# Model for Quality Tracing of Agricultural Products Using RFID and Internet Systems

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***ABSTRACT***

*Due to nationwide health hazard problems and the development and prevalence of information industry, Internet of Things (IOT)-based traceability system has gradually been applied to agricultural products to monitor the whole process from fields to final consumers, covering production, processing, and sales. This paper first analysis the factors that affect production-based processing enterprises and supermarkets as main patterns of direct link between farmers and supermarkets. A model for tracing the system or factors that affect agriculture product quality is then proposed. Finally, a prototype system is established and its application is discussed by adopting radio frequency identification (RFID) technology, ASP.NET, and Web services technologies, with Visual Studio as the software development platform and SQL Server as the backstage database. The RFID is used here as an aid to gather product information. The importance of the system developed in this study lies in as follows: firstly, this system can realize the effective traceability of the whole process for agricultural products from the origin to final customers through the processing enterprises and supermarkets; secondly, adaptation of this system enables the transparency of the agricultural product information and, thus, the enterprises can be better managed; lastly, this system enhances the safety, consciousness of consumers, and supervision of government department for agricultural products quality.*

## 1. INTRODUCTION

In recent years, the problem of deteriorating quality, prevailing in agricultural products, has frequently affected, directly or indirectly, the life of general mass, and has threatened people's health and life quality. This nationwide health hazard problem that is appearing at each stage of the global supply chains of agriculture products makes it essential to define critical control points to capture the data such as ingredients, manufacture and certain dates (sell-by, use-by), and to provide related information in a transparent manner to participants and consumers of supply chains.

Traceability refers to “the ability to trace the history, application or location of that which is under consideration” or “when considering a product, traceability can be related to the origin of materials and parts, the processing history, and the distribution and location of the product after delivery” [1]. European Union (EU) firstly launched the traceability system in 1997 for the purpose of dealing with Bovine spongiform encephalopathy (BSE), and the regulation of mandatory enforcement of traceability was issued in 2005, which requires all foods and feeds in EU market to be traceable [2]. A similar strict rule became effective in Japan in 2005[3].

With the development and prevalence of information industry, Internet of Things (IOT)-based traceability system has been gradually applied to agricultural products to monitor the whole process from the field to the final consumers covering production, processing, and sales. Efficiency, process control, and consumer communications are all closely related to the use of information and communication technology (ICT). An efficient and effective system transmitting accurate, timely, complete, and consistent information about products through the supply chain can significantly reduce operating costs and can increase productivity. At the same time, such a system contains many product safety elements: it makes consumers safer by providing detailed information about where an item comes from, what its components and origin are, and about its processing history [4].

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Radio frequency identification (RFID) has been successfully applied to traceability control and supply chain management processes because of its ability to identify, categorize, and manage the flow of goods [5, 6]. The use of the Electronic Product Code (EPC) standard improves the efficiency of the supply chain and allows the exchange of information between different companies.

Information Technology (IT) in the form of RFID is powerful when been applied to overcome the problems associated with traditional solutions (alphanumerical codes and barcode labels). Some advantages of using RFID are listed followed.

(1) With RFID, data can be gathered through a variety of external materials without light sources.

(2) The RFID can be used in many extreme environments and can last much longer than traditional technology.

(3) The RFID has a longer reading distance, and can be easily embedded or attached in different shapes and types of products.

(4) With RFID, data can be easily written and read. It takes less time for RFID to write data than to print bar code labels. Moreover, the contents of RFID tag can be processed at any time.

(5) The object attached RFID tag can be traced back and located.

The RFID techniques has been deployed in manufacturing environments in order to achieve real-time traceability and visibility while minimizing the total cost [7]. The link between RFID sensing devices and improved cool chain management methods such as the Quality Oriented Tracking and Tracing Systems (QTT) offers new features. An example of this approach is the Safety Monitoring and Assurance System (SMAS) that was developed to reduce customers' risk of consuming microbiologically contaminated meat. This traceability control can be further improved by implementing RFID in combination with mobile phones and web based network computing [8].

This paper studies how to use RFID to collect and trace information for each echelon of an agri-products supply chain. Firstly, it aims at the analysis of factors which affect production base-processing enterprises-supermarket as a main pattern of direct link between farmers and supermarkets. Then the model of the tracing system is proposed. Finally, a prototype system for vegetable traceability is designed in which the RFID technology is adopted as an aid to gather product information, he Visual Studio is used as the software development platform, and the SQL Server is used to build up the backstage Database. Through a case, this system can be proved to realize the effective traceability of the whole process for agricultural products from the origin to final customers through the processing enterprises and supermarkets.

With application of this system, the transparency of agricultural product information is available and the management level of enterprises can be improved. Furthermore, the safety consciousness of consumers and the quality of the supervision of government department for the safety of agricultural products can be also enhanced.

## 2. THE TRACEABILITY FRAMEWORK

In this part, the circulation of agriculture product in China is analysed firstly. Due to the disadvantages of traditional circulation mode, "Integrate with Agricultural Base & Supermarket" is adopted. Then, a distribution mode of agricultural products connected with supermarkets is proposed. Finally, based this mode, the structure of agricultural products traceability system is set up.

### *2.1. THE WHOLE PROCESS OF AGRICULTURE QUALITY CONTROL SYSTEM*

In China, wholesale market of Agricultural products has been the main channel of the circulation of agricultural products, which is an important part of the market system of agricultural products[9]. There are many problems in the current operation of the traditional wholesale market of agricultural products, such as order confusion, lack of management, lack of information, traffic congestion, environmental pollution, lower efficiency. Many factors have inevitably leaded to reduction of agricultural products freshness and increase of the loss, such as too many intermediate links of the circulation of agricultural products, long circulation time, invalid numbers of handling, and storage. Moreover, intermediary businesses do increase the cost.

"Integration of Agricultural Base & Supermarket" flow of agricultural products is an innovative model of the supply chain management of agricultural products, which takes changes for agricultural products from traditional pattern to integration of the production, circulation and sales with fewer links of the circulation. This new mode is that the

supermarket can directly purchase agricultural products from the end supplier (such as famers), as well as, supervise and manage the whole supply chain of agricultural products. The members of this supply chain can make strategic partnership to share information and benefit.

For supermarket, on one hand, purchasing agricultural products directly from the supplier base can cut down the cost, reduce the circulation link, shorten the circulation time and expand sales. On the other hand, this mode is conductive to the supermarket to exam products and to provide technical guidance to suppliers to improve management level of food safety. Moreover, the supermarket can realize the implementation of monitoring the whole process of production and circulation of agricultural products.

For farmers, they produce agricultural products according to supermarkets' orders as so to reduce his difficulties in selling the fresh agricultural products, difficulties in transportation, difficulties in storage. The supermarket gives impetus to the development of processing industry for agricultural products, including primary products, semi-finished products, small packaging of various specifications of agricultural products, which can increase the income of farmers. The supermarket has mandatory requirements and testing standards for quality, specifications, health inspection and quarantine standards, agricultural pesticides and chemical fertilizers for agricultural products and their residues, so the farmers can be strictly supervised to a certain degree, which can promote the informatization and standardization development of agricultural products.

Under this mode, agricultural supermarkets offer convenient, fresh products and can guarantee food safety and health. For consumers, they are the ultimate beneficiaries of the supply chain of agriculture production since they can enjoy reasonable price and appropriate processing services.

At present, more than 70% of the total sales of agricultural products are sold though supermarket in Asia Pacific and 80% in USA, while only about 15% in China [9]. Distribution mode of integration of agricultural base & supermarket is adopted as shown in figure 1.

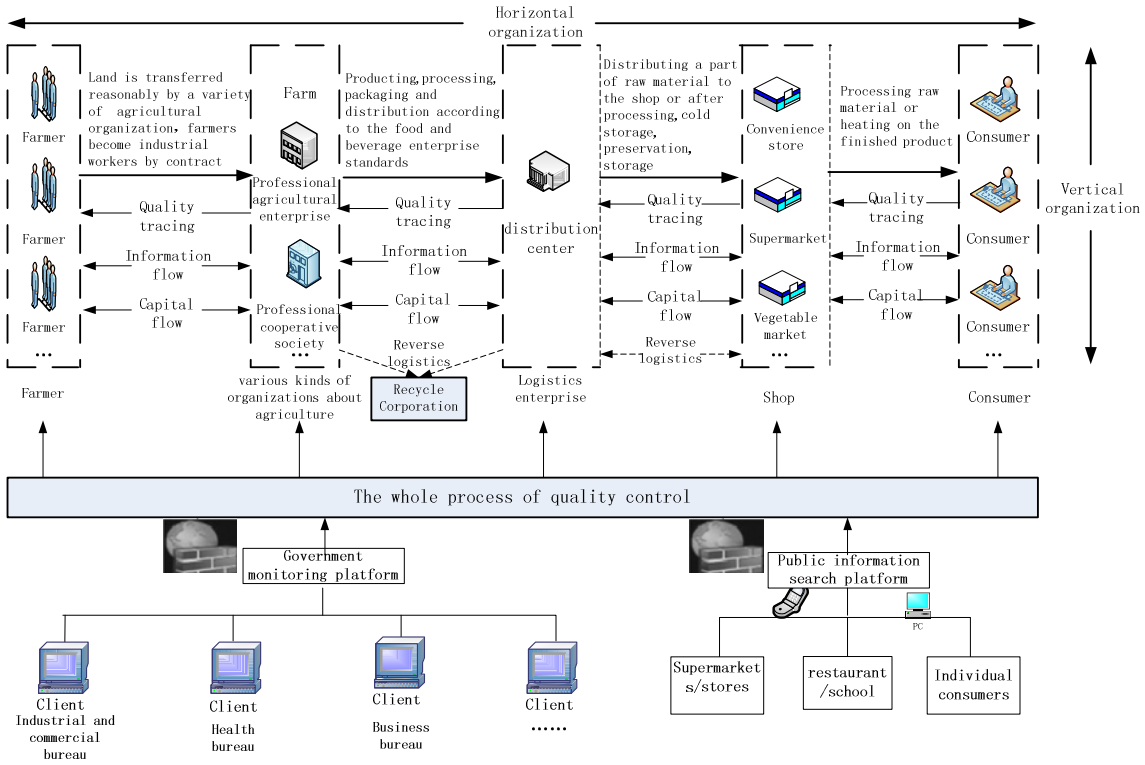


Figure 1. Distribution Mode of Integration of Agricultural Base & Supermarket.

Looking from the horizontal structure of the distribution mode, the logistics enterprise is in the middle, the core of the supply chain, which plays an important role in the cohesion and management. Starting from the consumer terminal, supermarkets can feedback to a series of operations of agricultural products including production, processing,

packaging, transportation, storage and distribution in order to realize the rapid circulation of agricultural products and value-added goals throughout the process.

Furthermore, looked from the vertical structure, each subject related with supply chain has his own partners or competitors, which mainly reflects the relationship among competitions. Particularly, the various agricultural organizations, with their continuous development and growth, will produce competition with another. The more enterprises in the competition, the more intense the competition become. As a result, the services and the prices to the customers all become better.

Under such a mode, supermarkets provide accurate information to the farmer specialized cooperative society in order to guide farmers to produce higher quality that can meet the market requirement. Traceability information system for quality of agricultural products should be established in the information platform to carry out the whole quality control, so related bureaus consumers can check on information related product quality and safety, shown as in figure 1.

### *2.2. THE STRUCTURE OF SYSTEM*

Agricultural products traceability system is fundamentally based on 4 modules, namely production information module, processing information module, sales information module and system management module. Each function module is, in turns, divided into several sub modules as well Shown as in figure 2.

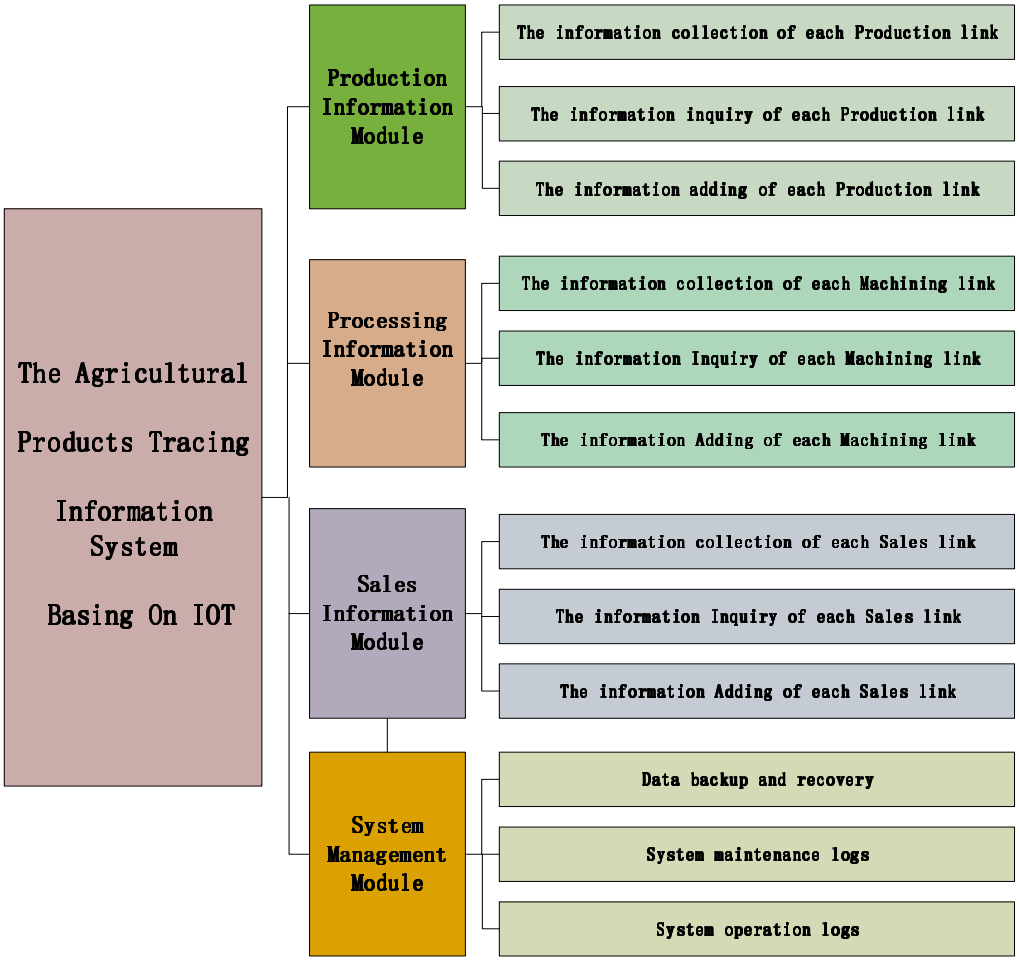


Figure 2. Framework for Product Traceability System Concept.

(1) Production information module

Gathering information of production is the first link in the entire information chain. Main function modules of this link are to supervise, record and control the product origin and detailed information of the product. The gathered data

include basic information of agricultural product origin (origin contact ID, name of origin, origin contact, environmental conditions, etc.) and the basic information of agricultural products (product name, product number, production date, production quantity, medications, etc.).

(2) Processing modules

The processing is the second link of supply chain. In processing information query module, it is inquired that the basic information in agricultural products processing, including basic processing information (product name, machining time, machining quantity, batch number, product warranty, etc.) and processing companies (factory code, machining employee number, employee name, address, contact processors, etc.).

(3) Sales information module

The sale or delivery is the last link. In query module for sales information, it is inquired that the basic sale information of agricultural product, including information of storage and information of POS (Point Of Sale). Vendors can sell products in aid of RFID reader. Consumers can use the query module of this system to query the detailed information of the bought product.

(4) System management module

System management mainly includes the data backup and recovery, system maintenance, system operation log logging. In the process of operating system, in case of an unexpected accident which incurs relevant data loss, the data can be recovery through data backup in advance.

### *2.3. MAIN FUNCTIONS OF THE SYSTEM*

In this system, the main functions are product identification, data to trace, product routing, and Information sharing.

(1) The step of product identification

The step of product identification is fundamental, with physical characteristics such as volume, weight, dimensions, and packaging having a direct impact. Other classes of information are required to deal with mechanical properties (shortness, condition of surfaces) and the length of the life cycle.

In information identification module, a complete set of product codes have been established. At each point of information acquisition, product codes can be scanned into the database through the RFID technology automatically. Product codes record detailed information about agricultural products including their origins, thus, the quality and safety in the supply chain of agricultural products can be effectively monitored and controlled with the aid of the codes. If a safety accident of agricultural products happens, consumers can complain to the food administration department of the supermarket according to the specific product code. The administration department can then identify the reasons for the problem promptly by tracing back to the production, processing units on the basis of the information, which can save the time and costs associated with dealing the food safety accident.

(2) Data to trace.

The characteristics of the information, such as those related to kind (digits, strings, ranges, etc.) and number, or to the confidential levels, that the system must manage are absolutely relevant to correct design.

In the process of agricultural production, processing, and sales, the basic information related to agricultural products can be queried and added online in time.

(3) Product routing

A product traceability system must take the production process into account. The system must record “product life” along the supply chain, then through both production activities and movement or storage activities. Clearly, product lead times, equipment required, the degree of process automation, and other process information all have a direct impact on traceability.

(4) Information sharing

Through sharing and exchanging information, the system can improve the effectiveness of the management and service quality to customers and suppliers.

## 3. HELPFUL HINTS ABOUT THE REALIZATION OF VEGETABLE TRACEABILITY SYSTEM

Agricultural resources are abundant in Hubei province, China. However, there exist some information management problems, especially for the vegetable products. Some of the problems are listed as follow:

(1) The basic production unit cannot be accurate identification.

(2) The recording of production process is not perfect and the efficiency is low.

(3) Processing units are disconnected with associated production units.

So, it is difficult to trace and supervise the quality and safety of the agricultural products in Hubei province. At the mode of agricultural products linked with supermarket, agricultural products quality tracing system is established to solve the problems existing in production of special agricultural products in Hubei at the present time.

RFID application in fresh vegetable traceability system can not only ensure the high quality data communication of traceability system, but also be attached in the packing of the products in any form. This is because that the RFID system can provide separate identification and storage history for each piece of vegetable products as well as a detailed and unique perspective of traceability system to ensure that the source of the vegetables products to supermarket shelves and restaurant kitchen is clear. This system can also improve the automation level of the agricultural products from farmland to customs in a great degree.

In this section, a traceability system of Vegetable product in Hubei province is designed as a case.

### *3.1. RFID AND COMMUNICATION INTERFACE*

A tag and a reader are two basic components of RFID technology. The tag is attached to an object that is to be identified. The tag consists of a microchip, which contains the identification information about the object to which the tag is attached, and an antenna to communicate that information via radio waves. The reader creates a radio frequency field and detects radio waves reflected back from the tag when the tag passes through the radio frequency field, thus identifying the object. Figure 3 shows how the RFID works in principle diagram.

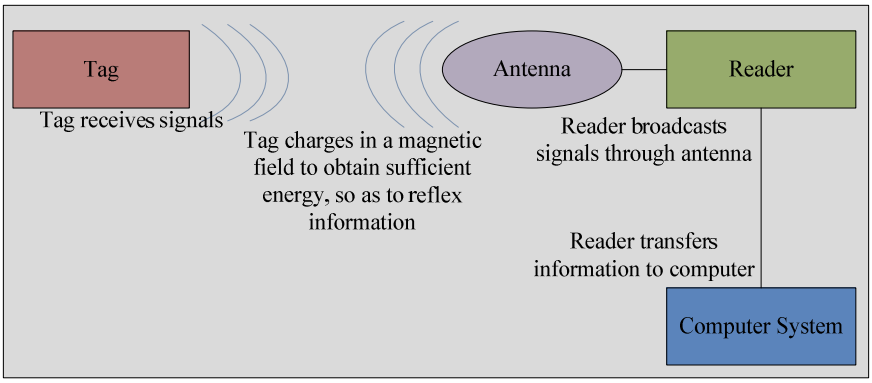


Figure 3. RFID System working principle diagram.

Each tag is essentially a computing device that acts as a node in a network. A RFID tag can be attached to a pallet, a case, an item, etc. Item-level tagging enables companies to have better visibility of their products [10].

In RFID devices, the main task of RFID reader is to realize the acquisition of labelled data information and the client computer or PC is to realize the processing and transmission of data. Interface devices for the RFID reader communicating with PC include RS232, RS485 and USB interface in RFID-ISO14443 equipments. According to the general data acquisition and processing of RFID equipment, the USB is chosen as the interface between RFID reader and computer.

### *3.2. SYSTEM DEVELOPMENT ENVIRONMENT*

This system is developed in B/S structure with ASP.NET technology, using Microsoft Visual Studio 2008 and Microsoft SQL Server 2008 as the development platform and development tools, respectively. The ADO.NET is used

to connect the system with the Microsoft SQL Server 2008 background system. The C# is used as the programming language of the front desk program design.

The operation system of clients is the Windows 7, the operation system server is Windows 2003, and database management system is Microsoft SQL Server 2008.

### *3.3. THE MAIN INTERFACES OF THE SYSTEM*

In the agricultural products traceability system, users need to input user name and password, and then log on to the system's main page. After logging in, users can see six main menus, which are the production of information, the processing information, the sales information, the early warning information, the system management, the information collection, and the tracing information, respectively. Clicking on any options will appear the required interface.

3.3.1 The information acquisition

The first step to establish traceability system is to realize information collection function of the agricultural products from production to sales, which is the fundamental requirement for the design and development of information systems. For data acquisition, each key terminal logs in traceability system of agricultural products according to permissions assigned by the system, and then input related information according to the predefined data format. The information containing all of product attributes is then input into the RFID tag. Finally, the data in tag is entered into the central database through the RFID reader.

Card serial number in the RFID-ISO14443 is 40 (UID =5Byte) and the card has 16 different data sectors each of which has 4 blocks, that is, Block 0, Block 1, Block 2 and Block 3, respectively. Since each block has 16 bytes, a sector has a total of 16 Bytes X 4 = 64 Bytes. Block 3 of every sector (the fourth pieces) contains the sector code A (6 bytes), access control (4 bytes), password B (6 bytes), which is a special block. The remaining three blocks are data blocks in general, but the Block 0 of sector 0 is a special one that is cured by manufacturer's code and cannot be rewritten. Each sector of RFID for product information is shown as in Figure 4. During the process of collecting information, corresponding information is stored in the sector of each data block in data form, and is finally stored in the database after character conversion from sixteen hexadecimal code into a corresponding character. Since the information collected by each tag is dynamic, the system can record the logistics tracking to realize the network management of agricultural products traceability.

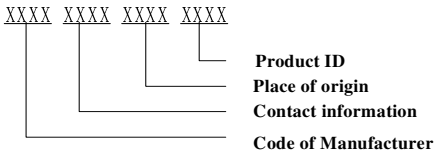


Figure 4. The Data Structure of RFID for Product.

3.3.2 The information query and traceability

The information query module includes production information query, processing information query and sales information query. Each link of the whole process of agricultural products from production to sale can be monitored and queried in real time and the product information can be traced back through the agricultural product code. If a problem of products (such as cabbage) arises, consumers can check the related information of Chinese cabbage, including production, processing and sales by code 0213 and supervision departments can timely and effectively query which link cause the problem and timely solve it to make the damage to the lowest. This module includes sales of agricultural products, name, place name, serial number, product processing, as shown in figure5.

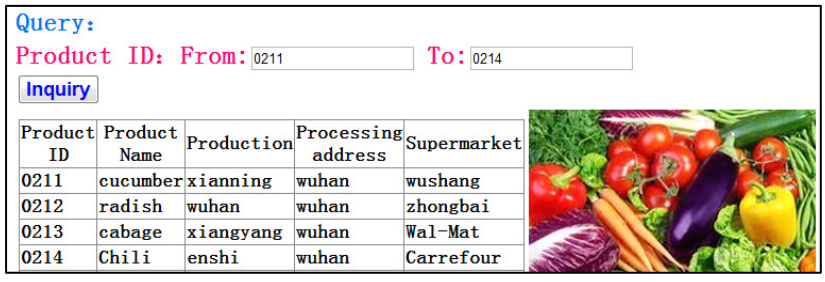


Figure 5. Information Query of Origin.

## 4. SUMMARY

Associated with the increasing demand from the end customer for healthy safe foods is a large requirement for a well structured traceability system. The new framework presented in this paper represents the starting structure for an effective traceability system for agriculture products. It is based on four modules (the production information module, the processing information module, the sales information module, and the system management module) and results in a systematic organic design of a traceability system for each agriculture supply chain. This framework has been applied to the vegetable supply chain in Hubei province of China and has created a traceability system that works very well for both farmers and consumers.

Radio frequency identification (RFID) has more potential and more advantages. By using the RFID system, consumers, farmers, manufacturers and supermarkets, food secure departments are able to trace the product along the chain with great precision and can apply possible recall strategies very rapidly. By inputting a code on an Internet web site, customers can find the history of the portion of vegetable that they have bought.

With application of this system, the transparency of product information during the growing and process is achieved and the management level of enterprises is improved. The safety consciousness of consumers and supervision of government department for agricultural products quality safety is also enhanced. Moreover, although usually created for safety reasons, a traceability system of agriculture products presents farmers with an opportunity as the design and management of a traceability system improves process control, indicates cause and effect when the product fails to conform to standard, improves planning so that raw material use is optimized, and improves grounds for implementing IT solutions to control and manage production.

This study may be extended to take into consideration of combining the use of cellular phones to provide a 7/24 availability for inquiry. Another improvement of this system lies in the utilization of a series of sensors to real-time supervise important parameters such as temperature and humidity.

## ACKNOWLEDGEMENTS

This paper has been funded by the National Natural Science Foundation of China (No.51175394).

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