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Organic RFID Based on Traceability System of Rice Supply Chain

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Abstract

Organic RFID tags have the features of two-dimensional bar codes, inexpensive, flexible and thin, while also integrated the merits of inorganic RFID tags, making them promising in facilitating the wide application of RFID technology. In this paper, organic RFID technology and its characteristics are analyzed, and the feasibility of its application in rice tracing is studied. Based on the analysis of characteristics of each links in rice supply chain, and with organic RFID technology as tracing means, a rice supply chain tracing system is designed using database and sensors. Focusing on characteristics of major links in tracing and the requirements of electronic tags, application scheme of the system is proposed for the tracking and tracing of links in rice supply chain. In the meantime, schemes are designed for the association of major information in the tracing system to ensure the accuracy and reliability of tracking and tracing.

Keywords: *organic RFID, tracing, rice, supply chain, association, link*

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1. Introduction

As staple food for over 60% of the population, rice (Oryza sativa) is a major crop in China. In recent years, due to excessive use of chemical fertilizers and pesticides and abusive application of food additives, rice quality has attracted more concerns by consumers. The traceability of the quality and safety of rice, as well as other agricultural products, has thus become particularly important. With the gradual improvement in national rice standards, food quality and safety laws and regulations system, researches and implementation of rice tracing systems are on track, however tracing system with rice as study object has rarely been reported.

Rice trading involves many links, mistakes in any of which could cause inconsistency of bar codes on delivery bags with rice information data, leading to very common inventory transshipments. Meanwhile, since rice trading often happens in harsh environments, bar codes that are bound to delivery bags could easily fall off or be damaged. Loss or damage of bar codes causes loss of rice information and makes rice tracing almost impossible. Therefore, it is crucial to design a rice tracing system that is secure, reliable, and accurate.

Radio Frequency Identification (RFID) [1] is a non-contact automatic identification technology using radio-frequency signals to identify objects and obtain data and information [2]. The application of RFID is simple, practical, accurate, reliable and flexible, and even suitable for many harsh environments. Therefore, it has been researched and widely used in many countries [3]. With the development of RFID technology, it has started serving for the quality and safety guarantee of agricultural products in tracing systems [4]. In Europe, the U.S. and Australia, RFID tags have been applied to regulate the whole process of food industry in order to provide quality assured products to the markets [5-7]. Although RFID tags are considered the most promising technology in global trading and logistics, their high costs constrained their application in food safety tracing systems. The emergence of organic RFID solved this issue very well and gives RFID technology the opportunity to be widely applied in agricultural product tracing systems. In this study, with rice tracing system as an example, an agricultural product

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tracing system that uses RFID as tracing means is proposed. The purpose of this study is to provide basis for food quality and safety tracing.

2. Organic RFID Tag and Related Studies

2.1. Organic RFID Tag

Organic RFID technology is the product combining RFID with organic semiconductor. Data is obtained through radio-frequency [8] and objects are identified automatically without human intervention. Organic RFID tags have similar structure with inorganic RFID tags, mainly composed of antenna, RF module, control module and memory [9]. Figure 1 presented the structure of organic RFID tags. Organic RFID tags have improved materials and manufacturing technique comparing with conventional RFID tags. With organic thin-film transistors (OTFT), IC circuits are prepared to cheap plastic bases to replace traditional high-cost Si-(silicon) chips. Through roll to roll (R2R) printing, tags are manufactured in batches, so that the manufacturing is simplified and high cost reduced.

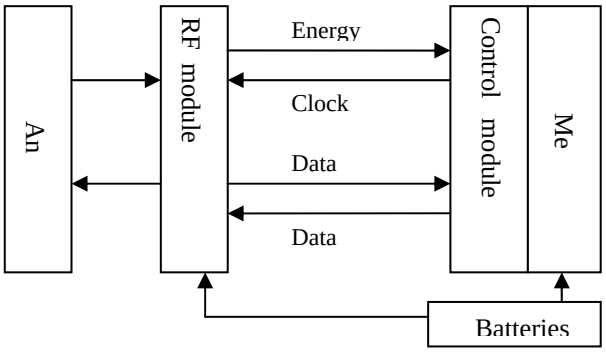

Figure 1. Structure of RFID System

2.2. Features of Organic RFID Technology

According to a report from the Nature Material Commentary magazine, cost of all-organic RFID tags can be reduced to 0.01~0.02 dollar per tag [11]. While integrated the features of two-dimensional bar codes, inexpensive, soft and thin, organic RFID tags kept most merits of inorganic RFID tags, accurate, easily applicable, interference resistant, and suitable for harsh environments. For applications of long cycles, organic RFID tags have a limited service life of only one year. However, for rice and other agricultural products with short operating cycles or products that have short life cycles, organic RFID tags can fully meet the requirements.

2.3. Current Studies on Organic RFID Technology

Currently, many countries, regions, and institutions are facilitating organic RFID development. PolyIC company in German made significant progress by using printing and R2R technology to produce organic RFID tags with operating frequency of 13.56MHz. Hundreds of organic transistors are integrated in one tag, providing 8-, 32- and 64-bit data memory [12, 13]. In the Germany organic electronics conference of 2007, organic RFID tags were used in conference tickets. Johns Hopkins University successfully developed a new type of low-voltage electronic load hybrid transistor that can be applied to organic RFID circuits [14]. In China, there are also studies on organic RFID technology. XU, Zheng, et al. of Beijing Jiaotong University studied the radio-frequency signal modulation for organic RFID tags [15], and ZHAO, Qiuyan, et al. studied future applications of organic RFID tags in animal food tracing.

3. Information Architecture of Organic RFID-Based Rice Tracing System

Multiple links are involved in rice supply chain, including rice planting, rice processing, product distribution and rice consumption, as well as the various activities throughout the links and the upstream and downstream circulation, including storage, transportation, loading and

unloading, and carrying. In this study, based on the rice production, circulation, and consumption situations in China and combining field surveys, pertinent data of rice planting, harvesting, milling, processing, inspection, distribution, transportation and selling are gathered, and these data are then recorded by organic RFID tags and uploaded to data center of the system layer by layer. Through these steps, links in rice supply chain are tracked. Each of the links in rice supply chain, participated units, key steps and processes in each link of every batch of rice are tracked to ensure the traceability of the whole process. In the meantime, consumers and government regulators can browse and query history information of rice with the RFID tags as medium. The traceability of data in rice supply chain is possessed. Information flow of the tracing system is presented in Figure 2.

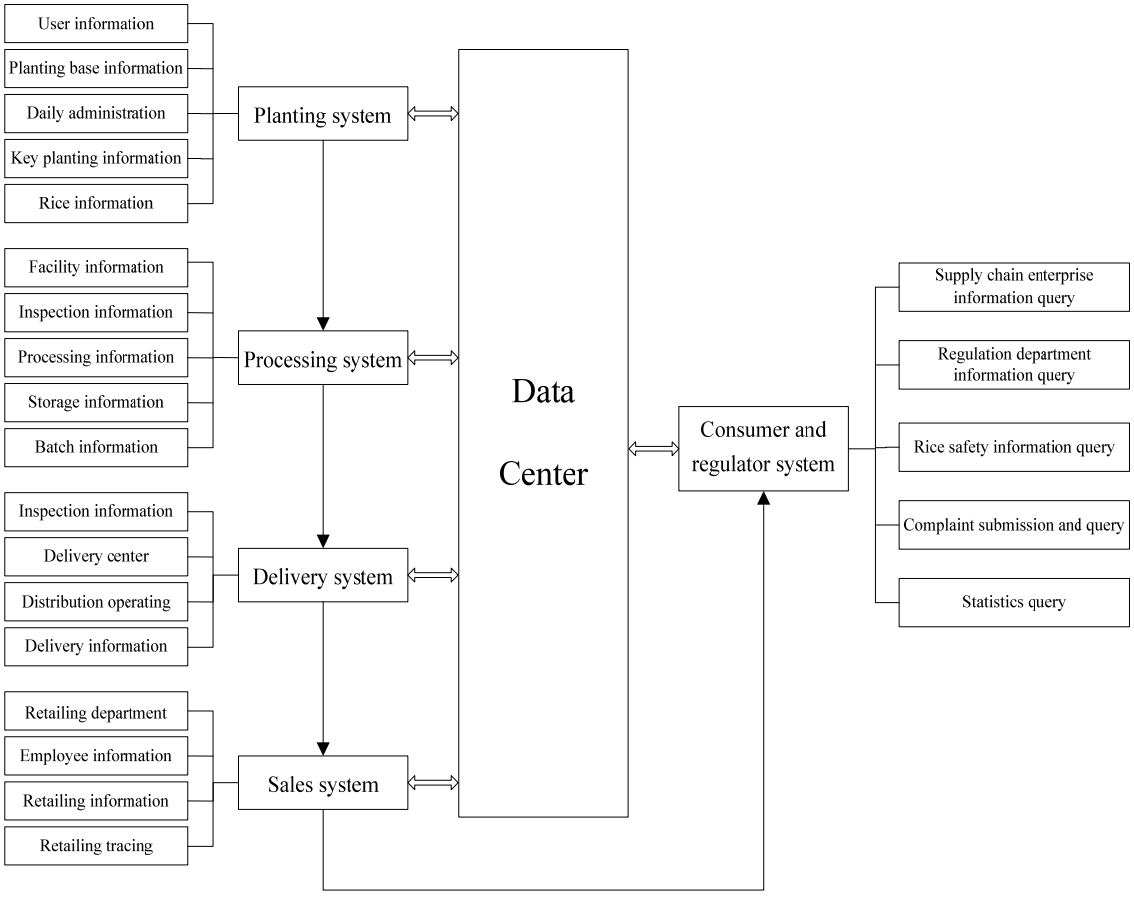

Figure 2. Information Flow of Organic RFID-based Rice Supply Chain Tracing System

4. Realization of Organic RFID-Based Rice Supply Chain Tracing System

4.1. Application of RFID in Rice Planting and Harvesting Sub-system

Rice planting and harvesting sub-system is the most important link in rice supply chain, providing original basic data for rice tracing. In this sub-system, organic RFID tags have two roles, one is to be combined with database in order to collect and record rice information, and the other is to mark the planting and harvesting information of the rice being delivered to processing facilities. The information recorded in this link includes basic user information, basic rise information, daily administration information, key planting information, etc. Figure 3 presents details of these information. Considering the expansibility of the rice supply chain tracing system, RFID devices with EPC standard were chosen.

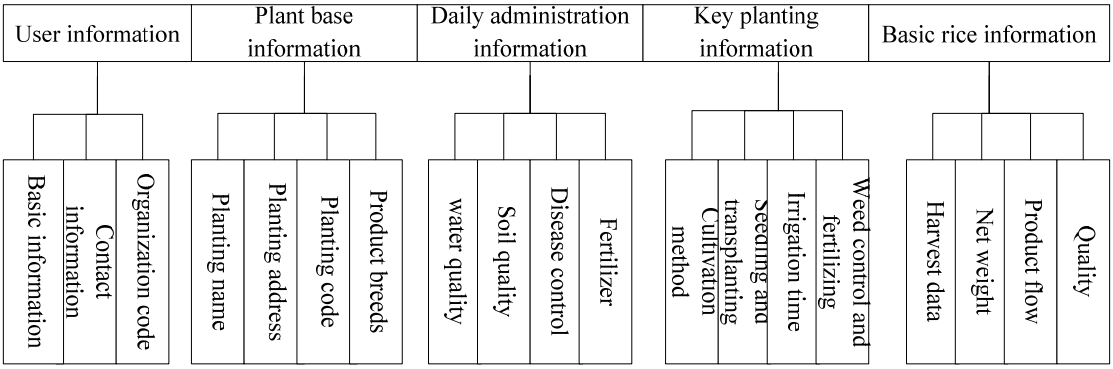

Figure 3. Basic Information of Planting Sub-system

4.1.1. Application in Field Management

First step of the system is to code the fields using letters and digits. As shown in Figure 4, C005 stands for field No. 5 in rice base C. Ordinarily, rice of the same breed is planted in the same base, and in the same field, planting environment, fertilizer amount, pesticides amount and disease treatment are basically the same. For ease of administration and benefit of organic RFID, in this system an organic RFID tag is assigned to each field. Combining with database, "Production identifiers" are established for the recording of information of the planting link and daily administration, and to facilitate the information association of subsequent links.

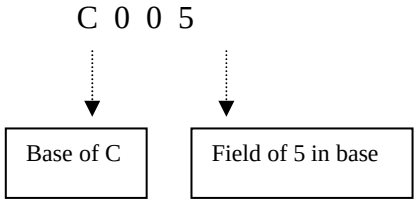

Figure 4. Rice Base Coding Schemes

4.1.2. Application in Tracing Planting and Harvesting Information

Harvested rice is shipped to processing facilities in bags. Here we call these bags "collecting bags". The bags are numbered in the format of Identifier + Base code + Flow code as shown in Figure 5. Considering other packing bags in the chain, in this study we use the first letter of word "collect" as the identifier, zip code plus three digits of flow code as base code. Meanwhile, considering the large consumption of collecting bags, flow codes consist of six digits, capable of marking 999,999 collecting bags.

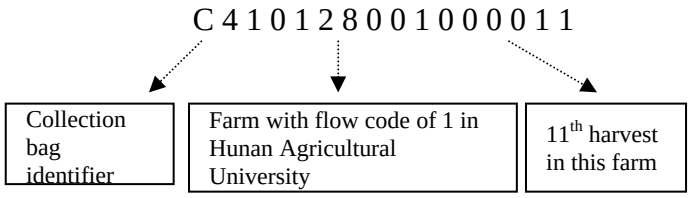

Figure 5. Coding of Collecting Bags

Since organic RFID tags are inexpensive, flexible and easily read, they can fulfill the large requirements and the demand of foldable of collecting bags, thus they are used as the carriers of collecting bag codes. A sample of organic RFID tags is presented in Figure 6. These tags are sewed to the sidelines of collecting bags, with half part inside the bags and half

outside. The external part is for easy view, and the internal part is for the cases where the external part is damaged or has fallen off.

Figure 6. Sample Organic RFID Tag Sewed to Sidelines of Collecting Bags

With RFID technology to read the organic RFID tags of collecting bags and fields, association could be established between the bags and the rice planting and harvesting information. By transferring these information to the tracing system with WSN technology, system security and foundation are provided. With organic RFID tracing information, not only farmers can trace flow directions of their rice, realizing downstream tracking, but also consumers and regulators can trace basic information of rice, realizing upstream tracing.

4.2 Application of Organic RFID in Milling and Rice Processing Sub-system

To improve tracing accuracy, information of the whole process is closely associated in the system. In processing sub-system, information about the inspection of rice delivered to the processing facilities, distribution information of products, and information in transportation process are recorded through organic RFID technology for the tracing of rice information.

4.2.1. Association of Rice Information and Processing Information

Rice information can be read from the codes of collecting bags, while processing information contains related information of milling links including rice polishing, grading, color sorting, timing, and weighing, as well as information of the rice products. Only when information of these two units is associated, rice tracing can be accurate. With antenna signals of a fixed reader installed at the “gantry” covering the loading and unloading area, the system automatically read data when collecting bags are delivered to this area. Since processing information of the same batch of rice is consistent to a certain extent, inorganic RFID is used to establish reusable processing information record. Rice information and processing information are associated by reading codes of collecting bags and system data; the operation is easy and highly accurate.

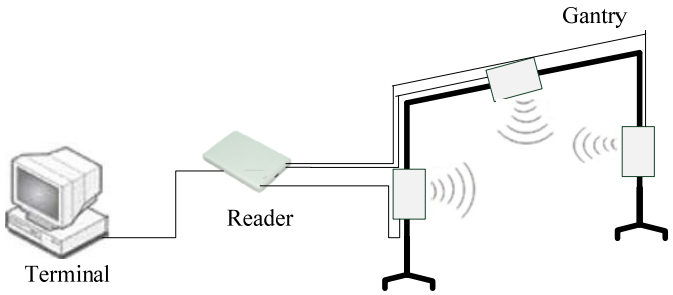

Figure 7. Gantry Structure

4.2.2. Association of Storage and Delivery Information

Rice from the same processing warehouse may be transported to different distribution centers, thus association between distribution batch and storage must to be established. Based on existing rice information and processing information, and combining the temperature and

humidity in temporary storages detected by sensors, storage information is formed. Code the "delivery bags" in the same format of coding collecting bags, with the identifier of "D". Before rice left the storages, associate the storage information and delivery information of each batch by bulk association of storage information and delivery bags' codes.

4.3 Application of Organic RFID in Rice Delivery Sub-system

Prior to warehouse acceptance, codes of delivery bags are read by the "gantry" to obtain rice data, and inspectors then check the rice quality and upload quality indicators to database. After inspection and ensuring the match between codes of delivery bags and inspecting indicators, rice is arranged for storage. Before rice gets out from storages, specific product flow and other delivery information of the current retail batch are associated to the organic RFID tags, establishing association between consumption information and delivery information. In the sales sub-system, this could effectively prevent inventory transshipment. From packing rice delivery bags, storing in storages of delivery centers, to the end of a short selling period, the one-year life cycle of organic RFID could fully cover the distribution cycle.

With organic RFID technology to plan procurement and inventory, delivery centers could improve their administration quality and efficiency, as well as reduce logistics costs. Meanwhile, it helps enterprises to obtain realistic data by applying organic RFID technology in gathering data of many links, including storage, warehouse entry inspection, acceptance, allocation, shipments, etc.

4.4. Application of Organic RFID in Rice Sales Sub-system

Considering realities in the sales link of rice, this system combines organic RFID technology with bar codes. By sticking bar codes to retail packages of rice or rice products as carriers of information, association between organic FRID tags and tracing codes is established in data center. The application of organic RFID technology in sales link could improve the operating efficiency of rice supply chain, ensure on-time delivery of commodity, and help monitoring the delivery of goods within the chain. Meanwhile, it can also increase sales, reduce stock and reduce labor costs. It should be the developing direction of retailing to design automatic sales system integrating burglar precaution, early warning and payment using RFID technology.

4.5. Application of Organic RFID in Consumer and Regulator Sub-system

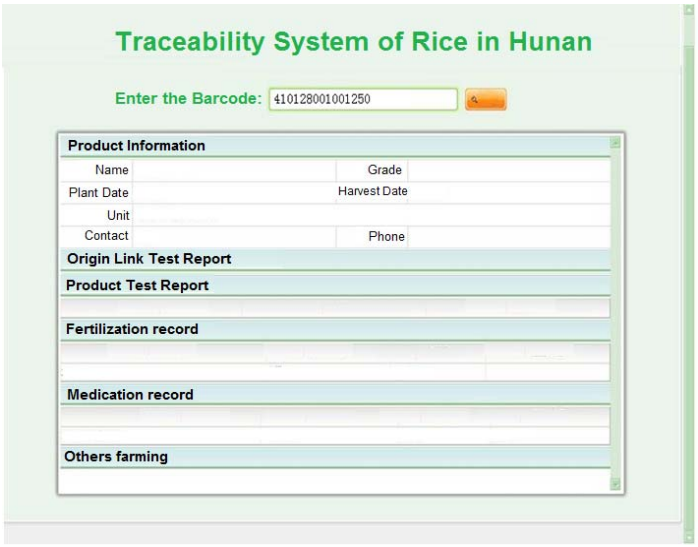

Figure 8. Website Query Interface

For customers' convenience, the system provides multiple querying channels, including website, text messages, telephone, two-dimensional code and self-service terminals. Figure 8

presents the website query page provided by the tracing system. Meanwhile, touch query machines and electronic tag and bar code scanning devices are also set up for consumers to check rice information. With the organic RFID tag or bar code attached to the rise they purchased, consumers could trace distribution information of rice in delivery centers, the processing, storage and delivery information of rice, as well as the planting information during the growth of the rice. Through terminals, consumers could view the information and carry out effective tracing once they found any problem.

5. Conclusion

Organic RFID tags have the features of two-dimensional bar codes, inexpensive, flexible and thin, while also keep the merits of inorganic RFID tags, accurate, easily applicable, interference resistant, and suitable for harsh environments. In this study, based on the analysis of characteristics of each links in rice supply chain, and organic RFID technology as tracing means, a rice supply chain tracing system is designed. This system can provide information checking, tracking and tracing to farmers, consumers, and other related parties. It can help with the regulation of rice production, rice quality and safety ensuring, and the protection of consumer rights. The design and investigation in this study demonstrated the following:

1) The rice supply chain tracing system designed with organic RFID technology integrated the features and functions of both inorganic RFID-based tracing system and bar code-based tracing system. With two tracing systems merged together, this system has the merits of low cost, high accuracy, fast and automatic collection, and various query channels.

2) By associating rice information and processing information, storage information and delivery information, as well as organic RFID tags and tracing codes, a scheme to improve tracing accuracy was designed to enhance the traceability of basic links in rice supply chain.

3) The tracing system is divided into five sub-systems, including planting, processing, delivery, sales, and consumer sub-systems. Reasonable application of organic RFID technology to each link ensures the organization and modularity of information, facilitating the fast and accurate tracking and tracing of rice.

Acknowledgements

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