



Cloud-based system for rational use of pesticide to guarantee the source safety of traceable vegetables

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ABSTRACT

Recent legal requirements and market demands have motivated more food companies to implement traceability systems. Ensuring safe farming practices is the first step in food supply chain traceability, and reasonable pesticide use is a main feature of food safety and sustainable production. This study describes the design and development of a cloud-based platform for rational pesticide use to guarantee the source safety of traceable vegetables. The system includes a pesticide use control cloud platform (PUCC) and a pesticide user application (PUA), which interactively guide users through the steps of pesticide purchasing, pesticide application, harvest time, and pesticide evaluation. Models for evaluating and recommending potential pesticides were developed based on an open library of pesticide use rules. The PUCC, which includes the main functions of farmer registration, authentication of platform administrator, and information management for plant protection service agencies, was developed using Microsoft Visual Studio 2010 and deployed on the Internet. The PUA provides interfaces for pesticide purchasing guideline, pesticide application, optimal harvest time, and feedback. As a case study, the system was used for about a year in 24 vegetable bases in Tianjin. The effectiveness of the system was evaluated by investigating 8 management center staff members and 41 farmers. Management agencies noted the positive effects of promoting reasonable pesticide use, facilitating information accessibility, and enhancing management. Advantages to farmers included reducing the risk of unreasonable pesticide usage, decreasing the risk of counterfeit pesticides, and improving vegetable quality and safety; disadvantages included increased costs and reduced efficiency. In addition, the system improved external and internal traceability to ensure crop quality and safety.

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1. Introduction

Human activities are posing increasingly severe threats to ecosystem health and global food security and safety (Popp, Pető, & Nagy, 2013). For example, the impacts of global climate change, desertification, pesticide exposure, antibiotic-resistant strains of microorganisms, animal growth hormone residues in human food, development and widespread dissemination of GMOs, and other challenges are causing widespread environmental problems (Notarnicola, Hayashi, Curran, & Huisingsh, 2012; Thiollot-Scholtus

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& Bockstaller, 2015). Over recent years, many agro-foods have failed to meet market and consumer demands due to difficulty in complying with quality, security, and environmental sustainability requirements (Borit & Santos, 2015). Traceability is an effective way to ensure food safety and quality as well as reduce the costs associated with recalls (Regattieri, Gamberi, & Manzini, 2007). Based on existing definitions of traceability (Bertolini, Bevilacqua, & Massini, 2006; Dabbene & Gay, 2011; McEntire et al., 2010), Olsen and Borit (2013), a new definition can be provided: the ability to access any or all information related to the product under consideration throughout its entire life cycle by means of recorded information.

For vegetable traceability, farming is the original step in the product's life cycle. Pesticides are an essential part of agricultural management and play an important role in increasing the yield and quality of crops (Barriere, Lecompte, & Lescourret, 2015; Hossard

et al., 2014; Poole & Arnaudin, 2014). However, pesticide use can also impact the environment (air, soil, water) and organisms. For example, depending on their bioavailability and toxicity, PPPs and their degradation products can threaten the health of animals (Mailly, Hossard, Barbier, Thiollet-Scholtus, & Gary, 2017). Spraying time (i.e., the growth stage during which crops are treated) also influences the extent of toxic pressure on ecosystems. Unreasonable use of pesticide may threaten the safety of crops (Damos, 2015).

Recently, information and communication technology (ICT) has improved the recording capacity of real-time and on-site information through use of mobile devices (e.g., mobile phones, PDA, tablet PC) (Qian et al., 2012; So-In, Poolsanguan, & Rujirakul, 2014). Steinberger, Rothmund, and Auernhammer (2009) developed a mobile system for collecting farming data that transmitted information to a server through the Internet. A bidirectional acquisition system for recording farm and environmental information was developed for orchard precision management and implemented through smartphones and radio frequency identification (RFID) (Qian et al., 2015). Yang et al. (2016) developed a management platform for improving traceability credibility based on authentication, production management, and supervision information. In addition, ICT can help improve decision support through cloud data management and data mining (Jula, Sundararajan, & Othman, 2014; Sharma, Javadi, Si, & Sun, 2016). Cloud computing technology has revolutionized general-purpose computing applications over the past decade. The cloud paradigm offers advantages such as reduced operation costs, server consolidation, flexible system configuration, and elastic resource provisioning (García-Valls, Cucinotta, & Lu, 2014). Xing, Qian, and Zaman (2016) proposed a cloud-based life-cycle assessment (LCA) platform that enables dynamic data collection and supports supply chain collaboration for environmental footprint assessments.

Improving pesticide control is necessary to ensure product quality and safety as well as environmental sustainability. Previous studies have addressed the aspects of pesticide dosage (Li, Qian, Yang, Sun, & Ji, 2010), efficient spraying (Walklate, Cross, & Pergher, 2011), optimizing spray coverage (Nansen et al., 2015) and so on. However, there is significant room for improvement in three main aspects of ICT-based pesticide management: 1) cloud databases: pesticide use rules can be updated to the cloud in real-time; 2) mobile phone data collection: pesticide knowledge can be obtained on-scene according to different requirements; 3) framework flexibility: cloud and mobile phone users can communicate freely. Therefore, a pesticide use control system on a cloud-based platform was proposed in this paper. Section 2 presents the system framework including cloud and mobile phone clients. A decision model for pesticide use control is studied in Section 3. System implementation and function is described in Section 4. Finally, the system was applied and evaluated.

2. System framework

Pesticide-related operations and information begin with crop planting. A pesticide use control chain, including pesticide purchasing, pesticide use, harvest, and use feedback, is presented in Fig. 1. In the pesticide purchasing step, a product's authenticity and qualifications are validated based on pesticide registration certificates. Next, the application method and dosage according to guidelines for different vegetables are provided in the pesticide use step. If vegetables are harvested before the appropriate time, pesticide residue likely will remain on crops and affect food safety. Therefore, the optimal harvest time is calculated in the third step. When the vegetable planting period is over, feedback is submitted in order to share and compare experiences.

In view of ICT and the system structure, two system layers were designed. The pesticide use control cloud platform (PUCC) is an open platform that combines information on many pesticides and guidelines for their use. The pesticide use application (PUA) system is a light-weight system that can be run on mobile devices. It provides the convenience of obtaining information and decision-making in real time and on site. The two layers can communicate through a wireless network. The system flow is described on the below:

2.1. Part 1. Pesticide purchasing

2.1.1. Barcode scanning

Pasting barcodes on pesticide packages will become a mandatory requirement in China. Every pesticide has a unique registration ID. By scanning the barcode with the PUA, the registration ID can be extracted.

2.1.2. Information retrieval

Information including the ID, pesticide name, manufacturer, active ingredient, content, time of registration, and so on can be obtained. When the PUCC accepts the ID, the PUCC searches for relevant information.

2.1.3. Result return

If the pesticide is certificated, detailed information is provided. Otherwise, a warning is generated.

2.1.4. Result display

The results from the PUCC are displayed in the PUA interface, and the operator can use the information to make a purchasing decision.

2.2. Part 2. Pesticide use

2.2.1. Barcode scanning and selection of crop information

In China, the rules for pesticide usage according to the regulatory systems for non-public hazard agro-food, green agro-food, and organic agro-food are combined to ensure the quality and safety of agricultural products (Li et al., 2010). There are different application guidelines for different crops, even if the same pesticide is used. To obtain reasonable guidelines for pesticide use, the pesticide name, vegetable name, and certification type need be recorded. The crop information needs be entered in the PUA in addition to scanning the barcode.

2.2.2. Information searching

The pesticide and vegetable are entered, and the application method and dose are provided according to the specific pesticide and vegetable.

2.2.3. Application dosage return

The information of application method and dose are returned to the PUA.

2.2.4. Application rules obtaining

The PUA interface displays the application rules.

2.3. Part 3. Harvest

2.3.1. Harvest time input

The harvest time is automatically or manually selected.

2.3.2. Time interval comparison

Every pesticide has a safety interval between use and harvest to

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