widely adopted [4]. For instance, the European Union launched a food traceability project in 2002, primarily for the production and distribution of beef. It uses a unified central database to manage all production information, achieving quality control throughout the process from the pasture to the dining table. The United States Department of Agriculture has also established the National Animal Identification System (NAIS) to monitor poultry, livestock, and other captive animals, preventing the spread of fatal diseases. These systems employ RFID technology, assigning a unique ID number to each animal and recording information throughout its breeding, slaughter, processing, transportation, and sales [5-6]. However, most of these meat traceability systems still have numerous drawbacks: insufficient completeness of traceability information; centralized traceability systems, making traceability information vulnerable to tampering, deletion, and falsification; low security in traceability information transmission, with information easily intercepted and leaked; difficulty in tracing individual meat products for most meat items, resulting in low traceability efficiency [7].

The aforementioned issues have resulted in an inability to guarantee the safety of supplied meat products, and when meat safety problems arise, it becomes difficult to identify the responsible parties. Therefore, to address the problems of poor information integrity, centralization, low security in information transmission, and low efficiency in individual product traceability within the traceability systems, this paper proposes research on a meat traceability system based on Radio Frequency Identification (RFID) technology. The aim is to establish an online monitoring system, develop a pork electronic traceability system utilizing RFID technology and other carriers, and integrate it with other processing systems to achieve intelligent functions such as processing information input, recognition, storage, and production line control.

## 2. SYSTEM DESIGN AND DEVELOPMENT

### 2.1. Radio Frequency Identification Technology

Radio Frequency Identification (RFID) technology is a method that automatically identifies target objects and acquires their associated information through wireless radio frequency signals. The wireless RFID system mainly consists of three components: electronic tags, readers, and computer networks.

Electronic Tags: Electronic tags are composed of chips and tag antennas, communicating with readers through inductive coupling or electromagnetic backscatter principles. These tags are typically attached to items requiring identification and contain relevant information about the items. Readers can retrieve tag information through non-contact methods.

Readers: Readers are devices that utilize radio frequency technology to read and write information from electronic tags. They are composed of radio frequency modules, control modules, power supplies, and other components. The tag information read by the reader can be managed and transmitted through computer networks [8].

Computer Networks: In RFID systems, computer communication networks are primarily responsible for data transmission and management. Readers can connect to computer networks through standard interfaces, enabling communication and data transmission functions [9-10].

## 2.2. Radio Frequency Identification Technology

The microcontroller system architecture is designed with a 32f103c8t6 microcontroller as the core, utilizing an ESP8266 WiFi remote communication module to facilitate connection with the host computer, which uses a web interface for monitoring.

All modules based on analog signal acquisition require analog-to-digital conversion to convert the collected analog voltage data into digital signals for analysis by the microcontroller. Essentially, this is achieved through ADC (Analog-to-Digital Converter). Therefore, the key lies in the design of the ADC. The process is as follows: after startup, the ADC channels that need to be configured are detected for parameters such as sampling rate and bit depth. Then, ADC detection is enabled to obtain voltage data, which is further converted into final data based on hardware circuit parameters for output.

An ADC, or Analog-to-Digital Converter, is a type of device used to convert continuous analog signals into discrete digital signals. The role of an ADC is to convert continuously varying analog signals into discrete digital signals. Real-world analog signals, such as temperature, pressure, sound, or images, need to be converted into digital form that is easier to store, process, and transmit, so that they can be accepted and processed by computer systems.

The ESP8266 is an ultra-low-power UART-WiFi transparent transmission module with industry-leading packaging size and ultra-low energy consumption technology. It is specifically designed for mobile devices and IoT applications, capable of connecting users' physical devices to Wi-Fi networks for internet or LAN communication, enabling internet connectivity.

WiFi serves as an important medium for communication between the hardware and software components. It establishes communication with the microcontroller through serial communication (UART), responsible for receiving and sending data. The TX interface is responsible for data transmission, while the RX interface is responsible for data reception. Since the design uses WiFi for internet connectivity, it is necessary to configure the WiFi functionality of the ESP module. In the source code (Figure 1), the WiFi is configured to automatically search for the network name and password "12345678".

The system also has product quality inspection and traceability functions. By monitoring and recording key parameters during the processing process in real-time, the system can promptly identify potential quality issues and trace the source of the problems. This provides enterprises with effective quality control measures and offers consumers safer and more reliable products.

In summary, the core functions and features of the intelligent traceability system are mainly reflected in raw material traceability, processing process monitoring, and product quality inspection and traceability. The realization of these functions not only improves the production efficiency and quality level of livestock meat processing enterprises but also provides consumers with more transparent and reliable product information. Additionally, the intelligent management of the system provides strong support for the sustainable development of enterprises.

## 2.3. System page design

When designing a webpage for a traceability system based on RFID technology for livestock meat processing, it is essential to ensure both practicality and aesthetics, while also making it user-friendly and easy to navigate. The login page serves as the entry point for users, featuring input fields for username and password, along with a login button for users to click. The login page should be concise, with the username and password input boxes centered and the login button placed below. When users input information or click the button, error messages should be provided in case of any mistakes [13]. The passwords entered by users should be encrypted to ensure account security.

As shown in Figure 2, the user management page is designed to be visible only to administrators. It displays all accounts and login passwords, allowing administrators to add, delete, modify, and query users. Users are categorized as administrators and regular users, with the latter not having access to this page.

The homepage presents the core functions and important information of the system. On the traceability query page, a simple data table is designed. Administrators can swipe cards to change the current card number and only record content for the current card number. The recorded content displays the card number and record time, which can be modified. The record time is automatically updated to the current time when modifications are made (Figure 3). Regular users can only view the information and do not have permission to modify it. The page offers multiple query methods and supports fuzzy queries, enabling users to quickly locate the needed information. Users can query the processing flow, raw material source, quality inspection report, and other textual record information corresponding to the card number by entering the card number of the livestock meat or the record time (Figure 4).

The recorded content in the data table can be viewed as all data or filtered to show only the current card number (Figure 5). It can also be exported to generate an Excel table (Figure 6), allowing users to retain and view the data.

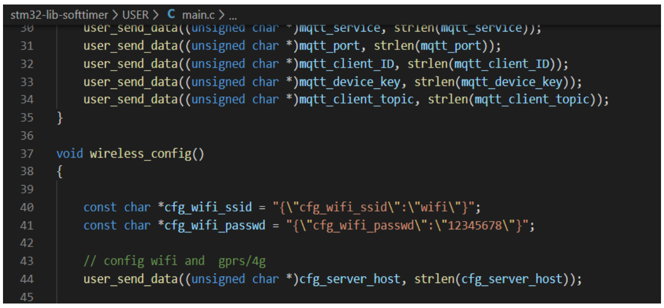


**Figure 1.** MCU partial source code

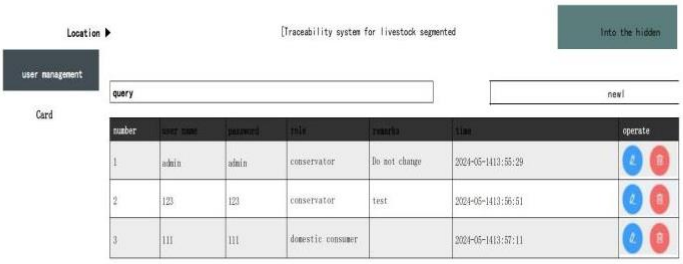


**Figure 2.** Administrator page

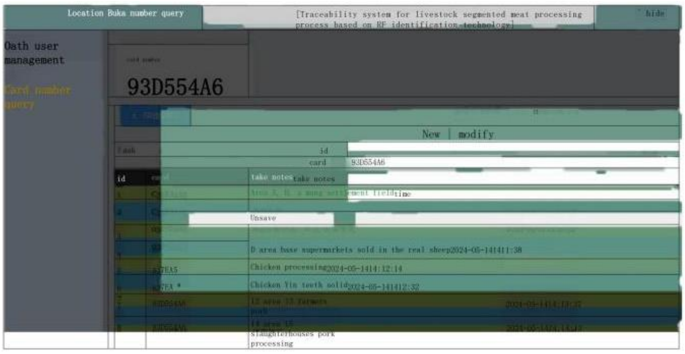


**Figure 3.** Traceable record modification

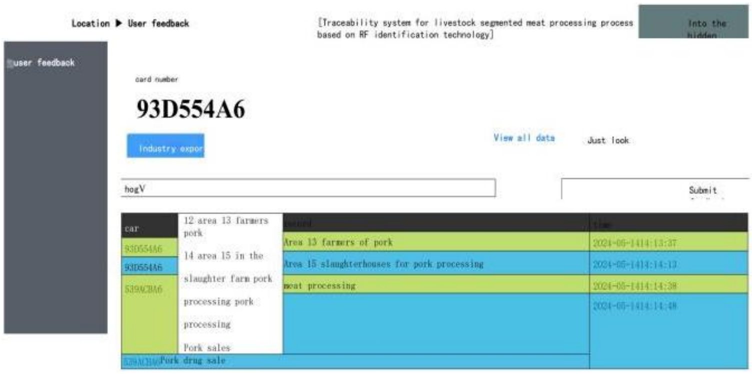


**Figure 4.** Traceability record query

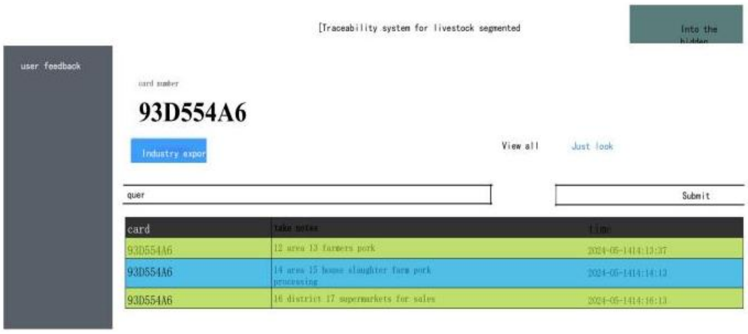


**Figure 5.** Only looks at the current card number

| | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| | id | card | take notes | time | | | |
| 2 | | C35EA1A5 | Beef slaughter in area A on farm B | 2024/5/1414:10 | | | |
| 3 | 2 | C35EA1A5 | Beef segmentation | 2024/5/1414:05 | | | |
| 4 | 3 | 0387E9A6 | Sheep from A farmer in area A were transported into the C slaughterhouse | 2024/5/1414:10 | | | |
| 5 | 4 | 0387E9A6 | D A supermarket in area D sells mutton | 2024/5/1414:11 | | | |
| 6 | 5 | 633A7EA5 | Chicken processing | 2024/5/1414:12 | | | |
| 7 | 6 | 633A7EA5 | Chicken for sale | 2024/5/1414:12 | | | |
| 8 | 7 | 93D554A6 | 12 area 13 farmers pork | 2024/5/1414:13 | | | |
| 9 | 8 | 93D554A6 | 14 area 15 slaughterhouses pork processing | 2024/5/1414:14 | | | |
| 0 | 9 | 539ACBA6 | Pork processing | 2024/5/1414:14 | | | |
| 1 | 10 | 539ACBA6 | Pork sales | 2024/5/1414:14 | | | |
| [illegible] | 11 | C35EA1A5 | Beef pickled processing | 2024/5/1414:06 | | | |
| 3 | 12 | C35EA1A5 | Beef packaging | 2024/5/1414:06 | | | |
| 4 | 13 | 93D554A6 | 16 district 17 supermarkets for sales | 2024/5/1414:16 | | | |
| 5 | | | | | | | |

**Figure 6.** Simulated generating an excel table

## 2.4. System Development

In the process of building a full-process intelligent traceability system based on RFID technology, the technical path and implementation plan were clearly defined. Firstly, a thorough analysis of the current situation in the livestock meat processing industry was conducted, revealing deficiencies in data accuracy and real-time performance in existing traceability systems. To address these issues, RFID technology was chosen as the core solution.

On the technical path, high-frequency RFID technology was selected due to its advantages of fast identification speed, high accuracy, and strong anti-interference capabilities. A complete RFID tag management system was designed to ensure accurate tracking of raw materials and products at each stage. Additionally, leveraging cloud computing and big data technologies, a robust data processing center was established for storing and analyzing massive amounts of traceability data.

In terms of implementation, a phased approach was adopted. Initially, RFID readers were installed at key nodes to enable automatic data collection during raw material storage, processing, and finished product shipment. Subsequently, an intelligent analysis system was developed for real-time analysis and early warning. For instance, when quality issues with a particular batch of raw materials are detected, the system immediately triggers an alarm to notify staff for prompt handling.

Furthermore, emphasis was placed on the scalability and maintainability of the system. A modular design was adopted to allow the system to be flexibly expanded based on actual needs. Meanwhile, a comprehensive maintenance mechanism was established to regularly maintain and upgrade the system, ensuring stable operation.

Through this intelligent traceability system, comprehensive tracking and monitoring of raw materials, processing stages, and finished products were achieved. This not only enhanced product quality and safety but also provided valuable data support for enterprises, facilitating optimization of production processes, resource allocation, and reduction of operational costs. Simultaneously, it increased transparency and reliability of product information for consumers, enhancing trust and satisfaction.

# 3. SYSTEM TESTING AND EVALUATION

## 3.1. System Testing

As shown in Tables 1-3, during the system testing phase, diversified testing methods are employed to ensure the stability and reliability of the traceability system. Implementing unit testing is a crucial step in guaranteeing the proper functioning of each module within the software system, aimed at ensuring that each module can stably and reliably perform its expected functions.

In the unit testing of the radio frequency identification (RFID) module, various environments such as cold and humid conditions are simulated during the experimental process to comprehensively examine the performance of the RFID system. The ability of the system to maintain normal operation in these complex environments will be a key indicator of its reliability. Additionally, there is a strong focus on aspects such as the RFID system's reading distance, reading speed, and data storage capacity, ensuring that the system exhibits high stability and reliability in practical applications.

System reliability testing is essential for ensuring the performance of the RFID system. By comprehensively examining the system's stability and reliability in various harsh environments, its identification accuracy and stability can be fully verified. This process allows for the identification and resolution of potential issues, laying a solid foundation for the stable operation of the system.

As a vital component of modern automated systems, the stability and reliability of the RFID module directly impact the overall system's performance. Therefore, during unit testing, it is necessary to strictly follow the test plan and simulate various possible environmental conditions to conduct thorough testing of the RFID module. By collecting and analyzing test data, the performance of the module can be accurately assessed, and existing issues can be identified and resolved promptly.

During the testing process, a rigorous attitude must be maintained to ensure the objectivity and accuracy of the test results. At the same time, it is necessary to strengthen communication and coordination with other departments to ensure the smooth progress of the testing work. Through joint efforts, the unit testing of the RFID module will achieve complete success, making a positive contribution to enhancing the overall system's quality and stability.

In summary, implementing unit testing is one of the important means to ensure the quality of software systems. We will continue to strengthen testing efforts to ensure that each module functions normally and stably, contributing to the advancement of China's information construction endeavors.

**Table 1.** User login test

| Test method | Test function | Test case | Expected result | Test result |
|---|---|---|---|---|
| Functional test | Login testing | Log in with the administrator's account and password | Login successfully | Log in to the administrator page successfully |
| | | Log in with the account and password of the ordinary user | Login successfully | Log in to the ordinary user page successfully |
| | | Log in with the correct account and the wrong password | Login failure | Login failure |
| | | Log in with the wrong account and password | Login failure | Login failure |
| Summary: The account and password existing on the user management page can log in successfully when entered correctly. If entered incorrectly, the login will fail. | | | | |

Integration testing is a crucial phase in the software development process, with the primary objective of integrating various modules together and examining whether their interactions and collaborations function properly. During the integration testing phase, special attention is given to the efficiency of data transmission and processing, as well as the system's performance under different loads. By conducting integration testing, certain performance bottlenecks can be identified and optimized, ultimately enhancing the overall performance and stability of the system.

**Table 2.** Traceability record test

| Test method | Test function | Test case | Expected result | Test result |
|---|---|---|---|---|
| Integration testing | Record testing | Simulate and record using the currently displayed card number | Record successfully | This card number simulation record was successful |
| | | Carry out simulated recording by changing the card number | Record successfully | The simulation record of the new card number was successful |
| | | Modify the random simulation records | Record modification succeeded | This simulation record modification was successful |
| | | Delete the random simulation records | Record modification succeeded | This simulation record deletion was successful |
| Summary: The administrator page enables operations such as record addition, modification, and deletion. | | | | |

Efficiency in data transmission and processing is a crucial aspect to focus on during integration testing. Data transmission efficiency is influenced by factors such as transmission rate, transmission protocol, and network bandwidth. To enhance data transmission efficiency, efficient data transmission protocols can be employed, data structures can be optimized, and unnecessary data transmissions can be reduced. Additionally, it is essential to inspect the data processing stages to ensure that each module can efficiently handle incoming data and perform calculations and storage as expected.

The performance of the system under different loads is also a significant aspect of integration testing. During the testing process, it is necessary to simulate real-world application scenarios, apply varying degrees of workload to the system, and observe its performance under these various loads [14]. This helps identify potential performance issues that may arise under high loads, such as slower response times or system crashes. To address these issues, measures such as optimizing algorithms and adjusting the system architecture can be taken to improve the system's performance under high loads.

**Table 3.** Radio frequency identification test

| Test method | Test function | Test case | Expected result | Test result |
|---|---|---|---|---|
| Dynamic testing | Microcontroller test | The hardware establishes communication with the web via WiFi | Establishment succeeded | The hardware connected to WiFi successfully |
| | | Swipe the card on the radio frequency identification module and check the hardware | Card swiping succeeded | The feedback light glows to indicate success |
| | | Swipe the card on the radio frequency identification module and view the administrator page | Card swiping succeeded | The card number was changed successfully |
| | | Swipe the card on the radio frequency identification module and view the ordinary user page | Card swiping succeeded | The card number was changed successfully |

During system testing, real operational processes are simulated to evaluate the overall performance and stability of the system. User acceptance testing involves inviting representatives from livestock meat processing enterprises to participate, collecting their feedback and suggestions. These tests help identify and improve any deficiencies in the system. RFID technology enables full process tracking of a cut of meat from the slaughterhouse to the supermarket. In the event of food safety issues, it can quickly locate the problematic segment, protecting the legitimate rights and interests of consumers. At the same time, this technology also helps improve enterprise management levels, reduce operating costs, and enhance market competitiveness. With the support of our government, the application of RFID technology in the field of food safety traceability will become more widespread.

The entire testing process utilizes automated testing tools and methods to enhance testing efficiency and accuracy. At the same time, detailed test reports and data analysis models are established to thoroughly analyze and summarize the test results. These measures provide strong support for system optimization and improvement.

## 3.2. System Evaluation

In the results and analysis section of the system evaluation, a comprehensive assessment of the RFID-based intelligent traceability system for the whole process of livestock meat processing was conducted using various evaluation methods, including functional testing, performance testing, and user satisfaction surveys. The evaluation results indicate that the system achieves efficient and accurate traceability throughout the entire process of livestock meat processing, significantly improving product quality and safety.

In terms of functional testing, the entire process from raw material procurement to product processing was simulated, with real-time monitoring and data collection at each stage using RFID technology. The test results demonstrate that the system can accurately record information at every step, including key data such as raw material sources, processing times, and temperatures, providing a reliable basis for product quality traceability.

Regarding performance testing, the stability and reliability of the system were evaluated. Through long-term operation and simulation of extensive data processing, the system exhibited good stability and high data processing capabilities, meeting the actual needs of meat processing enterprises.

Additionally, a user satisfaction survey was conducted to collect feedback on the system's user experience. The survey results revealed that users highly praised the system's ease of use, operation interface, and data accuracy, believing that it effectively enhances work efficiency and product quality.

In summary, the RFID-based traceability system for the entire process of livestock meat processing performed exceptionally well in the evaluation, providing an efficient and reliable traceability solution for the livestock meat processing industry. The application of this system will strongly promote digital transformation and intelligent upgrading in the livestock meat processing industry.

## 4. CONCLUSION

This research focuses on the development of a whole-process traceability system for livestock meat processing based on Radio Frequency Identification (RFID) technology, and delves into the application of RFID technology in the livestock meat processing sector and its pivotal role in the whole-process traceability system. Through system testing and evaluation, the effectiveness and reliability of this traceability system in practical applications have been confirmed, providing strong support for food safety and quality traceability in the livestock meat processing industry.


## ACKNOWLEDGEMENTS

Key Scientific Research Project of Henan Higher Education Institutions+23A520034, Henan Provincial focus on research and development Project+231111220700


## REFERENCES


[1] Ding Zhiguo. Research and Implementation of Key Technologies of RFID [D]. University of Science and Technology of China, 2009.

[2] Wu Yongxiang. Research Status and Development Prospect of Radio Frequency Identification (RFID) Technology [J]. Microcomputer Information, 2006, (32): 234-236+230.

[3] Li Jin, Guo Meirong, Gao Liangliang. Application and Innovative Development Strategies of Agricultural Internet of Things Technology [J]. Transactions of the Chinese Society of Agricultural Engineering, 2015, 31 (S2): 200-209.

[4] Zheng Huoguo. Research on Food Safety Traceability System [D]. Chinese Academy of Agricultural Sciences, 2012.

[5] Zhang Xiaheng. Optimization of Supply Chain Management Model Based on Blockchain [J]. China Business and Market, 2018, 32 (08): 42-50.

[6] Li Mingjia, Wang Deng, Zeng Xiaoshan, Bai Qianlan, Sun Yaojie. Design of Food Safety Traceability System Based on Blockchain [J]. Food Science, 2019, 40 (03): 279-285.

[7] Suo Fang. On the Perfection of China's Food Safety Supervision System [D]. Anhui University, 2011.

[8] Shen Subin, Fan Quli, Zong Ping, Mao Yanqin, Huang Wei. Research on the Architecture and Related Technologies of the Internet of Things [J]. Journal of Nanjing University of Posts and Telecommunications (Natural Science Edition), 2009, 29 (06): 1-11.

[9] Ning Huansheng, Xu Qunyu. Global Development of the Internet of Things and Some Thoughts on the Construction of the Internet of Things in China [J]. Acta Electronica Sinica, 2010, 38 (11): 2590-2599.

[10] Hu Dinghuan. The "Dual Structure" Theory of Agricultural Products - On the Impact of Supermarket Development on Agriculture and Food Safety [J]. Chinese Rural Economy, 2005, (02): 12-18.

[11] Shen Jianfeng. Indoor Environmental Monitoring and Control System [D]. Dalian Polytechnic University, 2012.

[12] Mao Min. Research on Greenhouse Monitoring System Based on Internet of Things Technology [J]. Electrical Automation, 2021, 43 (01): 34-36.

[13] Ba Gui. Design and Implementation of Accurate Generator Tripping System for Power Grid Stability Control [D]. University of Electronic Science and Technology of China, 2018.

[14] Hu Shipeng, Zuo Qigang, Wang Qing. Research on the Recovery Management System of Components of Automobile Charging Piles Based on Internet of Things Technology [J]. Automobile Test Report, 2023, (09): 152-154.