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Research Article

Development of Traceability for a Chemical-Free Vegetables System using a QR Code

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Abstract: Farmers at Ban Kaset Jun La Pan require the cultivation of chemical-free vegetables with less pesticides and bio stimulants in order to provide safety for farmers and consumers. An information system was designed and implemented to meet this requirement by taking advantage of a QR code. This system enables traceability of agricultural products, from production to storage. The research objectives were as follows. - 1) to develop traceability of chemical-free vegetables via a QR code system and 2) to evaluate the efficiency of traceability of agricultural products using experts. The system was designed in a way that the administrator had full access to the system, and farmers were given permission to manage their own data. Both smartphones and computers were supported. The consumer could access the stored data using an application that supported a QR code to scan and show the farm's name, phone number, vegetable profiles, cultivation details, origins of products, and profiles of vegetables in the same batch. The application could then direct consumers to the web application. Evaluation by the experts indicated that the average score was at the highest level ($\overline{X}$=4.60, SD=0.51); the system could provide a production data center that meets a variety of user requirements.

1. Introduction

A QR is a machine-readable square-shaped code that holds information and has a wide range of uses. Several sectors have implemented such a code for different purposes, for example, implementing traceability for peanut industrial chains, according to the Thai agricultural standard (Ta-Kham, Chaiwongsar, & Chumjai, 2021), an organic traceability system using blockchain technology and coffee products (Ta-Kham *et al.*, 2021). Owing to the recent trends of health consciousness and food safety, traceability has become increasingly important. This is in line with the advocacy of Kasikorn Research Center (2022), which pointed out that over the next 10 years, traceability will help create credibility and expand market opportunities for Thai organic products at home and abroad, especially for super-foods and free-foam foods. The market value of Thai organic products is expected to grow at 6.5% (CAGR) during 2020-2024 and 8.7% (CAGR) during 2025-2029 because of their broad-based commercial production. In addition, the progressive advancement of technology will result in behavioral changes in consumers. Access to information, goods, and services is now at their fingertips and tailored to their different needs. Nowadays, several programs and applications have been developed and allow users to have easier access to abundant information, with simple camera-supported applications that can "scan QR codes". The statistics provided by the Food Sanitation Division Health Department BMA (2022), there was an increase in pesticide usage as well as overusing of chemical substances. This has resulted in health problems for farmers and consumers who are unconsciously affected by chemical residues, and the consequence is unavoidably a tarnished branding image and a decrease in the prices of Thailand's agricultural products. Most consumers do not even recognize the difference between organic and chemical-free vegetables.

In this study, the researcher initiated the idea to implement a QR code on the products of farmers at Ban Kaset Jun La Pan, Hua Sai District, in Nakhon Si Thammarat Province, Thailand. This was for traceability of chemical-free vegetables, working on the Client Server architecture, which is compatible with all devices that support QR code scanning. The system can display information that leads users to the origin of vegetables, keeping them assured of the quality of what they are buying. Such information is considered necessary because it ensures the safety of food products as well as the origin of agricultural products, which maintains the perception of trustworthiness by consumers. Besides, implementing a QR code brings a helpful innovation to the community, makes the products outstanding, promotes competitiveness, and increases farmers' income. The system was technically divided into two main modules. 1) The Administrator module enables the management of plots of fields, vegetable profiles, consumption information, farmer profiles, cultivation details, harvest details, as well as storage of vegetables.

2) The consumer module displays the farm's name, phone number, vegetable profiles, cultivation details, origins of products, and profiles of vegetables in the same batch. These data are accessible via a QR code, which increases competitiveness, encourages farmers to apply such technology to their routine work, and adds qualitative value to their products.

2. Materials and Methods

Agricultural data from 10 farmers in the community were collected to implement a pilot model of QR code-assisted traceability of chemical-free vegetables.

2.1 Literature Review

Nowadays, consumers strive to eat better, exercise more, and focus on living a longer and healthier life. Eating vegetables every day is vital for health. They provide essential vitamins, minerals, and other nutrients, such as antioxidants and fiber. chemical-free vegetables are without pesticide residues, resulting in market opportunities Phetcharat *et al.* (2022). customers are willing to pay a premium price for chemical-free vegetables (Kaewtathip *et al.* 2022) and the factors affecting consumers' decision to purchase chemical-free vegetables are product, price, distribution channels, and promotional marketing (Wongyos, 2021). Sansaeng *et al.* (2019) also confirmed that health, price, store cleanliness, and product certification marks are essential.

Traceability of edible plant cultivation is a system that keeps consumers assured of the goods they purchase (Tantidontanet & Boonying, 2021) and can guarantee the quality of the products, ensuring that they are all clean and free of residues (Zhang *et al.*, 2021). Consumers can trace vegetables from upstream to downstream processes, ranging from cultivation, harvesting, processing, storage, transportation, and distribution. These offer the utmost convenience for consumers to help reduce excessive expenses on product return, which is expected to be processed more precisely with the shortest duration possible (Mahawang, 2017). Tracking and Traceability are two major process in the syste. (Tantidontanet & Boonying, 2021). The system can achieve these objectives by systematically recording data and applying information technology that transfers the data electronically. The recorded data are in XML format to prevent potential abuse (Janekarn *et al.*, 2019). Necessary input is recorded in the database. This conforms to the protocol of the Global GS1 Traceability Standard (GS1) (Sukchareonpong & Thammasiri, 2018), which is responsible for regulating and promoting the global standards of traceability and setting standards of autosaving and data communications in the industrial sector. Traceability is used worldwide, including in Thailand. GS1 Thailand and the Federation of Thai Industries arefmanage this system in Thailand.rtraceability processes are run with two steps. - 1) searching for product origin, and 2) tracing back to where delivery of products

is initiated. The latter is aimed to facilitate the case where the products are made of defective materials, or the production process is later found harmful to consumers. Effective traceability reduces the number of disqualified products, which can help reduce the chance of distributing defective products to consumers, thereby significantly decreasing product returns. Rotsios *et al.* (2022) point out that food labels alone cannot guarantee product quality. In summary, traceability is the technology developed upon a system and a mechanism for tracing goods, products, materials, or data from one point to another within the supply chain. The primary purpose is to ensure openness and responsibility for consumer health. It enables users to precisely look back at the origin of products from the beginning to the destination, which keeps them assured of food safety.

The ADDIE model is a model for design framework used in the development of practical learning experiences. It includes. - 1) Analysis: analyzing the learning needs of farmers and consumers and considering any constraints or limitations. 2) Design: The design phase is crucial for establishing the overall structure of a system. 3) Development: Applying the design results to develop the system. 4) Implementation: testing the system as a whole, and 5) Evaluation: Evaluation of the quality of the system that has been developed. Both improve and fix to get a quality system. Chaiyasut (2021) developed Aui Sorn Larn applications for learning about inheritance of local wisdom of Kuet Chang Community and Chaipattanamatee (2021) used the ADDIE model for designing interactive multimedia: dietary approaches to stop Hypertension (DASH) for Elderly.

A QR code contains representatives of data and is quickly responsive (Yao, Wang, & Shen, 2022), using a black-and-white rectangular pattern to represent information that is interpreted byra scanning tool. Furthermore, Zhang *et al.* (2021) and Al Dallal & Al Mukhtar (2023) indicated tha, it is a versatile innovation that can be used for various purposes, for example, marketing campaigns (Ta-Kham *et al.*, 2021), traceability in the food industry (Sutopo, Susmartini, & Herdima, 2021; Thongkaem *et al.*, 2023), traceability of rice and vegetables (Sukchareonpong & Thammasiri, 2018; Khaocha, Runglum, & Srisawang, 2020) and traceability of agricultural products (Sukchareonpong & Thammasiri, 2018; Jitjak, Taothaichana, & Nakornpa, 2021). With no fees, consumers can scan a QR code so the system displays profiles of farmersdand locates thr sources of products, product quantity, and the conditios of products they have. Implementation of QR codes can add value to Thai agricultural products, promote competitiveness against foreign counterparts (Jedsadanurak, 2018; Jitjak, Taothaichana, & Nakornpan, 2021) and lessen environmental problems. Using a QR code reduces the need for paper documents, prevents the accidental loss of documents, and can be accessible in real time. Users can also store data in the URL format on websites (Imanullah & Reswan, 2022).

A QR code is a two-dimensional barcode that stores an incredible amount of data andlcan be used many times. It is also affordable and compatible with all devices that support QR code scanning. This technology facilitates accessibility of information and offers anbettet experience (Radhi, 2022). To illustrate, using a QR code can enable the traceability of chemical-free vegetables and agricultural products. Informationssystems support the traceability of dairy products and vegetables, which benefits manufacturers and consumers as it provides a dependable tool. The system processes data to satisfy each stage of the production procedure and enhances traceability efficiency. It displays the data in the form of Hypertext Markup Language (HTML), and it functions on two different sides. - 1) web client or web browser, which generates requests for data access from the web server, and 2) web server, which is an application that receives and processes requests from users and then displays the output on the web browser. Five major components of the system include hardware, software, user, data, and procedure. These components cooperate to render the output that best meets user requirements (Tarapitakwong, 2021). Improvement of the information system for the production and distribution of rice seeds managed to maintain records of purchases, orders, disbursements, production costs, sales, and other relevant orders, and meanwhile, the system also generated other reports. Using the information system is not complicated because of its accuracy and efficiency. This resembles the study, which developed the information system for organic garlic harvest and utilized it to support a decision in the expansion of the area (Chitiyaphol & Dornpinij, 2022). In such a study, MySQL was set as the database and developed on the Bootstrap framework, CSS, and PHP to record and render the data on the website.

2.2 Methods

The procedure of design and development of traceability of chemical-free vegetables through QR code was based on the theory of ADDIED (Chaiyasut, 2021), which consisted of 5 steps as follows.

Step 1: Analysis and Planning. Farmer data and data involving cultivation plots, growth, together yield were analyzed. Figure 1 shows the conceptual framework as well as details of these data.

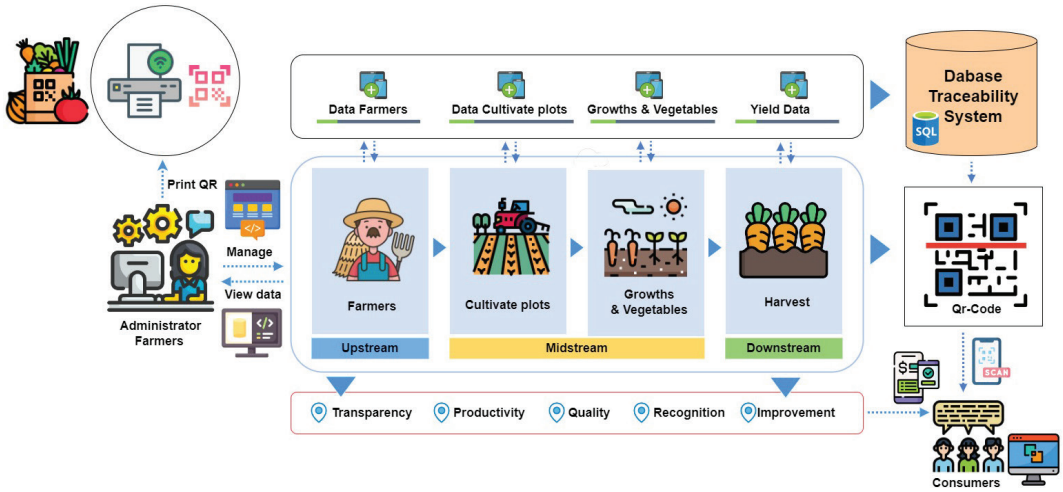

Figure 1. Purpose conceptual framework

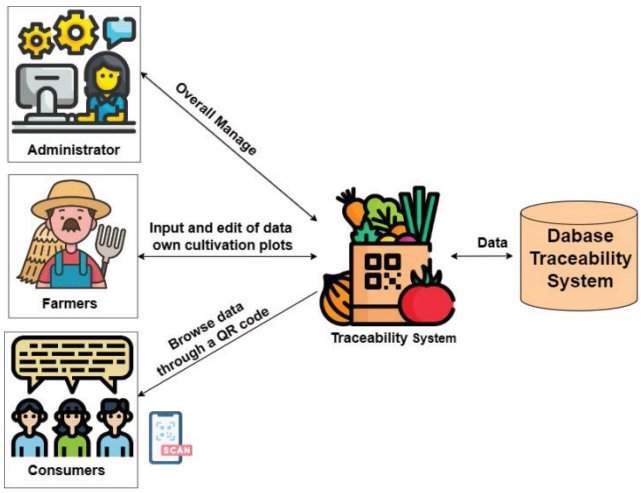

Figure 2. System permission

As illustrated in Figure 1, the system has three major parts. *(Part 1) System permission*. Three types of users are categorized. 1) an Administrator is assigned to manage data regarding cultivation plots, vegetables, farmer profiles, growths, accessibility, harvest time, as well as distributions. 2) Farmers are responsible for inputting and editing data regarding their cultivation plots, vegetables, growths, harvest time, as well as distributios. 3) Consumers are given access to browse particular data through a provided QR code (See Figure 2).

(Part 2) Traceability of chemical-free vegetables database. This database was developed on the phpMyAdmin program. It stores data regarding growts, vegetables, consumer profiles, farmer profiles, harvest time, storage recommendations, and QR code generation.

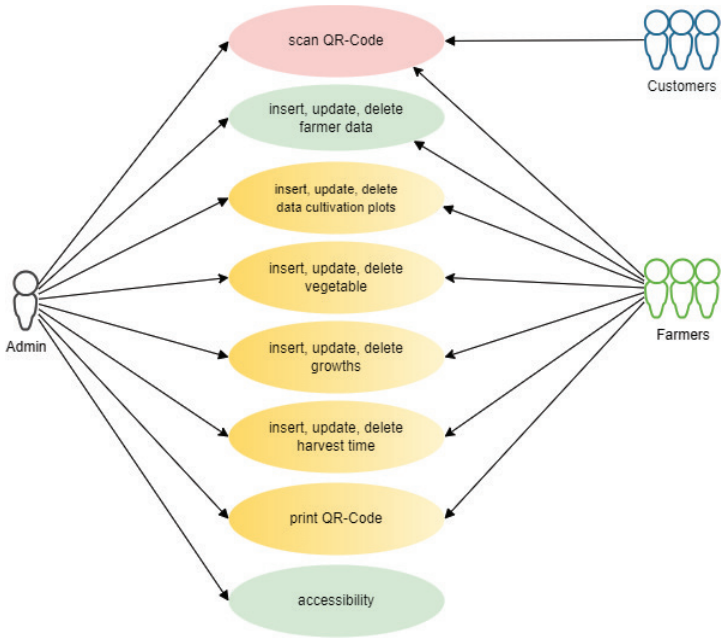

Figure 3. Use case diagram

*(Part 3) A QR code***.** A generated QR code is the medium of communication between farmers and consumers. Consumers can use their smartphones to scan a QR code and access the products' traceability, which could keep them assured of what they have bought.

Step 2: Design solutions. The data retrieved in Step 1 were analyzed to design a Use Case Diagram so the system can best meet users' needs. As shown in Figure 3, the three main stakeholders are the administrator, farmers, and consumers. This design solution consists of 3 modules as follows. - Module A: the system administrators, Module B: the farmers, and module C: the customers or consumers. This solution is similar tonthat illustrated in (Tantidontanet & Boonying, 2020).

According to Figure 3, the Use Case Diagram shows functions in the following ways.

1. The Administrator is assigned to manage data regarding cultivation plots, vegetables, farmer profiles, growths, accessibility, harvest time, as well as storage.

2. Farmers are responsible for inputting and editing data regarding their own cultivation plots, vegetables, growts, harvest time, as well as storage.

3. Consumers are given access to browse such data via a provided QR code.

Step 3: Development. The program was written in PHP, while the database ran on MySQL. Bootstrap front-ended framework handlesd data, which was then rendered on the web client (See Figure 4).

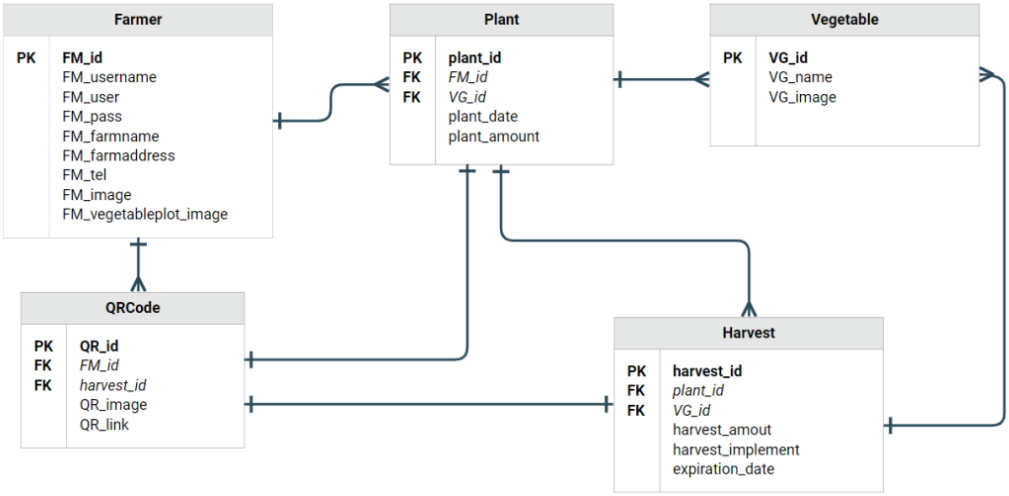

Figure 4. Entity relationship diagram

Step 4: Implementation. The system was implemented using existing data samples. Itswas compatible with smartphones that support QR code scanning.

Step 5: Evaluation. The efficiency of the system samples was evaluated by 5 experts. The evaluaten results were then analyzed using mean and standard deviation.

3. Results and Discussion

A traceability system of chemical-free vegetables using QR codes was designed and developed. In order to support a variety of devices and window or screen sizes on both Android and iOS smartphones, the responsive design was chosen. The QR codee were printed on sticker papers in size mm using A6 paper printers with a resolution of 200 dpi. The research results were as follows.

For the ADDIED-based development, a QR code-assisted traceability of chemical-free vegetables had three sections.

1) An administrator section responsible for the management of data regarding cultivation plots, vegetables, farmer profiles, growth, accessibility, harvest time, as well as storage. Signing into the system requires a registered email address and password. The system is accessible either through a smartphone or web client. As illustrated in Figure 5 and Figure 6, the administrator has permission to manage the data listed in the menu.

2) A farmer section allows registered farmers to input and edit data regarding their cultivation plots, vegetables, growths, harvest time, as well as storage (see Figures 7-9). Farmers may generate and print out a QR code and paste it on their own vegetable products as shown in Figure 10.

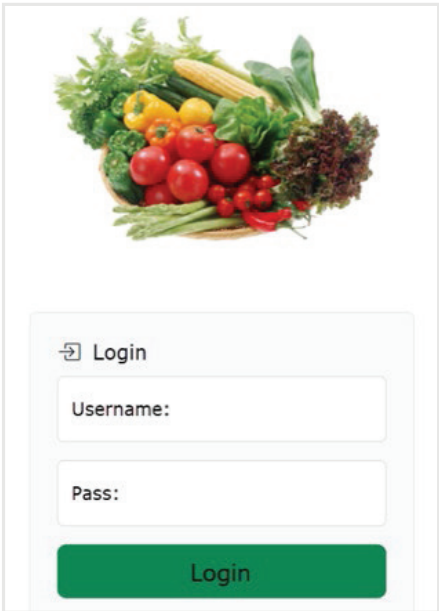

Figure 5. Sign in

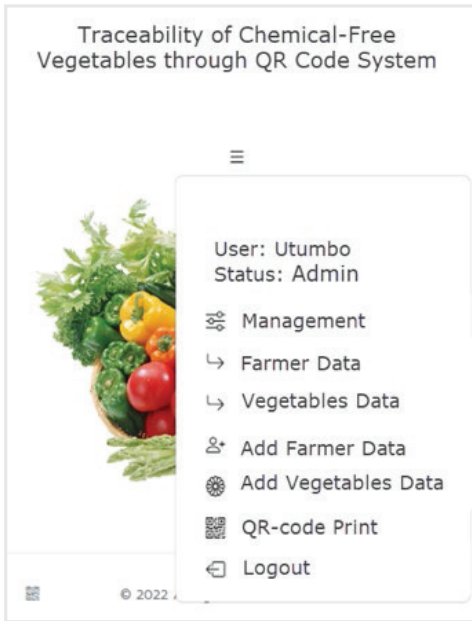

Figure 6. System management

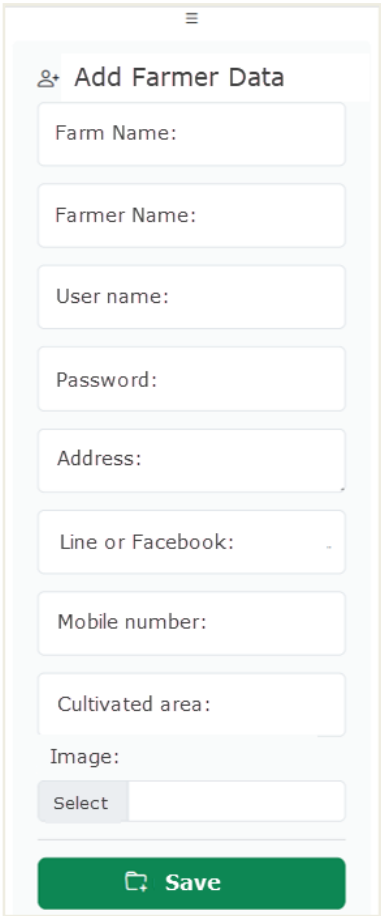

Figure 7. Insert farmer data

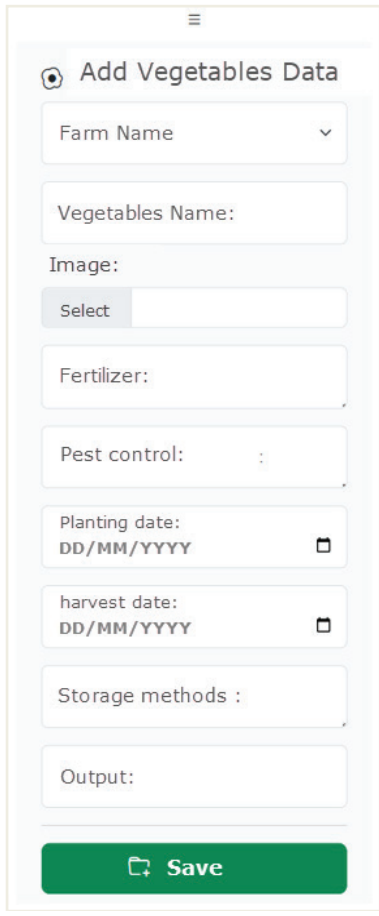

Figure 8. Insert vegetable data

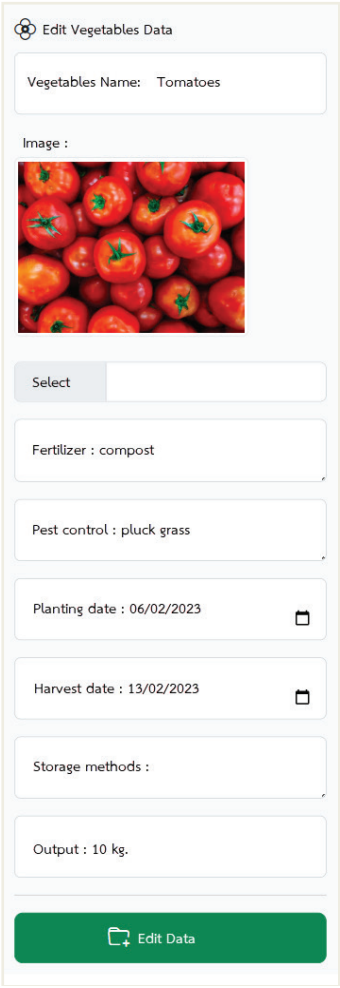

Figure 9. Edit vegetable data

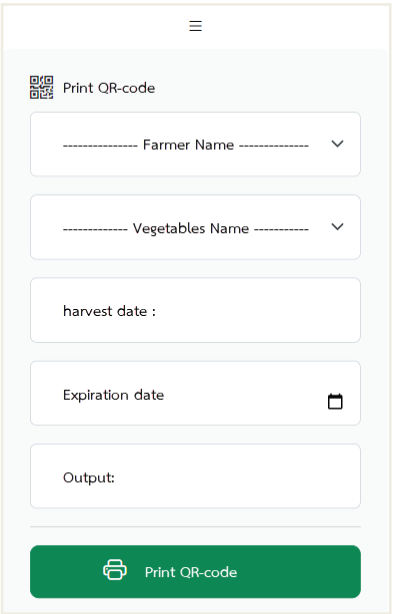

Figure 10. Print a QR code

Figure 11. QR code

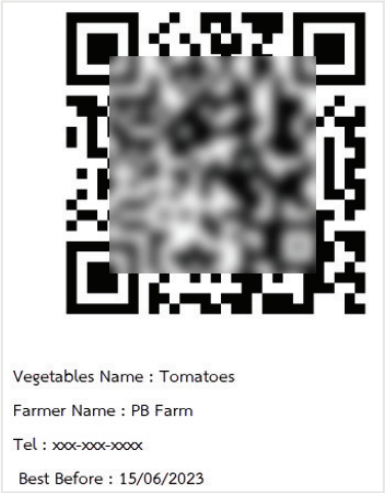

Figure 12. Output of QR code

Table 1. Results of efficiency evaluation by experts

Criterion	$\bar{X}$	S.D.	Interpreted
1. Compatibility with all devices.	4.80	0.45	Highest
2. Comprehensiveness of data	4.40	0.55	High
3. Preciseness of working permissions	4.40	0.55	High
4. Accuracy of QR code generator	4.80	0.45	Highest
5. QR code printing	4.80	0.45	Highest
6. Convenience and compatibility with compact printers	4.60	0.55	Highest
7. Enhanced trustworthiness of agricultural products	4.60	0.55	Highest
8. Security	4.40	0.55	High
Total	**4.60**	**0.51**	**Highest**

3) In the consumer section, consumers are allowed to browse information about products via a QR code by scanning it with a smartphone that supports QR code scanning. Consumers can also trace any products of their interest. In Figure 11, the sticker attached to each product contains a QR code, a vegetable name, a farm or garden name, a phone number, and an expiration date. As shown in Figure 12, if customers scan a QR code, additional information of a vegetable photo, a vegetable name, a farm or garden name, a phone number, a cultivation date, a harvest date, quantity of products in the same lot, together with storage method will be shown. This information could contribute to increasing customer trust and promoting values-based farming.

QR code-assisted traceability was evaluated by 5 experts, and the result indicated that the average score was 4.60, SD=0.51, which was at the highest level.

4. Conclusion

This study aimed to develop traceability of chemical-free vegetables via QR codes. It involved farmers at Ban Kaset Jun La Pan, Hua Sai District, in Nakhon Si Thammarat Province, Thailand, from which the agricultural data were collected to generate a pilot model of the system. There were three main sections of the system which functioned differently. 1) System permissions were granted to three groups of users. First, the administrator was assigned to manage data overall. Second, farmers were responsible for inputting and editing data regarding their own cultivation plots, vegetables, growth, harvest time, as well as storage. Third, consumers were given access to browse particular data through a provided QR code. 2) Application software was based on freeware, so there were no additional costs, as planned initially. 3) A QR code can be scanned using a smartphone as an approach to obtain sufficient and accurate

data that leads to the traceability of vegetable products. Thus, this research achieved traceability of chemical-free vegetables via QR codes. The system can store all the data, from cultivation to harvest procedures. Also, farmers may generate a QR code indicating product quality, and consumers can have it scanned by compatible smartphones. The system provides production data and meets different farmer's requirements from different areas and products. The evaluation of the system by the experts indicated that the average score was at the highest level.

A recommendation for further studies is to integrate Google Maps API into the system. Doing so could keep farmers and consumers notified via their smartphones when the system detects an anomaly. With the integration of Google Maps API, the system could promote smart farming, adding value to agricultural products and increasing the opportunity for farmers to be involved more in setting their product prices without relying on middlemen.

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