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Developing A RFID-based Food Traceability System in Korea Ginseng Industry: Focused on the Business Process Reengineering

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Abstract

Despite the many concerns and expectations of academia and the practitioner community, a radio frequency identification (RFID)–based food traceability system (FTS) has not yet been successfully developed and implemented in the food industry. Through closer examination of unsuccessful pilot projects of RFID-based traceability systems for the Korean ginseng industry, this study proposes business process reengineering points with RFID and sensor technology and an RFID-based ginseng traceability system architecture according to the Electronic Product Code (EPC) global framework. This approach and system architecture will contribute to the successful development and implementation of an RFID-based FTS for food products. In addition, this study extends the scope of the theoretical discussion of RFID-based FTSs for health foods and medical herbs, like ginseng.

Keywords*: RFID, Sensor, Food Traceability System, Business Process Reengineering, Ginseng*

1. Introduction

In recent years, consumers have been faced with several incidences of contaminated food, such as the various outbreaks of mad cow disease. As a consequence, consumer concerns about food safety issues have risen considerably (Chang *et al.*, 2013). Therefore, to ensure food safety, tracing food along the entire supply chain has become an important issue, and each government has issued regulations for this process (Kehagia *et al*., 2007). With the advances of information technology (IT), such as radio frequency identification (RFID), a food traceability system (FTS) has been introduced to reduce uncertainties in the food purchasing process by providing information about the whole process from the farm to the table in terms of quality and safety (Choe *et al*., 2009).

RFID is a wireless automatic identification technology that enables automatic data capture, product identification, and information interchanges, thereby increasing the efficiency of product tracking, inventory sorting, and distribution data collection and analysis along the supply chain (Cheng & Yeh, 2011). Information on a product's history can be gathered by attaching an RFID tag to the product, and the RFID-based FTS then tracks this information in real time. Therefore, the use of RFID-based FTS in the food industry has received fairly extensive attention from both academic and practitioner communities. To date, most of the companies that are trying to introduce the RFID-based FTS are those that sell higher priced food items, such as health food and gourmet food, because of the high investment costs associated with the tagging process (Chryssochoidis *et al*., 2009).

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For example, the Korean ginseng industry is extremely interested in using the RFID-based FTS to provide product traceability information to their customer, thereby increasing reliability and safety. In 2011, some business associations in ginseng-growing regions in Korea undertook government-sponsored pilot projects of an RFID-based ginseng traceability system. However, these projects did not progress any further, and the developed pilot system is not being used in the ginseng supply chain today. According to experts who was in charge of these projects, the main reason that they were unsuccessful was because of the fact that they were using an RFID-based ginseng traceability system without business process reengineering (BPR). For instance, the process of mixing ginseng together from several growers in various regions to efficiently cleanse and steam the ginseng was the chief reason for the loss of traceability information, such as the cultivators and growing areas. Since the process was not reengineered, the effectiveness of the traceability system was lower than expected.

Developing and implementing an RFID system does not just consist of buying hardware and software; rather, an organization must adopt BPR with an innovative approach to achieve a high level of synergy (Tzeng, 2008). FTS is implemented across the entire food supply chain and involves all supply chain actors, such as the growers, manufacturers, distributors, retailers, and customers. Therefore, when advanced technology (like RFID) is developed and applied to a traceability system, the established business process of the entire supply chain and the interdependent processes among the various actors should be carefully evaluated (Bevilacqua, 2009). However, BPR is often overlooked when developing an RFID-based FTS across the food supply chain. In the field of research, only a few studies have explored the development of FTSs that included BPR.

Therefore, this study proposes an RFID-based ginseng traceability system architecture that is focused on the BPR of Korea's local ginseng associations as a reference model for successfully developing an RFID-based FTS. In the paper, a relevant literature review of RFID-based FTSs and the Korean ginseng industry are presented first. Then, the strategic points of BPR in the ginseng industry are described and the RFID-based ginseng traceability system architecture is presented in the Section 3. Finally, conclusions and future work are discussed in Section 4.

2. Literature Review

2.1. Food Traceability System

An FTS provides all relevant information about the food process ‘from the farm to the table’ (Choe *et al.*, 2009). All participants in the food chain, including the final consumers, can extract detailed information on food products from a database via the Internet (Ruiz-Garcia *et al.*, 2010). Using this system, consumers are able to easily verify how the food that they purchase is produced, processed, and delivered. Wilson and Clarke (1998) described a possible mechanism for the design and development of a software system for the collation, location, and dissemination of traceability data. Jansen-Vullers (2003) proposed a graph modeling approach to designing information systems that could trace the flow of goods. Hobbs (2004) identified the role of food traceability systems in resolving information asymmetry in food markets. Folinas *et al.*, (2006) introduced a generic architecture of traceability data management as a guideline for all food business operators, and Bevilacqua *et al.*, (2009) developed a BCR for the supply chain of vegetable products.

The discussion of RFID technology being applied to traceability systems began in the early 2000s. Sahin *et al.*, (2002) provided a framework for identifying functionalities of a traceability system in the context of a global supply chain by simply evaluating the performance of RFID-based traceability systems. Nagi *et al.*, (2007) performed a case study of an aircraft engineering company in Hong Kong as it developed an RFID-based traceability system with a focus on critical success factors. Kelepouris *et al.*, (2007) examined how an RFID can meet the requirements of traceability and outlined both an information data model and a system architecture of RFID-based traceability. Hsu et al. (2008) proposed an RFID-enabled traceability system for the live fish supply chain, the system architecture of which was designed according to the specific requirements of live fish processing. Abad et al. (2009) evaluated an RFID smart tag developed for real-time traceability and cold chain monitoring of fresh fish. Most recently, Storøy *et al.*, (2013) proposed a framework to guide the implementation of traceability in food value chains, and Parreño-Marchante *et al.*, (2014) presented a novel traceability system architecture based on an RFID and wireless sensor network (WSN) for the food supply chain. However, in the field of FTS research, only a few studies have focused on the BRP perspective, and no studies to date have sought to develop an RFID-based FTS focused on health food.

Many studies of IT have shown that BRP can drive the effectiveness of IT implementation in business organizations. Riggins and Mukhopadhyay (1994) demonstrated that aligning business processes with EDI adoption can lead to better performance through effective information sharing. Kohli and Sherer (2002) stated that supply chain actors need to conduct major changes in their business processes to fully capture the benefits of IT adoption in their supply chain. Wamba et al. (2008) described BRP points to develop an RFID system in the retail industry, including RFID-based improvement processes such as shipping, receiving, and put away. They also provided a guideline for the automatic trigger process and integrated interorganizational activities for RFID system development and implementation.

2.3. Korea Ginseng Industry

In Asia, particularly Korea and China, ginseng has been one of the most important items of trade in the health care and medicinal markets. It is currently distributed to 35 countries around the world (Baeg & So, 2013). Ginseng is a plant that belongs to the Araliaceae family and the genus *Panax,* and its roots are used for medicinal purposes. Its botanical classification is the perennial plants of docotyledon, umbelliflorae, and araliaceae (Korea Agro-Fisheries & Food Trade Corporation, 2011). Ginseng grows naturally in East Asia, including the Korean Peninsula and the Northeastern part of America, both of which are cold, humid, deciduous, and forested areas with low temperatures in winter and sufficient rainfall in summer, which is ginseng’s growing season. Two types of ginseng are generally consumed—red ginseng (47.8%) and fresh ginseng (45%) (MIFAFF, 2012).

Red ginseng is made by heating fresh ginseng with steam and then drying it. It is categorized as processed food and is normally standardized and packaged with its own brand. The type of ginseng that is not dried after harvest and is still in its original shape is called fresh ginseng (Lee *et al.*, 2012). Generally, fresh ginseng is sold by weight in a basket that is labeled with its place of origin. Korea is the world's largest ginseng distributor (1,140 million USD) and the second largest ginseng producer (27,480 tons) (Baeg & So, 2013). All ginseng grown in Korea is *Panax* ginseng Meyer 1st class. Currently, fresh ginseng root and a variety of processed products are the best-selling product in Korea. Local ginseng associations, such as Kum-san, Jin-an, and Gyeong-gi, play a leading role in monitoring ginseng growth, manufacture, and distribution.

3. An RFID-Based Ginseng Traceability System

To propose an RFID-based ginseng traceability system with BPR, this study focused on red ginseng, which is more widely sold than fresh ginseng and has a more complex business process. In as-is analysis, this study concentrates on the business processes of local ginseng associations in rural areas who oversee the growth, manufacture, and distribution of ginseng in Korea. From July to August 2013, interviews of managers and on-the-spot visits were conducted for the associations who participated in the pilot project of the RFID-based ginseng traceability system that was supported by the Korean government in 2011.

3.1. As-Is Analysis

A food traceability system is used to prepare for accidents and abnormal situations; the system also secures distribution route transparency. It simultaneously provides information to the consumer and the local competent authorities. Therefore, the system requires information for all entities from which the food originates, including where it is processed, packaged, and stocked.

Figure 1. Ginseng Traceability Timeline

A red ginseng traceability system that takes the production and circulation processes into consideration is based on three phases (Figure 1). Currently, information about the cultivation of ginseng is monitored inadequately. During the growing stage, farmers use hand-written daily logs to record physical phenomena, such as luminance, relative humidity, temperature, and CO_2 emission (Figure 2). This is time-consuming and obviously inefficient. This information is then passively transmitted to the processing and distribution channel, such as the local ginseng association. The processors manually enter the traceability information into their information system like Enterprise Resource Planning (ERP). Because the traceability information for the production stage is manually handled by the farmer and the growing period of ginseng is so long (4 to 6 years), the traceability information is frequently lost, and the inspection process for all phases (such as production, processing, and sales) is manually checked and labor-intensive.

Currently, the interdependent process of outbound and inbound information between the farmer and the processor is concentrated efficiently handle of many inventories in working areas without carefully transferring the traceability information for each item. After receiving the red ginseng parcels from the many farmers of various regions, the processor mixes and stores them together for efficient cleaning and steaming (Figure 2). This mixing of the inbound ginseng from various regions interrupts the flow of traceability information in the supply chain. As a result, the consumer does not receive a product with detailed traceability information about the production phase.

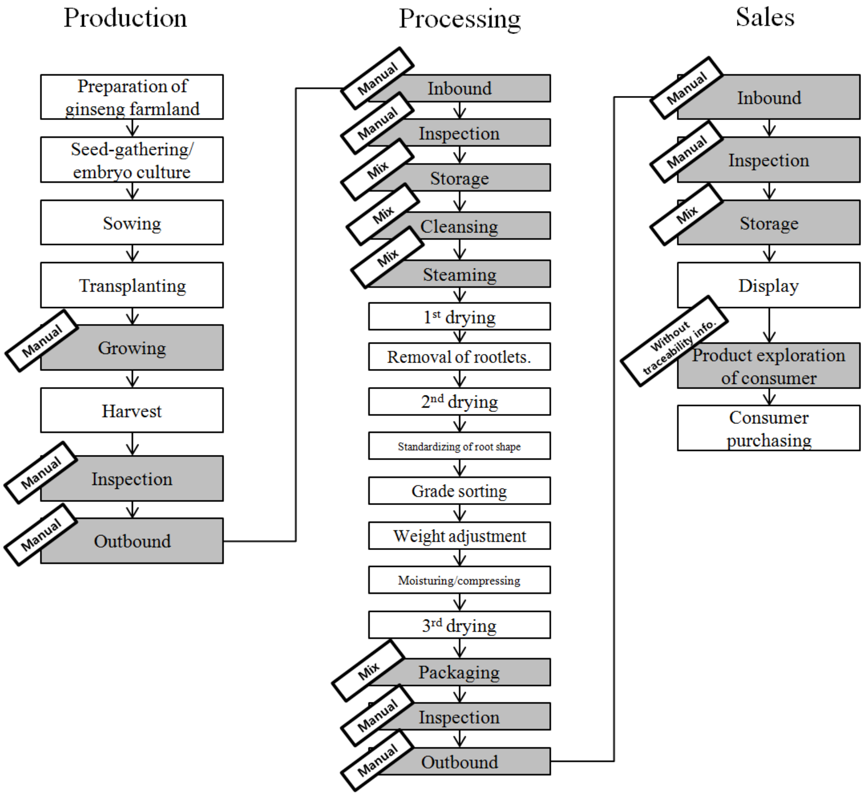

Figure 2. As-is Analysis of Red Ginseng Traceability Process

3.2. To-Be System

This study proposes a model for a red ginseng traceability system based upon BPR that overcomes the obstacles mentioned earlier, such as inefficient monitoring during the production stage, the loss and mixture of information at the processing phase, and the inability to provide information to the end user in a prompt manner. To address the inefficient daily log system, this study adopted a sensor network-based monitoring system. Figure 3 shows the proposed ginseng planting environment monitoring system based on the EPC Wireless Sensor Network (WSN). The basic system consists of a management ERP system to manage the ginseng growth environment, a sensor to capture information related to ginseng growth, and a sensor network to collect this information. The sensors are used to collect environment-related information on the surface and soil-related factors when implements the data collection and transmission subsystem. Sync-node and middleware (gateway) makes it easier to communicate the data through the system. Our middleware provides a data-processing framework for underlying sensor nodes and a robust monitoring and management of application logic and event flow. Moreover, a new type of gateway supports dual wireless access points for WiFi and 6LoWPAN. All the information collected from the sensor nodes and ERP is automatically uploaded to the EPC information service (EPCIS) through the gateway.

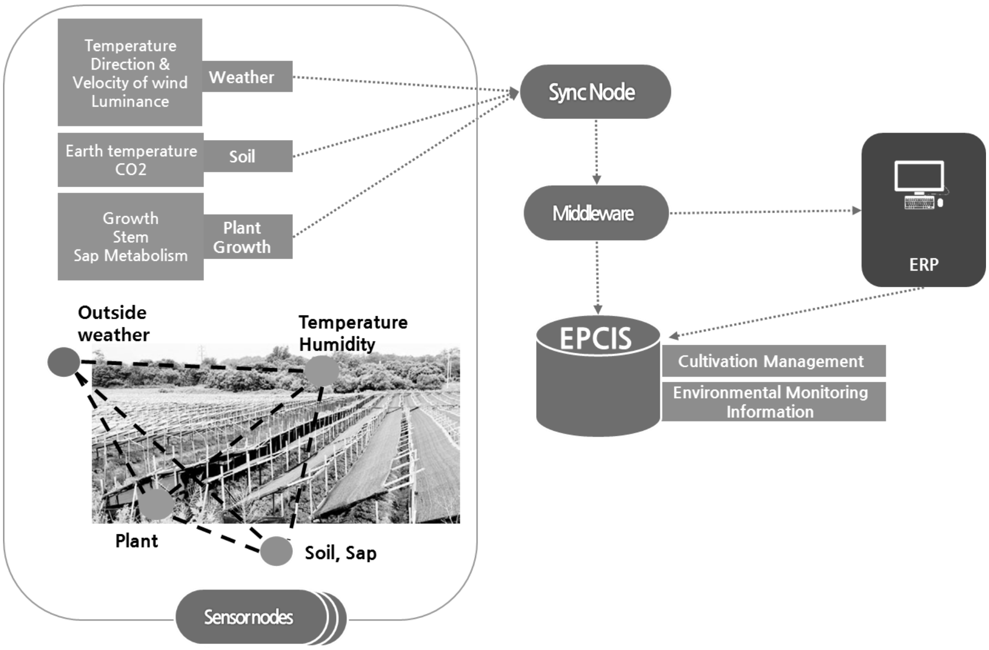

Figure 3. Environmental Monitoring System for Red Ginseng

Immediately after cultivation, all the fresh ginsengs are boxed and tagged with RFID tag-1 by famers delivered to distributors. Then, the baskets are promptly inspected and RFID tag-1 is replaced by RFID tag-2 with URI-convertible identification number such as GTIN, GLN, SSCC, and GRAI. These URI-convertible ids are identifier for trade item and are deployed to look up product information in a global standardized database such as EPCIS. Namely, the identification number makes replaced RFID tag-2 connect to the information collected from environmental monitoring system. A simple reading of RFID tag-2 provides the past history of production at any time during processing. As shown below Figure 4, the operation carried out very quickly and efficiently throughout the RFID readers. The tag is removed prior to packaging phase and the information is recorded in an EPCIS which is connected with other EPCIS. Another replaceable RFID tag-3 is attached to the packaging and GTIN code is marked on the surface. By using this code and the tag, the complete information throughout the entire process including production, inspection and processing can be retrieved at any time.

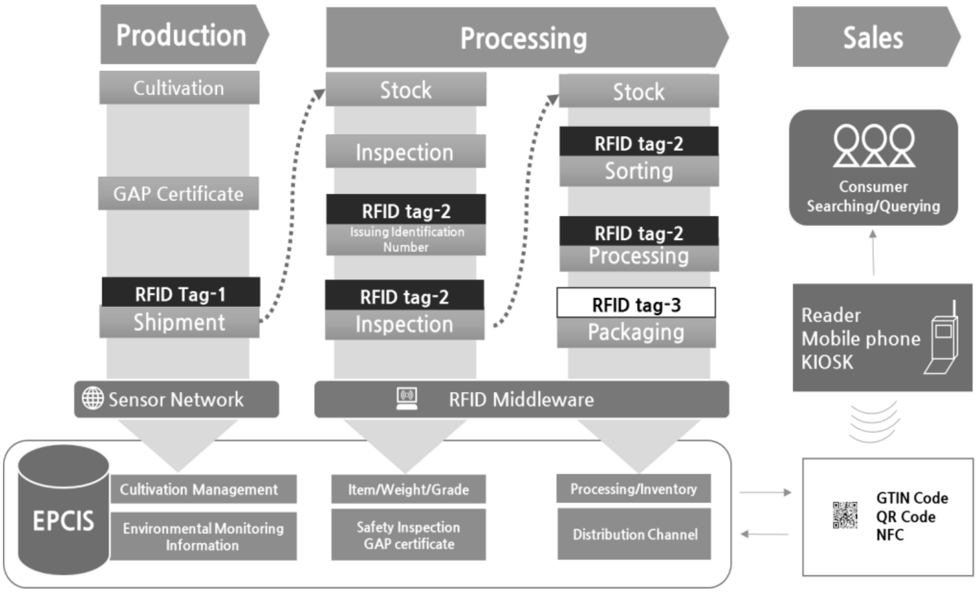

Figure 4. RFID-based Red Ginseng Traceability System

To avoid loss of information during the processing phase such as cleansing and steaming, this study redesigned the processing phase as shown below Figure 5. The processes are separately carried out according to the area of production. Each tagged basket is arranged in terms of area of its origin and processed independently. Nevertheless, the reengineering of processing eventually raise the cost of fixed and variable cost of red-ginseng product.

Figure 5. Reengineering of Mixing Problem in Red Ginseng Processing Phase

This study adopted the EPC global architecture framework to identify, capture, and share information about the ginseng. This is mainly possible because the framework is driven by end users, is royalty free, and meets global standards. Figure 6 shows the technical structure of the traceability system following the EPC guidelines. The network system manages the dynamic information of entities for individual ginseng products. The system includes an object naming server (ONS), a discovery service, and EPCIS (distributed). The ONS enables the discovery of object information on the basis of the EPC. With the EPC, a matched item is searched for within a database and sent back to the requester when it is found. The EPCIS network is formed to enable EPC-related data sharing across the organization and country. The presentation server manages a rich interface comprised of HTML, CSS, and JavaScript. The application is designed to help users easily look up traceability information.

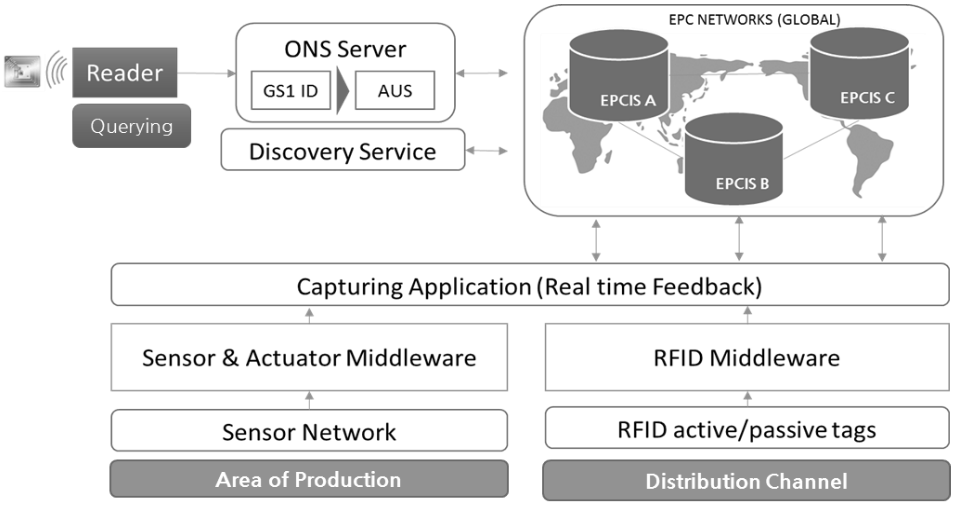

Figure 6. Ginseng Traceability System Architecture (EPC Global)

4. Conclusions

The main purpose of this study was to propose an RFID-based ginseng traceability system model. To increase the effectiveness of RFID-based FTS, this study concentrated on the development of an RFID-based ginseng traceability system focused on BPR. By interviewing ginseng farmers and the managers of local ginseng associations, along with visits to ginseng farms and processing plants, this study was able to identify major business processes that need to be reengineered for an RFID-based FTS. Then, strategic points of BPR, like the removal of the mixing problem and the RFID-based ginseng traceability system architecture, were proposed.

Despite the many concerns and expectations of the practitioner community, the development and implementation of an RFID-based FTS has been continually delayed. Through closer examination of the failure of pilot projects, this study has found that the business process of the food supply chain should be carefully rethought according to innovative features of RFID technology and the necessity of providing traceability information during the sales phase. Without mature consideration of BPR, the development of RFID-based FTSs will only consist of replacing the barcode system and will not include innovation of the entire food supply chain. The BPR approach and system architecture based on EPC Global that is described in this paper will help with the successful development and implementation of an RFID-based FTS for various food products. In addition, this study extends the theoretical discussion of RFID-based FTSs for health food like ginseng. Future work should include an effectiveness analysis of the RFID-based ginseng traceability system with BPR, as well as the development of an advanced sensor-based distribution management system for ginseng products that has temperature-sensitive characteristic. This could lead to the development of a more reliable and safer food supply chain.

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