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Information sharing in supply chain of agricultural products based on the Internet of Things

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Abstract

Purpose – The Internet of Things (IoT) is one of the efficient ways to solve the problems on information sharing in the supply chain of agricultural products. The paper aims to discuss this issue.
Design/methodology/approach – In this paper, a scheme of information sharing in the supply chain of agricultural products is developed and the information of agricultural products is designed and described with Physical Markup Language.
Findings – In addition, the EPC Information Services (EPCIS) system of agricultural products is analyzed and designed, and the design of tracking and tracing of the agricultural supply chain based on the IoT is proposed. Meanwhile, EPCDS registration is discussed, and two methods of information inquiry are proposed, especially the processes of inquiries for the static and dynamic information based on Object Name Service are emphasized.
Originality/value – Once a food safety incident occurs, the model can be used for tracking, tracing, and monitoring so as to deal with related products and strengthen the quality and safety management of agricultural products.

Keywords Supply chain, Internet of Things (IoT), Information sharing, Agricultural products
Paper type Research paper

1. Introduction

The field of agricultural products is a special industry because it is time-critical and high-risk, and characterized with security that is difficult to control and high requirement and demand on the supply chain integration. Agricultural products with quality issues may endanger people's lives. Thus, the timely tracing and tracking of information of agricultural products is important. To achieve effective information sharing and tracing of agricultural product information, tracking the complete supply chain of agricultural products using advanced information techniques is crucial; the information that follows the product's physical trail is traced and the information and data of agricultural products are collected in a timely and accurate manner (Feng *et al.*, 2013; Papetti *et al.*, 2012). At present, companies are adopting new electronic traceability systems ("information trails") to track production, purchases, inventory, and sales thereby providing a basis for good supply management; this process facilitates the efficient management of resources (Patel and Cassou, 2015; Prince *et al.*, 2014; Kwon *et al.*, 2014; Kang and Lee, 2013; Lotfi *et al.*, 2013; Bosona and Gebresenbet, 2013). The Internet of Things (IoT) is an efficient way of solving the problems related to information sharing in the supply chain of agricultural products.

The basic idea of IoT is inherent in all kinds of things or objects around us, such as radio-frequency identification (RFID) tags, sensors, actuators, and mobile phones. The US National Intelligence Council (2008) stated that "by 2025 Internet nodes may reside in everyday things-food packages, furniture, paper documents, and more." By addressing unique schemes, IoT systems can interact with each other and

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cooperate with their neighbors to attain common goals (Mejjaouli and Babiceanu, 2015; Chen and Chou, 2015; Wan *et al.*, 2014; Zhu *et al.*, 2012; Kiritsis, 2011; Wang *et al.*, 2011; Giusto *et al.*, 2010; So Park *et al.*, 2010; Yan *et al.*, 2015). IoT can realize intelligent identification, location, tracking, and monitoring and management functions. These functionalities have made IoT a highly investigated topic. IoT in the supply chain of agricultural products has gained wide application. The feasibility and flexibility of the architecture of this supply chain was proposed through a detailed implementation that uses wireless sensor networks and web services to introduce the use of the smart object framework; these networks encapsulate RFID, sensor technologies, embedded object logic, object ad hoc networking, and internet-based information infrastructure to realize the real-time monitoring of the flow of goods through a supply chain (Sanchez *et al.*, 2012). The implementation of RFID in the supply chain was employed to achieve real-time inventory monitoring and information sharing; such approach can help the system attain high-environmental benefits and economic benefits (Nativi and Lee, 2012). A structural model that adopts RFID technology improves information sharing among supply chain members; such model offers empirical support for the adoption of RFID technology within an enterprise resource planning context for the purpose of improving supply chain performance (Zelbst *et al.*, 2010). Two cases about the deployment of RFID in three organizational success indicators were studied to develop better RFID instantiations (Bardaki *et al.*, 2012). The generic framework of costs associated with process innovations in supply networks was tested; the tests clarified the various costs involved in the adoption of RFID technologies by early adopters, which influenced the decision to adopt such framework (Smart *et al.*, 2010). In essence, RFID technology and electronic data interchange technology based on the internet has matured. However, a gap continues to exist in the application of RFID in the safety of Chinese agriculture products, which is not case with advanced countries that have attained advanced levels of implementation.

Therefore, we explored the application of IoT in the supply chain of agriculture products to achieve information sharing based on the feature of IoT, such as "from anytime, anyplace connectivity for anyone, we will now have connectivity for anything" (International Telecommunication Union, 2005). First, the IoT application model in the supply chain of agricultural products was constructed. An EPC Information Services (EPCIS) system, which plays an important role in the information sharing of agricultural IoT, was designed and analyzed. The tracking and tracing of the agricultural supply chain were analyzed based on IoT, including registers, records, and inquiries for static and dynamic information. EPCDS registration was discussed. Two methods of information inquiry were proposed. The processes of inquiries for static and dynamic information based on Object Name Service (ONS) were emphasized. A scheme of information sharing in the supply chain of agricultural products was developed. Thus, the application of agricultural IoT guaranteed the security of the entire process of circulation of agricultural products.

2. Application of IoT in information sharing of supply chains

The components of IoT include all roles in the supply chain and the providers who offer services for the roles. Participants are connected by means of the internet or any other means. The IoT consists of six parts, namely, Electronic Product Code (EPC), RFID tags and reader, EPC middleware, Application Level Events (ALE), EPCIS, and ONS (Thiesse and Michahelles, 2009).

Combined with EPC and the internet, IoT can identify any uniquely labeled product in the supply chain. The target of IoT is to make the supply chain transparent toward attaining convenience for the users during the process of inquiring about relevant information. After the user obtains EPC information about relevant products from IoT, the information is disposed by the RFID middleware and passed to EPCIS, which will acquire the address of EPCIS by inquiring through ONS. Necessary information can be obtained by accessing relevant service according to the address. The data of information service will then be updated. Figure 1 shows the process of inquiry.

Consumer requirements for the quality and security of agricultural products have been growing rapidly. Thus, the monitoring of the supply chains of agricultural products, as well as the process of tracing and tracking their information, has become urgent. The applications of IoT in the fields of agricultural products and food security have been extended to the field of processing and circulation of agricultural production and to the entire supply chain of agricultural products.

3. IoT application model of agricultural supply chains based on RFID

3.1 IoT application model of agricultural supply chains

Information and data related to agricultural products in the supply chain were previously collected manually or by scanning bar codes. This process resulted in delays, errors, and lack of information on agricultural products. The emergence of RFID technology and IoT has facilitated the real-time acquisition of supply chain management information and solved the disconnect between logistics and information flow. This technology also offers real-time, comprehensive, and detailed electronic information related to the production area, transportation, storage, processing, loading and unloading, distribution, and sales of agricultural products for every link of the supply chain.

The RFID tag contains a unique code. RFID can only depend on the interaction between the EPC code and information system. Thus, the individual's interaction with the system is particularly important. The processes of creating the code, making associated correspondence, logging onto the data, registering, and performing static or

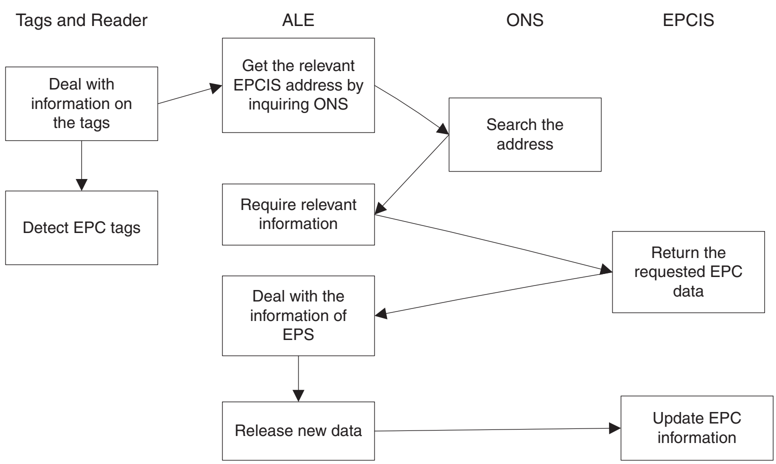

Figure 1. Process of EPC inquiry

dynamic inquiry involve innumerable individuals. Moreover, these processes require devices and systems, such as the RFID tag, RFID code, ONS, EPCDS, and every company's EPCIS. The information sharing model of the agricultural industry based on EPC IoT is shown in Figure 2.

However, some existing studies provide value to other elements, such as the RFID tag, RFID code, and EPCIS system. These elements include a general RFID-based solution. However, these elements are not solely focussed on agricultural supply chains based on RFID because general studies show that information sharing and traceability depend on a well-developed information system and RFID devices. Some details of the process should be valued in the study of supply chains. The IoT application model should be built based on these details.

EPC information is read by an RFID reader, and sent to ALE middleware, which is responsible for dealing with EPC information. The ALE middleware then sends the result to the information system as stored information for future use. The result becomes the basis of the decision making of the enterprise. By contrast, other enterprises can also search and find relevant EPC information, which can be static or dynamic, by inquiring through the local ONS or root ONS via the IoT application model. To further understand the model, we analyzed the four main parts of the model, namely, information release service, EPCIS system, Physical Markup Language (PML) of agricultural products, and ONS.

3.2 Information release service

The information release service of agricultural IoT is provided by agricultural service providers who release the information to the service center of the IoT. Information release service is one of the important basic services of IoT. Any user with permission from the service can register the specific information of agricultural products, such as name, price, and classification, in the public service platform of IoT. The information can then be tracked and released on time, as shown in Figure 3. Information release

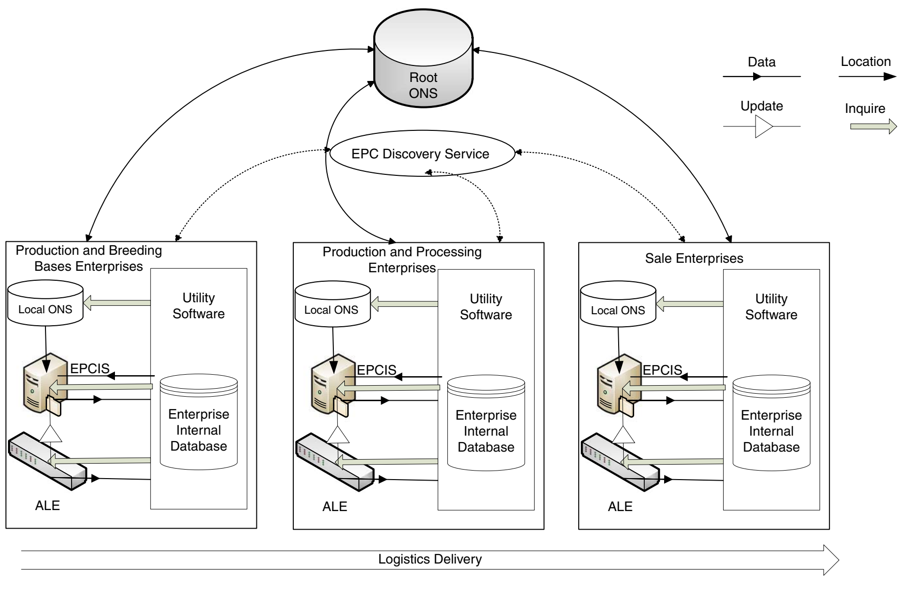

Figure 2.
IoT application model of agricultural supply chains

service marks the entrance of agricultural products to IoT. Only by registering EPC and mapping the addresses of agricultural products in the directory could information sharing be achieved.

The information delivery service of agricultural products in the model includes EPC registration, EPC cancellation, information release, information modification, and information deletion. Figure 4 shows the system architecture of the service and the position of the service in IoT.

EPC registration binds the memory addresses of agricultural product information to the EPC to form a one-to-one or N-to-one mapping relationship, which will be restored in the data center of ONS. EPC registration falls into two categories, namely, local EPC registration and global EPC registration. The former refers to the registration of single-product mapping to local ONS. The attributes of local ONS include the manager code, object classification code, and the EPCIS server address. The latter refers to the registration of product-level information of agricultural product mapping to root ONS. The attributes of root ONS include the manager code, local ONS address, and enterprise-level information that correspond to the manager code.

EPC cancellation refers to the cancellation of the bind between the memory addresses of agricultural product information and EPC. This process is divided into two categories, namely, local EPC cancellation and global EPC cancellation. Local EPC cancellation is the cancellation of dynamic information of agricultural product mapping to local ONS, whereas global cancellation is the cancellation of the static information of agricultural product mapping to root ONS.

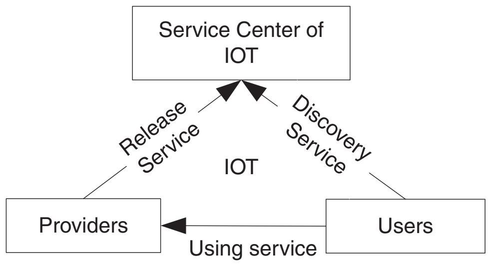

Figure 3.
Position of information release service

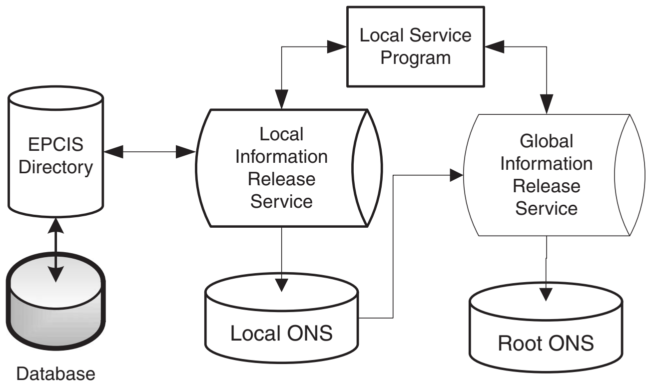

Figure 4.
Architecture of information release service

Information release refers to the release of detailed information of agricultural products to the EPCIS directory, as well as the release of the mapping information of routing information (logistics information) of agricultural products to ONS servers.

Information modification and information deletion is the process of modifying and deleting the information and routing information of agricultural products.

3.3 PML description of agricultural product information

The information received by EPCIS from ALE or other application programs is expressed in PML format. Request services are responded to with EPC-related data expressed in PML format. The PML file is an effective data storage tool in the EPCIS. Thus, PML plays an important role in EPCIS and becomes the standard of information interaction among the members of the supply chain system and their internal systems. Figure 5 shows the transmission of information in IoT. The information contained in the PML file meets the tracking and traceability requirements to achieve information sharing. For example, the database of aquaculture production for primary agricultural products includes information about names of farms and products, batches and serial numbers, lineages, breeding, and epidemic prevention (such as poultry) data. The information is stored in the EPCIS of the farm in the form of PML.

The information of agricultural products in IoT, such as the characteristics and class of products, is transferred in the form of PML. Based on the example of the emu, Figure 6 shows a PML file that describes the basic information of the emu. The file records the information on pedigree, name of production, information of father and mother, breeding records, epidemic prevention records, and name of the breeding base of the emu. The file is easy to understand and read. In this study, we briefly covered the PML file to facilitate comprehensive understanding of its design:

(1) PML elements are located between the start tag (the tag is not RFID tag) and the end tag.

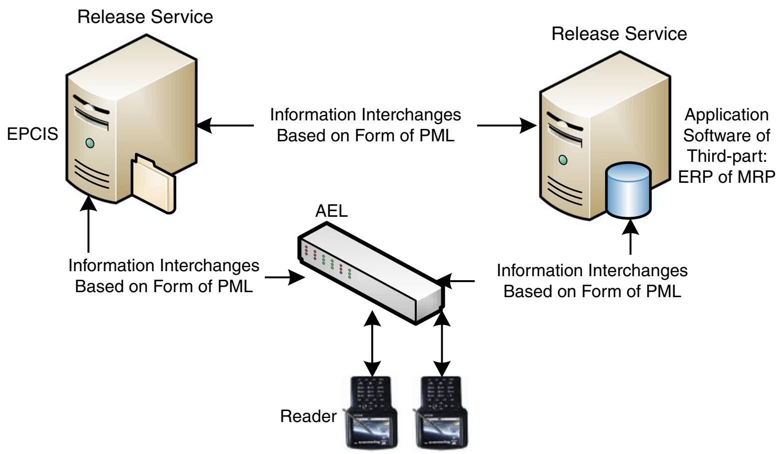

Figure 5.
Diagram of
PML as interface

```
<pmlcore:observation>
  <pmlcore:DateTime>20100125160328 </pmlcore:DateTime>
    <pmlcore:Tag><pmluid:ID> <urn:epc:53.3.67.257><pmluid:ID>
    <pmlcore:productinformation>
     <pmlcore:XML>
      <Tag:xmlns:="http://192.168.95.2/ermiaoinformation">
        <information>
                    <name>Emu</name>
                    <classname>Livestock</classname>
           <fathernumber1>urn:epc:1.1554.37401.2272361</fathernumber1>
           <fathernumber2>urn:epc:1.1554.37401.2274361</fathernumber2>
          <mathernumber1>urn:epc:1.1554.37401.2275361</mathernumber1>
           <housenumber>0304</housenumber>
           <feedname1>Corn Flour</feedname1>
           <feedname2>Bran Coat</feedname2>
           <vaccine1>Avian Influenza Vaccine</vaccine1>
           <vaccine2>Plague Vaccine</vaccine2>
           <vaccinedate>200901271303</vaccinedate>
             <Provincial>Guangdong</Provincial>
              <City>Meizhou</City>
           <producterea>No.114, Wuhua Breeding Base, Meizhou</producterea>
                  <ServerIP>192.168.95.2</ServerIP>
          </information>
     </pmlcore:XML>
    </pmlcore:productinformation>
     </pmlcore:Tag>
</pmlcore:observation>
```


Figure 6.
PML file of emu

(2) < pmlcore:Tag > < pmluid:ID > < urn:epc: 53.3.67.257 > < pmluid:ID >, which is transformed from binary EPC codes, expresses the EPC code in RFID tags. Translating the GID-96 EPC code leads to the uniform resource name.

(3) 192.168.95.2 shows the EPCIS server address of the breeding base.

(4) The file has a clear hierarchy and all labels in the file have prefixes and suffixes.

3.4 Design of the EPCIS system

The EPCIS system is designed to access the information read by readers and the relevant information of EPC code dealt by ALE. This process aims to store event data in the long term and facilitates the transmission of information in the form of PML. The EPCIS system is an information service system that can manage and release the information read by readers. An EPCIS system of the emu is designed in this study. During the culturing process, we recorded their basic information and noted their state information in real time when they trot. In the slaughtering process, the emu were slaughtered, disinfected, divided, loaded, and unloaded. We then obtained the status information of the emu during packing, processing, storage, out-storage, and sailing. We also recorded information on disinfection, shelf life, and so on. In the retail process, we noted their warehouse and sales information to realize the functions of information query, event registration, and so on. To achieve the functions shown above, the EPCIS system was designed to consist of the client module, the data storage module, and the data querying module as shown in Figure 7:

(1) The client module is responsible for the service that specifies the RFID tags point to EPCIS.

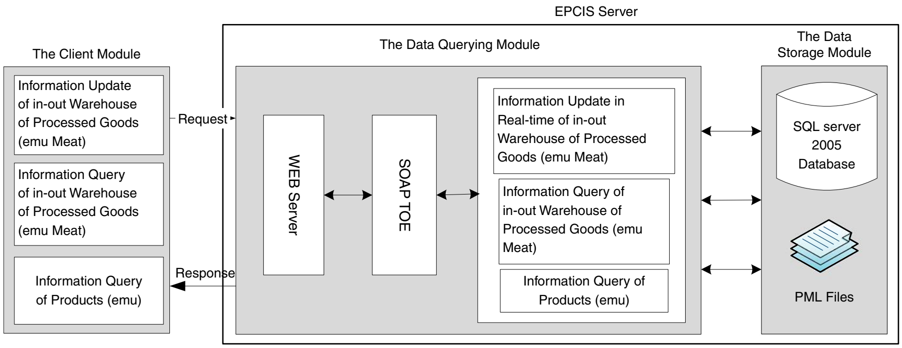

Figure 7.
Internal structures of EPCIS

(2) The data storage module stores universal data in the database, identifies the data for each product to match their EPC information when they are initialized, and stores the EPC information in PML files.

(3) The data querying module accesses the corresponding PML files according to the inquired requirements and permission of the client module. This module also generates HTML files and returns to the client module. In this module, data are stored in a system, which is a combination of SQL server database and PML files. The database is used to record the basic processing information of the emu, whereas the PML file establishes a tracking file for every product to facilitate ease of inquiry. In the query process, the system calls relevant information from the PML files to respond to the queries in the form of a web according to the permission of queries.

4. Logistics information tracing of agricultural products in IoT

4.1 Record and login of EPCDS information

In the culturing process of agricultural products, individuals have RFID labels that correspond to EPC codes. Before the agricultural products enter the next segment, the health and quarantine department will examine the security of products. The eligible products will then enter the next link (e.g. poultry products will enter the slaughtering processing). The staff will then record the process according to the quarantine information of the agricultural products quarantined by the health and quarantine department. The record will form a new PML file with quality information related to the cultivation of agricultural products. The file will be stored in the EPCIS (PML server) of cultivation and production enterprise as the initial record of each individual agricultural product. Without loss of generality, Figure 8 shows the emu as example and illustrates the transmission of logistics information of the emu from slaughtering to shipment. The RFID reader records the identified dynamic information to the local EPC information server while transforming the relevant information of agricultural products into PML files and stores them in the EPCIS. The process in Figure 8 can be summarized into the following three events.

Event 1: incoming inspections. Once the slaughtering plants receive the agricultural products (the emu) sent by breeding bases, the RFID reader reads their EPC. The ALE then records the event of incoming inspections to the EPCIS.

Event 2: processing and warehousing. The processed agricultural products (the emu) are sent to the freezer. The RFID reader reads the EPC of the emu, and the ALE records the event in the EPCIS.

Event 3: shipment. When the processed agricultural products (the emu) are sent to the downstream retailers from the slaughtering plants, the RFID reader reads the EPC and the ALE records the event in the EPCIS.

The information on the trade and outbound of products is recorded in the local EPCIS, whereas the EPC codes of agricultural products and the addresses of EPCIS server are registered in the local ONS server to produce the corresponding relationship in the ONS. Thus, ONS matches each EPC code to the EPCIS address of the information. The dynamic information of products is registered in the EPC discovery services by the local EPC information server. Figure 9 shows an example of the emu.

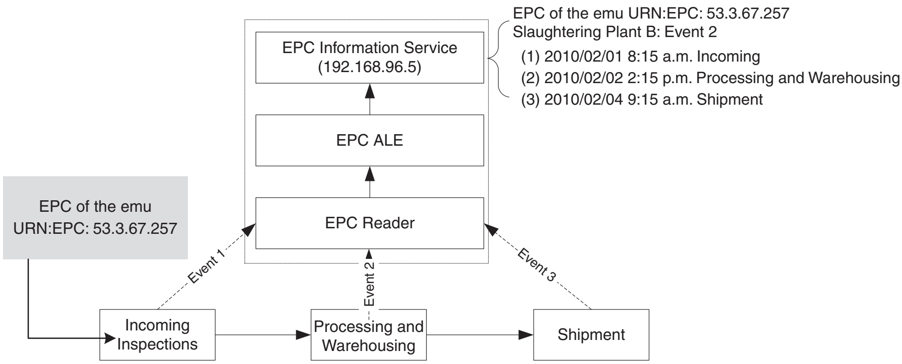

Figure 8. Transmission of logistics information of the slaughtering plant

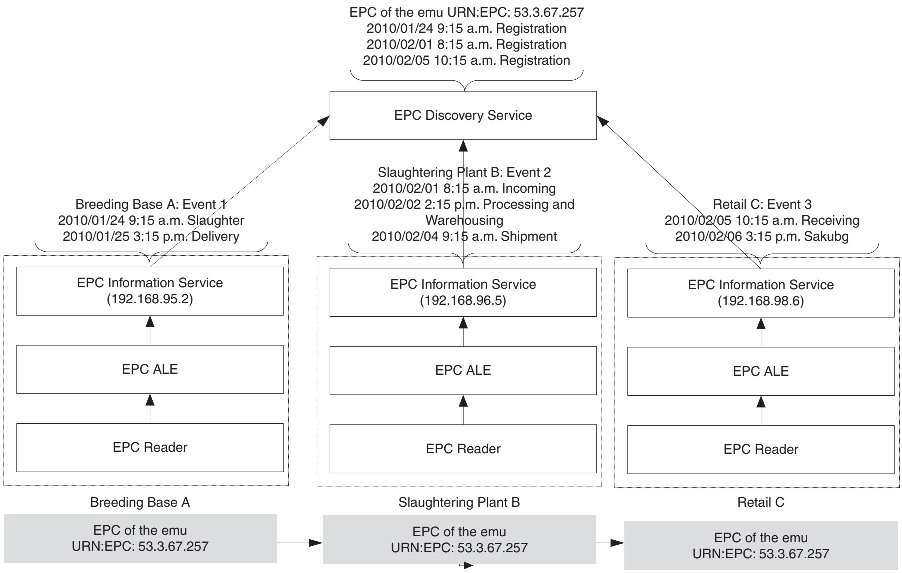

Figure 9. Registration process with EPCDS of logistics information

Figure 8 shows the registration process with the EPCDS of the logistic information of agricultural products. The process mainly consists of the following three events.

Event 1: breeding base A registration. When the information of agricultural products (the emu) appears on the EPCIS of the breeding base for the first time, they register their own EPCIS address with EPCDS.

Event 2: slaughtering plant B registration. When the agricultural products (the emu) are sent to the slaughtering plant, the information of the emu appears on the EPCIS of the slaughtering plant for the first time. Subsequently, they register their own EPCIS address with EPCDS.

Event 3: retail C registration. When the agricultural products (the emu) are sent to the retail, the information of the emu appears on the EPCIS of the retail for the first time. They register their own EPCIS address with EPCDS.

All information (such as essential features and lineages) in IoT is transmitted in the form of PML. These PML files may include real-time information, sensor information, and others.

4.2 Inquiry of static information

When consumers inquire about the fixed information of agricultural products (names of farms, fodder, and fundamental information of epidemic prevention) and other original information (static data), the system inquires the information through the root ONS by identifying codes in the RFID of agricultural products. According to the company code in EPC, the root ONS identifies the corresponding local ONS addresses to inform consumers where they can obtain further information. Local ONS identifies the EPCIS addresses according to the commodity codes, which are in the EPC, to inform the users about the EPCIS addresses of production and cultivation enterprises. The users inquire through the EPCIS of the enterprise by using the addresses. They acquire the relevant static information of the desired products after they are identified. ONS is important in the process of inquiry. Figure 10 shows the process. Figure 11 shows the inquiry process of the static information using ONS.

Step 1: querying the root ONS. Root ONS searches the address of local ONS according to company code (000000003) in the EPC and then sends the result to the queries for further inquiries.

Step 2: querying the local ONS. Local ONS searches the address of the EPCIS of agricultural products (the emu) according to the company code (000000067) in EPC then sends the result to the queries for further inquiries.

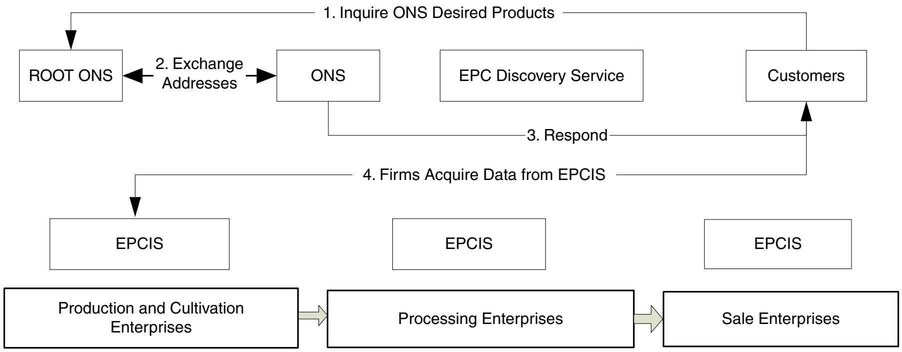

Figure 10.
Inquiring process of static information

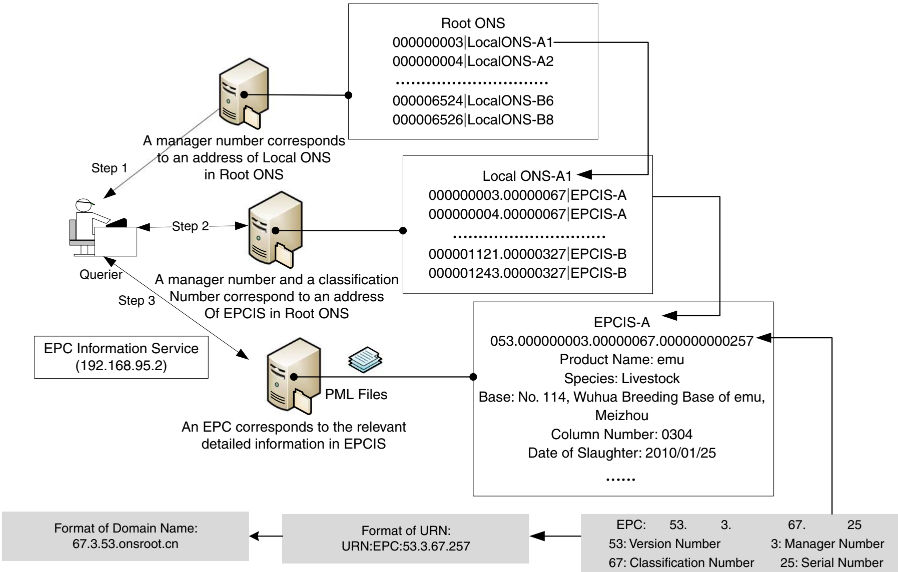

Figure 11. Inquiry of static information using ONS

Step 3: querying the address of EPCIS. The EPCIS server returns the corresponding information of the products (the emu) to the queries according to the EPC.

If the information was directly written in the agricultural products, such information can be directly obtained. Not all products (e.g. pork being sold in pieces) can use the RFID in circulation and retail link, which adds to the high cost of RFID labels. Thus, we adopted an economic method that matches each batch of bar codes to an EPC.

4.3 Inquiry of dynamic information

When consumers (or other members in the supply chain) need to inquire about the dynamic information of agricultural products, such as present location, and information about the processing of products, such as time, the system obtains the information in the root ONS by identifying codes in the RFID of agricultural products. If the local ONS cache has relevant information, it will return the information to EPCIS. Otherwise, it will require the high-root ONS to return the relevant information. The EPCIS will then inquire about the relevant information based on the returned information. Finally, the ONS will send to the users the addresses of the firms. The track and trace service function will be launched after users are identified by inquiring EPCIS. Manufacturers will inquire EPCDS. EPCIS will record the dynamic information of the desired products by using the identification numbers in the tags and obtain the EPCIS addresses related to the identification numbers in the labels. The manufacturers will access the EPCIS addresses to obtain the dynamic information and the entire tracking data in the supply chain of the desired products after identity verification. Finally, the firms will respond to consumers by sending the dynamic information of their desired information, such as processing information, delivery time, and so on.

The inquiry process is shown Figure 12. Figure 13 shows the inquiry process for obtaining dynamic information through EPCDS.

Step 1: querying the EPCDS. Inquire the EPCDS. The EPCIS records the dynamic information of agricultural products (the emu).

Step 2: querying the EPCIS. Inquire each EPCIS to obtain the entire tracking data in the supply chain of agricultural products (the emu).

EPCIS stores the information of all products in the film. Thus, EPCIS knows the locations of readers who are responsible for sending information. EPCIS also knows the producers of the products. If the agricultural products have quality problems, such as those related to pollution accidents, the root of the problems is eliminated and the related products are recalled by the system. Therefore, the application of IoT in the field of agriculture can enhance the safety management of agricultural products.

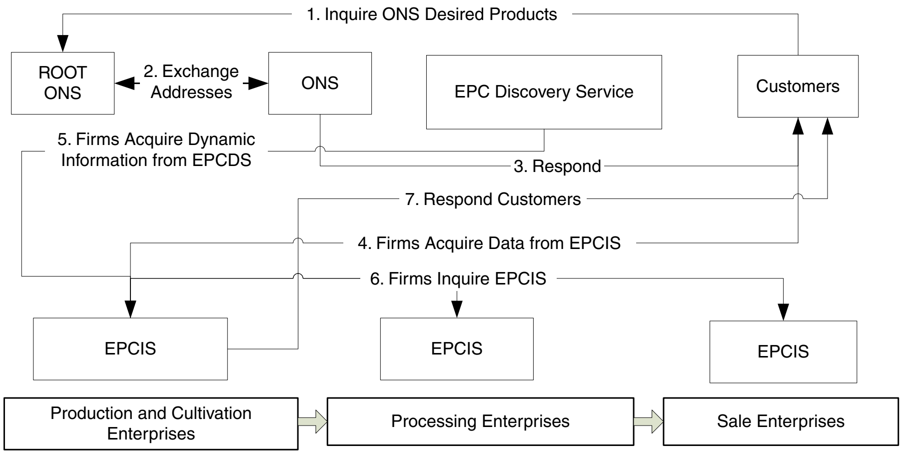

Figure 12.
Inquiring process of dynamic information

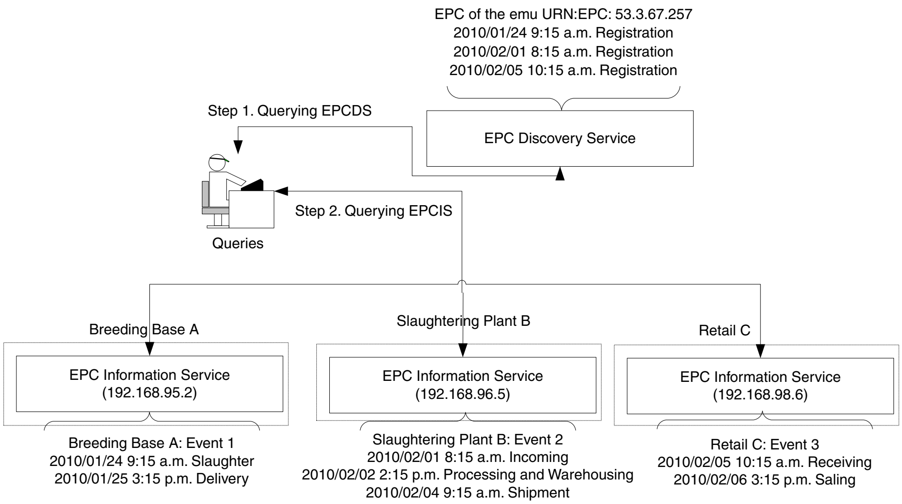

Figure 13.
Inquiry of dynamic information using EPCDS

5. Design and implementation of the system

We designed a networking environment for the tracking and tracing system of emu supply chain. This system is now being used in Wuhua emu breeding base in Meizhou city, Guangdong province.

5.1 System design

Based on standardized precision feeding, the system tracks and traces the information of the processing, packaging, storage, and selling of emu meat. This system is also used in the management of emu supply chain, which ensures the high quality of data communication in the supply chain to trace the quality of emu meat.

5.2 Database design

System users include cultural bases, emu abattoirs, and retail enterprises. Figure 14 shows that users have access to the emu supply chain traceability system via the internet; thus, they can upload traceability data to the background database or query information from the background database. The information collection technologies adopted by this system are mainly RFID and bar code. The staff of the supply chain uploads the traceability information to the system and establishes the corresponding relationship between each batch.

We adopted the PowerDesigner to design the database, which shows correspondence between data tables and clarifies the relationship between the data thereby reducing the generation of redundant data. Figures 14-17 show the data mode of the breeding node, slaughter node, and retail node.

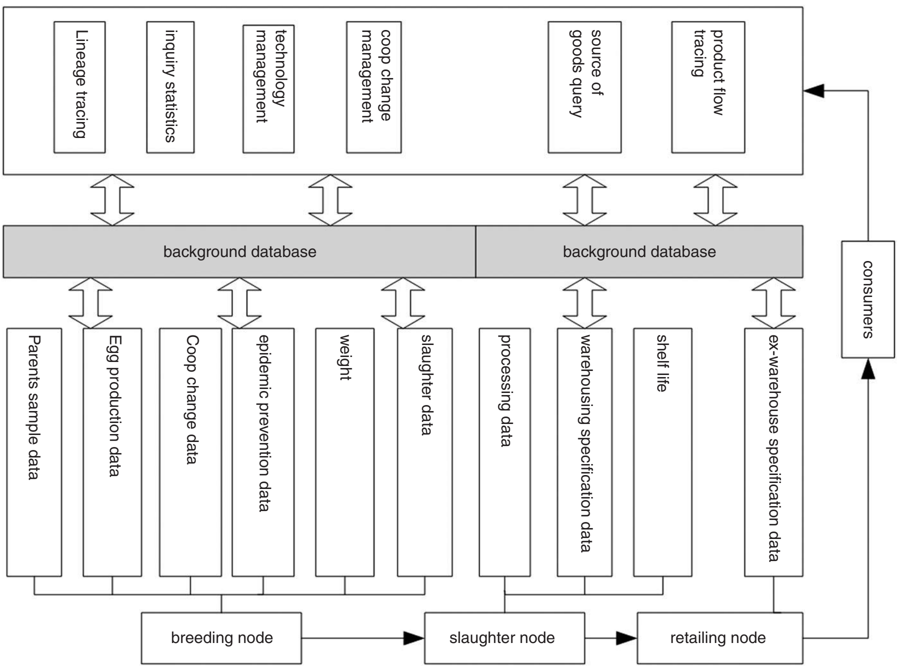

Figure 14. The structure diagram of emu breeding supply chain management based on IoT

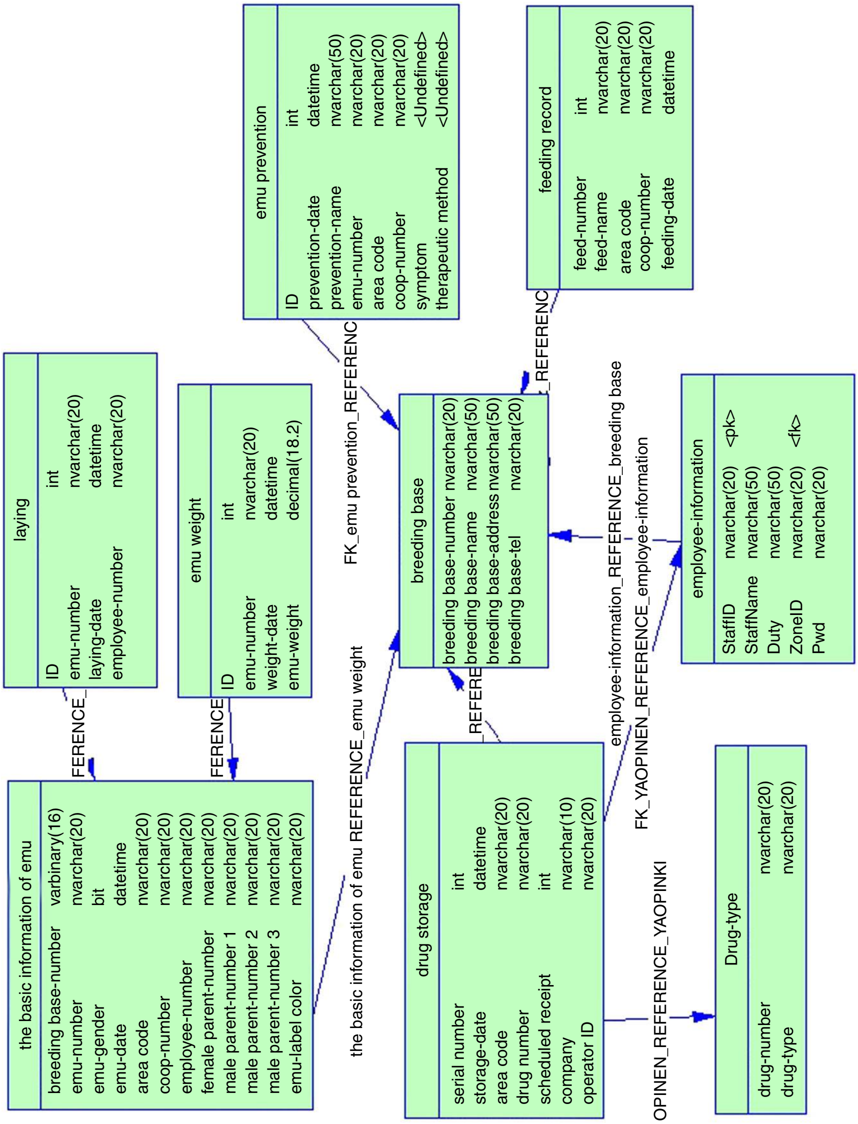

Figure 15.
The data model in breeding node

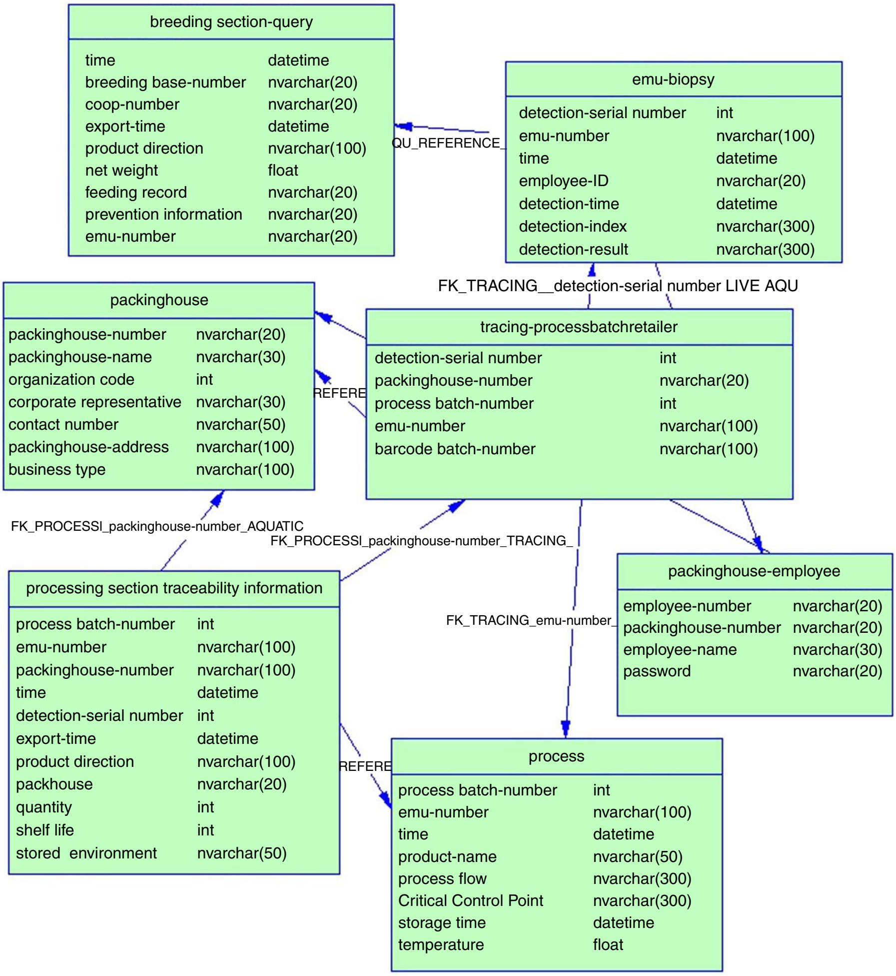

Figure 16.
The data model in slaughter node

5.3 System function module and the realization of key functions

Based on the user requirements, the system is divided into seven functional modules, namely, query statistics, coop management, technology management, warehouse management, site management, systems management, and traceability management. The implementation and application of this system has achieved good effect in the Wuhua emu cultural bases in Meizhou, Guangdong province. We provided the application interface of some system functions and their implementation.

System authority setting: the system sets up a strict operation authority for different users. Each user can only perform operations within their authority as shown in Figure 18.

Query statistics: the main query information includes emu information, storage information, employee information, customer relationship management information, and statistical analysis. Users can selectively query according to different combinations. The system will generate a corresponding information report as shown in Figure 19.

Figure 17.
The data model in retail node

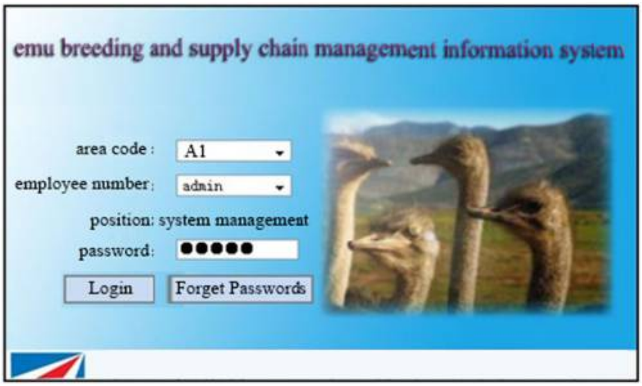

Figure 18.
The system logon interface

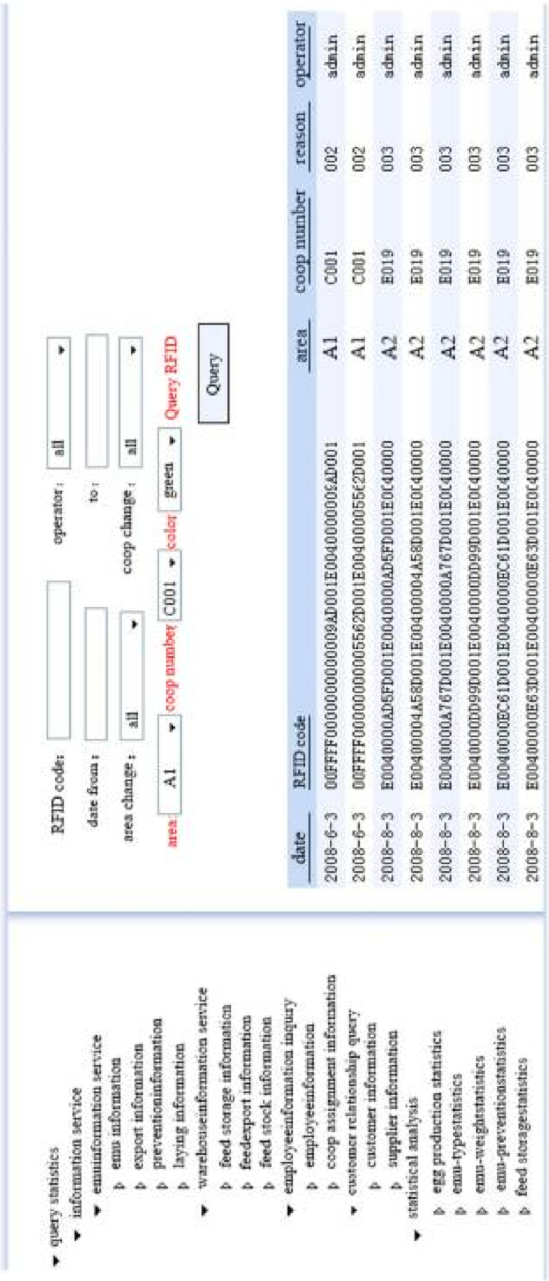

Figure 19.
The information query interface of emu breeding stage

Coop management: the basic information, egg production, and coop change of the emu are recorded. This module includes the management of emu transfer and the coop of emu. Thus, cultural bases can classify different types of emu (young birds, adult birds, and birds intended as goods).

Technology management: this module deals with emu epidemic prevention and quarantine management, including feed formula, feed species, records of epidemic prevention drugs injection, and weight input as shown in Figure 20. Lineage tracing can trace the egg production of emu. Thus, the inbreeding coefficient can be calculated to select the emu that is suitable for mating.

Warehouse management: this module involves feed inventory management, including feed warehousing registration, records of feed breeders pick, and feed query database.

Site management: this module allocates coop numbers to employees in different districts and records the information of the emu from different coops.

Systems management: this module mainly inputs and records basic data, including user management for users with different authority, such as employee management, coop management, and customer relationship management information.

Traceability management: this module records the key traceability information of the emu from breeding to slaughter and retail.

6. Conclusions

The survey of information sharing in the supply chains of agricultural products based on IoT aims to solve the problem of insufficient sharing of information, inefficiency, and poor quality of transmission of information in agricultural supply chains. This system can control the safety and quality of agricultural products. In this study, we introduced an IoT application model of agricultural supply chains. We designed and analyzed an EPCIS system, which is a key part of the information sharing of agricultural IoT. We also examined information registration using EPCDS and the information query of agricultural products by ONS. The application of agricultural IoT shows the capability of information sharing. IoT can help the operators of agricultural products establish a system of inspection and delivery that enables them to trace the flow of the products and manage production problems efficiently to guarantee the security of the circulation of agricultural products.

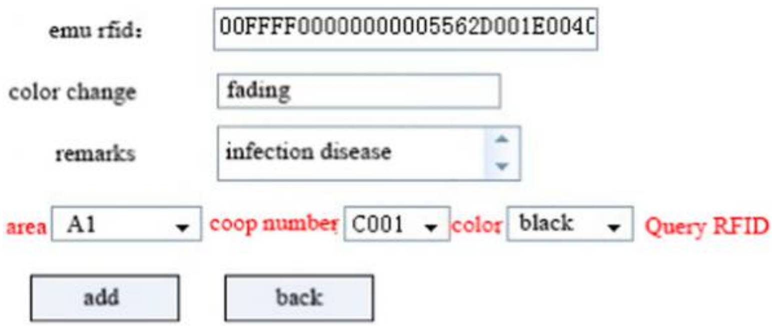

Figure 20.
The information record interface of security monitoring and control

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Further reading

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