DESIGN AND DEVELOPMENT OF AGRICULTURAL PRODUCT TRACEABILITY TO SUPPORT THE AGRICULTURAL SAFETY

Rataphol Sangkhasuk* and Pornthep Anussornnitisarn
Department of Industrial Engineering, Faculty of Engineering, Kasetsart University, Bangkok 10900

*E-mail: srataphol@gmail.com

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ABSTRACT

This research aimed to develop a traceability system for agricultural products in alignment with Thailand's food safety policies and international standards, including ThaiGAP, GlobalGAP, Organic Thailand, ACT, ISO 9001:2015, ISO 22000:2018, GHP, BRC Food Issue 8, and global coding standards. A prototype platform, KasetTrace.com, was designed to support barcode-based tracking (ITF-14, EAN-13, GS1-128, and QR Code) and enable access for both producers and consumers, with no login required for consumers. The research methodology involved field studies, in-depth interviews, and focus group discussions with stakeholders across the supply chain—including farmers, collectors, processors, distributors, and consumers—to analyze current logistics processes and design a system suitable for real-world application. The system also integrates Plus Codes technology to enhance geolocation accuracy and reduce search time. Experimental implementation with five agricultural products showed that the average traceability response time was 42.12 seconds, with complete and accurate data retrieval in every instance. Furthermore, user satisfaction was evaluated among 300 participants, yielding an overall average score of 4.06 out of 5, indicating a high level of satisfaction regarding usability, accuracy, and reliability. The findings suggest that the developed system can enhance transparency in agricultural logistics, promote food safety, and strengthen the competitiveness of Thai agricultural products in global markets.

Keywords: Agricultural traceability, Food safety, Global standardized codes, Plus codes

Introduction

Thailand is a predominantly agricultural country, playing a vital role in both the national economy and export sector. In 2023, the export value of agricultural and agro-processed products totaled USD 49.2 billion, accounting for 17.3% of the country's total exports (Department of Internal

Trade, 2023). However, persistent concerns regarding pesticide residues in fruits and vegetables remain a significant obstacle to consumer confidence and hinder acceptance in international markets, particularly within the European Union and China. Despite government policies banning hazardous chemical usage and promoting organic farming practices (Department of Agriculture, 2023), the absence of an integrated information system within the agricultural logistics chain continues to pose a critical limitation. Current systems primarily focus on the physical movement of goods, with minimal attention given to digital data collection, integration, and real-time feedback mechanisms. This results in ineffective traceability and a limited capacity to address food quality and safety issues, ultimately undermining consumer trust and increasing the risk of non-tariff trade barriers.

The agricultural supply chain in Thailand includes a wide range of stakeholders, from farmers and intermediaries to processors, distributors, retailers, and consumers. However, this complex network often lacks efficient communication and data-sharing mechanisms, making it difficult to trace product origins or provide timely feedback to producers. The integration of modern technologies—such as QR codes, Plus Codes for location precision, and cloud-based databases—can significantly enhance traceability and transparency in this context. To ensure compatibility with international food safety benchmarks, traceability systems must comply with well-established standards. Thailand has implemented various food safety certifications and schemes that emphasize traceability, including ThaiGAP, Organic Thailand, ACT (Organic Agriculture Certification Thailand), ISO 9001, ISO 22000, GHP (Good Hygiene Practices), JAS (Japanese Agricultural Standard), GlobalGAP, BRC (British Retail Consortium), and NOP (National Organic Program). These standards provide essential frameworks to ensure the quality, safety, and credibility of agricultural products in both domestic and global markets.

The findings of this study align with prior research. For instance, Tantidlatanes and Boonying (2018) developed a community-based organic rice traceability system that emphasized transparency and consumer trust. Similarly, Lv, Zheng, and Huang (2021) demonstrated the value of blockchain technology in enhancing transparency within agricultural supply chains. Zhang, Zhang, and Liu (2020) highlighted the combined role of IoT and blockchain in improving traceability and food safety, particularly in seafood supply chains. Furthermore, Fernández-Caramés, Suárez-Albela, and Fraga-Lamas (2018) emphasized the importance of integrating emerging technologies such as blockchain, IoT, and international standards like GS1 to enable real-time monitoring, transparency, and sustainable production practices.

Building on these foundations, the present study aims to develop an international-standard traceability system for agricultural products by integrating a web-based platform, mobile accessibility, and standardized identification mechanisms. The proposed system incorporates technologies such as Plus codes and QR codes while aligning with the traceability requirements of the aforementioned food agricultural Standards. This well-integrated approach offers a practical, scalable, and cost-effective solution that supports food safety, enhances supply chain transparency, and promotes the long-term sustainability of Thai agriculture in line with global trends.

Methods

1. Field Survey on Problems and Needs in Agricultural Logistics Systems

A field survey was conducted in selected target areas to gather qualitative data from key stakeholders across the agricultural supply chain. The sample group consisted of 5 farmers, 6 intermediaries—including collectors, processing facility operators, and distributors—and 10 consumers. Focus group discussions were employed as the primary data collection method. The objective of this study was to identify and analyze critical issues and stakeholder requirements related to agricultural logistics systems and traceability mechanisms.

2. Data Collection on Agricultural Product Flows

This phase focused on analyzing the flow of agricultural products from upstream to downstream. Focus group discussions were held with farmers and collectors to gather in-depth information on each stage of the supply chain. Based on the collected data, an “As-is” process diagram was developed to reflect actual logistics activities and connections observed in the field. This diagram (Figure 1) served as a foundational reference for designing a traceability system tailored to the context and needs of stakeholders, ensuring practical implementation in the agricultural sector.

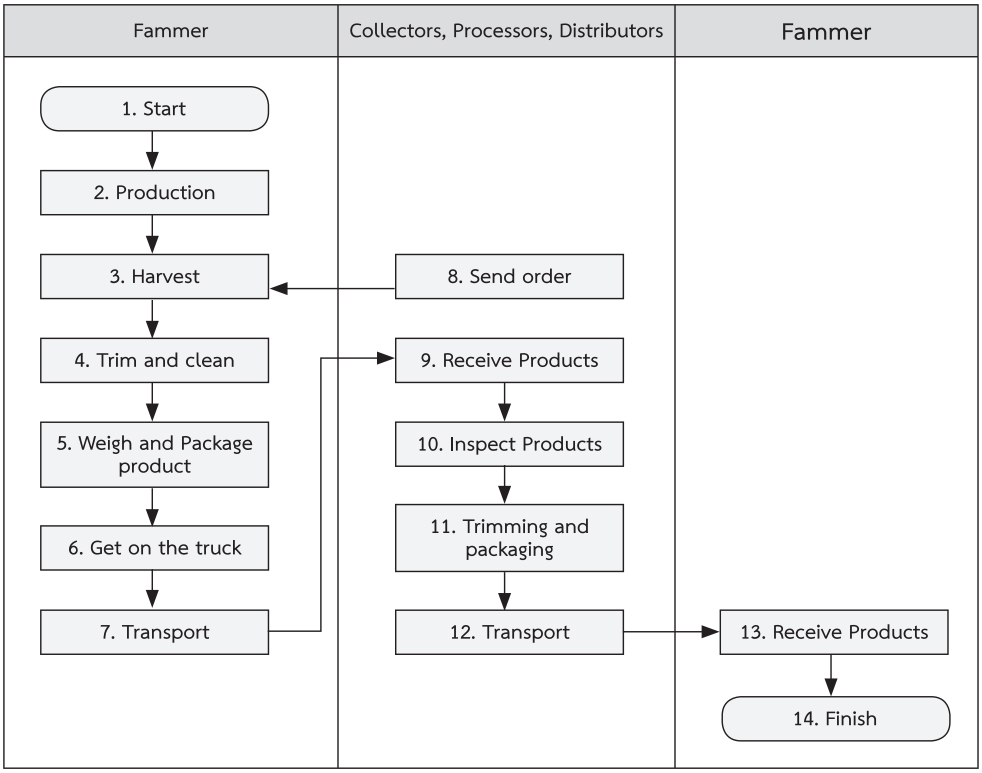

Figure 1 Current Process Flow Diagram (As-is)

As illustrated in Figure 1, the As-is process flow diagram depicts the logistics stream of agricultural products from upstream production to downstream delivery. The process begins with the farmer, who is responsible for initiating production, harvesting, trimming and cleaning the crops, weighing and packaging the products, and loading them onto transportation vehicles. The goods are then transported to collectors, processors, and distributors, who serve as intermediaries responsible for placing purchase orders, receiving and inspecting the products, conducting additional trimming and packaging if necessary, and organizing further transportation. In the final stage, the end recipient—such as consumers or downstream agricultural actors—receives the products, thereby completing the logistics cycle. This process reflects a clear and sequential connection between stakeholders in the agricultural supply chain, driven by demand signals (purchase orders) that trigger upstream production and enable product flow through various operational phases. The model also highlights opportunities for digital integration, such as real-time product tracking and geolocation encoding (e.g., QR codes or Plus Codes), to enhance transparency, traceability, and overall logistics efficiency within the agricultural sector.

3. Literature Review on Agricultural Logistics Data Collection

A comprehensive review of relevant literature was conducted to guide the design of an agricultural product traceability system. The key components identified include cultivation, harvesting, processing, storage, transportation, and distribution. Previous research has proposed various approaches to enhance transparency and traceability efficiency in agricultural supply chains. For instance, Worawitratnakul (2020) utilized smart contracts to increase legal transparency, while Tantidlatanes and Boonying (2020) developed a community-level traceability system for organic rice. Waisayadamrong (2021) implemented GS1 standards in food traceability systems. Other studies integrated IoT with predictive quality control (Praphathip, 2022) and combined blockchain with IoT to improve data security, immutability, and real-time traceability (Lv et al., 2023; Zhang et al., 2021; Fernández-Caramés et al., 2024).

4. Analysis of Agricultural Standards and plus codes technology in Traceability Systems

The agricultural product traceability system developed in this study is based on ten internationally recognized agricultural standards: Thai GAP, Organic Thailand, ACT, ISO 9001:2015, ISO 22000:2018, GHP, JAS, Global GAP, BRC Food Issue 8, and the National Organic Program (NOP). These standards were analyzed to extract key traceability requirements for vegetable production to ensure compliance with regulatory frameworks. To enhance traceability at the farm level, geolocation technologies were integrated into the system, particularly Plus Codes, an open-source digital addressing method. Plus Codes have been shown to offer location accuracy comparable to decimal degree GPS coordinates, with an average deviation of less than one meter—sufficient for identifying farm plots with high reliability (Google, 2020; Pradhan, Das, & Singh, 2022). A major advantage of Plus Codes is their ease of use, as they do not rely on conventional street names or address systems and can be easily converted into alphanumeric codes or QR codes for simplified sharing. This makes them especially suitable for rural or unmapped areas. Traditional GPS systems, meanwhile, retain an advantage in precision, offering centimeter-level accuracy that is ideal for precision agriculture and automated machinery applications.

From a long-term operational perspective, the traceability platform was developed as a web-based system with minimal ongoing maintenance costs. Annual domain renewal costs range from approximately 400 to 800 Thai Baht, while server hosting costs vary from 2,000 to 10,000 Thai Baht per year, depending on system capacity, bandwidth, and security requirements. These costs are considered affordable and manageable. Notably, the participating agricultural packing house expressed its willingness to assume responsibility for ongoing system maintenance, including technical support and renewal fees. Furthermore, since the system has been in use for a considerable period in field operations, its reliability and stability have been demonstrated. This long-term deployment has built confidence among agricultural producers and processors regarding the system's practical usability and sustainability, thereby reinforcing its potential to support long-term compliance with traceability standards in diverse agricultural contexts.

Table 1 Roles of Stakeholders under Agricultural Standards

Standard	Farmer	Collector	Processor	Distributor	Consumer
ThaiGAP	✓	✓	✓	✓	✗
Organic Thailand	✓	✗	✓	✓	✓
ACT	✓	✗	✓	✓	✓
ISO ๙๐๐๑	✓	✓	✓	✓	✗
ISO ๒๒๐๐๐	✓	✓	✓	✓	✗
GHP	✓	✓	✓	✓	✗
JAS	✓	✗	✓	✓	✓
GlobalGAP	✓	✓	✓	✓	✓
BRC	✓	✓	✓	✓	✗
NOP	✓	✗	✓	✓	✓

Note: ✓ = Participates in the system / ✗ = Does not directly participate in the system

Table 1 summarizes the involvement of key stakeholders—farmers, collectors, processors, distributors, and consumers—across ten widely recognized agricultural standards. While all standards engage farmers, processors, and distributors to varying degrees, only a few, such as Global GAP and organic standards (e.g., NOP, JAS, ACT), explicitly incorporate consumer participation. In contrast, standards like ISO 9001, ISO 22000, and GHP primarily focus on internal quality control within upstream operations, excluding consumers from direct engagement. The analysis highlights the varying scope of stakeholder inclusion, emphasizing the importance of selecting traceability standards that balance regulatory compliance with transparency and consumer trust.

5. Design of Barcode-Based Traceability System

To enhance traceability of agricultural products in Thailand, a barcode system based on international standards was developed. This system enables accurate, structured tracking of products throughout the supply chain. Additionally, Plus Codes were integrated to increase geolocation accuracy at the farm level. The system architecture is summarized in Table 2.

Table 2 Core Structure of the Integrated Traceability System

Stakeholders	Standard Name	Application Identifier (AI)	Data Description	Data Format
Farm	ITF-14	-	Packaging type, country code, company code, product code, check digit	N14
	GS1-128	2	Packaging type + product code	N2+N14
		10	Lot number (plot code, year, month, day)	N2+X…20
		11	Production date (year, month, day)	N2+N6
		37	Quantity in package	N2+N…
		91	Farm location (Pluscode)	N2+X7
Collectors, Processors, Distributors	EAN-13	-	Country code, company code, product code, check digit	N13
	GS1-128	2	Packaging type + product code	N2+N14
		10	Lot number	N2+X…20
		13	Packaging date (year, month, day)	N2+N6
		15	Expiration date (year, month, day)	N2+N6
		37	Quantity in package	N2+N…
		91	Processing plant location (Pluscode)	N2+X7
Customer	QR Code	-	Mobile QR code scanning system providing product information, user rating, and feedback features	-

6. Conceptual Framework for Traceability System Development

The traceability system was designed by integrating the current “As-is” process data with established traceability frameworks and agricultural Standards. GS1 standards were applied to build a stakeholder database, linking farmers via ITF-14 and GS1-128 codes, and connecting collectors, processors, and distributors through EAN-13 and GS1-128. Consumers can trace product origins and receive alerts regarding potential safety issues, thereby enhancing trust and supporting compliance with food safety regulations.

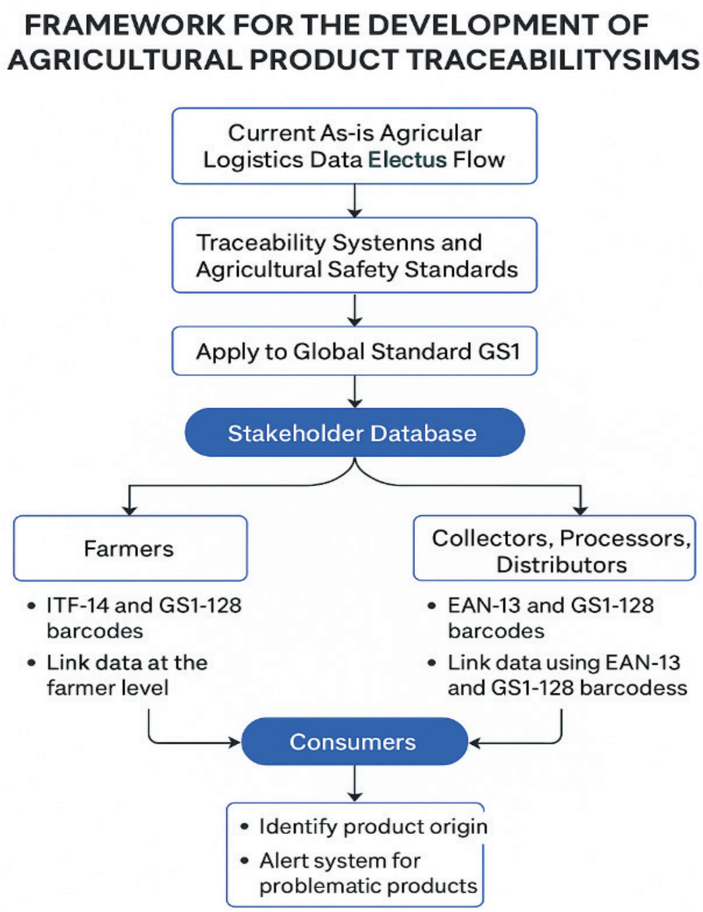

Figure 2 Conceptual Framework for Agricultural Traceability System

Figure 2 illustrates the conceptual framework of the agricultural product traceability system, which aims to manage data across the entire agricultural supply chain—ranging from farmers, collectors, processors, and distributors to consumers. The system begins with the integration of current agricultural logistics data into traceability mechanisms and agricultural safety standards, adopting the globally recognized GS1 standard. All stakeholder-related data is recorded and linked through a centralized stakeholder database. Each stakeholder contributes three categories of input data: (1) fixed data that remains unchanged across production cycles, such as farmer ID, farmer name, and farm plot coordinates; (2) variable data that changes per production cycle, including crop quantity and plot identification number; and (3) system-generated data, such as product lot numbers and goods receipt numbers, which are automatically created to support traceability functions. Farmers utilize ITF-14 and GS1-128 barcodes to link data at the farm level, while collectors, processors, and distributors employ EAN-13 and GS1-128 barcodes to integrate data throughout processing and distribution. The processing steps involve feeding all collected data into the system under GS1 protocols, storing and linking it within the stakeholder database, associating it through standardized barcodes, and enabling real-time data exchange and retrieval through a tracking platform. The system outputs allow consumers to identify product origin, receive alerts on problematic or unsafe products, and foster greater confidence in food safety and product quality. Nonetheless, the system constraints include technological limitations among small-scale producers, varying levels of digital literacy among stakeholders, inconsistency of data from multiple sources, and the cost of system installation and maintenance. These factors must be carefully considered to ensure the effectiveness and sustainability of application development for agricultural traceability.

7. Development of the Agricultural Traceability Platform

The website **www.kasetTrace.com** was developed as a web-based traceability platform designed to manage agricultural product data throughout the entire supply chain—from farm-level production to end-consumer distribution. The primary objective of the system is to promote transparency, accountability, and consumer trust by implementing traceability mechanisms aligned with international standards. To ensure data security, the platform employs a segregated database structure in which each stakeholder group—including farmers, collectors, processors, distributors, and consumers—is assigned a dedicated database with access controlled through individualized usernames and passwords. A notable feature of the system is its ability to enable traceability at the individual farm plot level using Plus Codes technology, which allows for the precise identification of geolocations and production sources. In addition, the system incorporates analysis and compliance mapping with ten key agricultural safety and certification standards: ThaiGAP, Organic Thailand, ACT, ISO 9001, ISO 22000, GHP, JAS, GlobalGAP, BRC, and NOP. Traceability operations are further supported by QR code technology, enabling users to scan and retrieve product data in real time using smartphones—eliminating the need for specialized barcode scanners or computers. This feature enhances accessibility and usability across the supply chain. The platform also supports cross-stakeholder traceability, allowing users to track product movement and history across multiple actors in the supply chain. Compared to traditional systems in Thailand, this approach offers a more robust, granular, and mobile-enabled traceability solution, contributing to improved food safety, regulatory compliance, and supply chain transparency.

8. Core Functions of the System

8.1 Membership Management The system supports registration and user role management for stakeholders such as farms, packing houses, and intermediaries, as illustrated in Figure 3(a).

8.2 Product and Lot Management Users can record and manage product information and packaging details using ITF-14 barcodes. Lot tracking and data editing functionalities are also supported, as shown in Figure 3(b).

(a) (b)

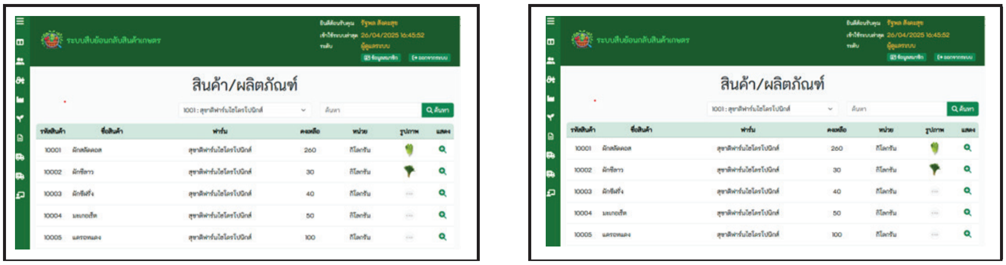

Figure 3. Member Management Interface (a) Product and Lot Management (b)

8.3 Document Management for Inbound and Outbound Goods The system allows the creation of inbound and outbound documents and printing of barcode stickers in EAN-13, ITF-14, and QR Code formats, as illustrated in Figure 4(a).

8.4 Traceability Search via Barcode Scanning Users can trace the origin of products by scanning or entering barcode data, which displays traceability results back to the farm and packing house, as shown in Figure 4(b).

(a) (b)

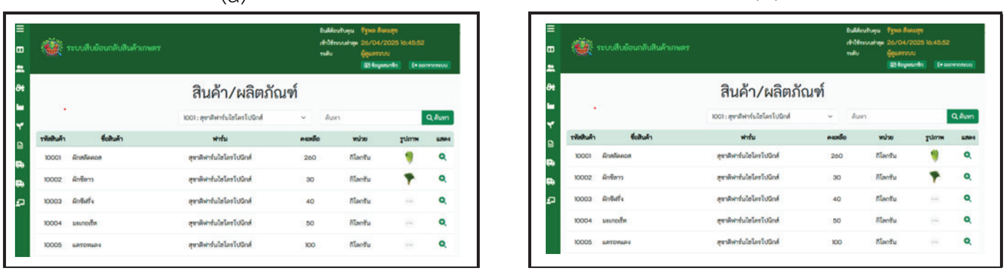

Figure 4. Document Management (a) Traceability Search Function (b)

8.5 Employee and Customer Data Management Farms and packing houses can store and manage employee and customer information to improve operational efficiency.

9. Agricultural Product Traceability System

The traceability system supports data exchange among all stakeholders in the supply chain, including farmers, collectors, processors, and distributors. Operated through the web platform www.kasetTrace.com, the system requires login credentials and complies with international barcode standards (ITF-14, GS1-128). Stakeholders can scan QR codes using barcode readers or mobile devices to log and retrieve data. The system links data between all supply chain actors. For consumers, traceability information is accessible without login via www.kasetTrace.com. Consumers can use EAN-13 or GS1-128 codes—internationally accepted formats—to retrieve product information by entering the code or scanning a QR code, as shown in Figure 5.

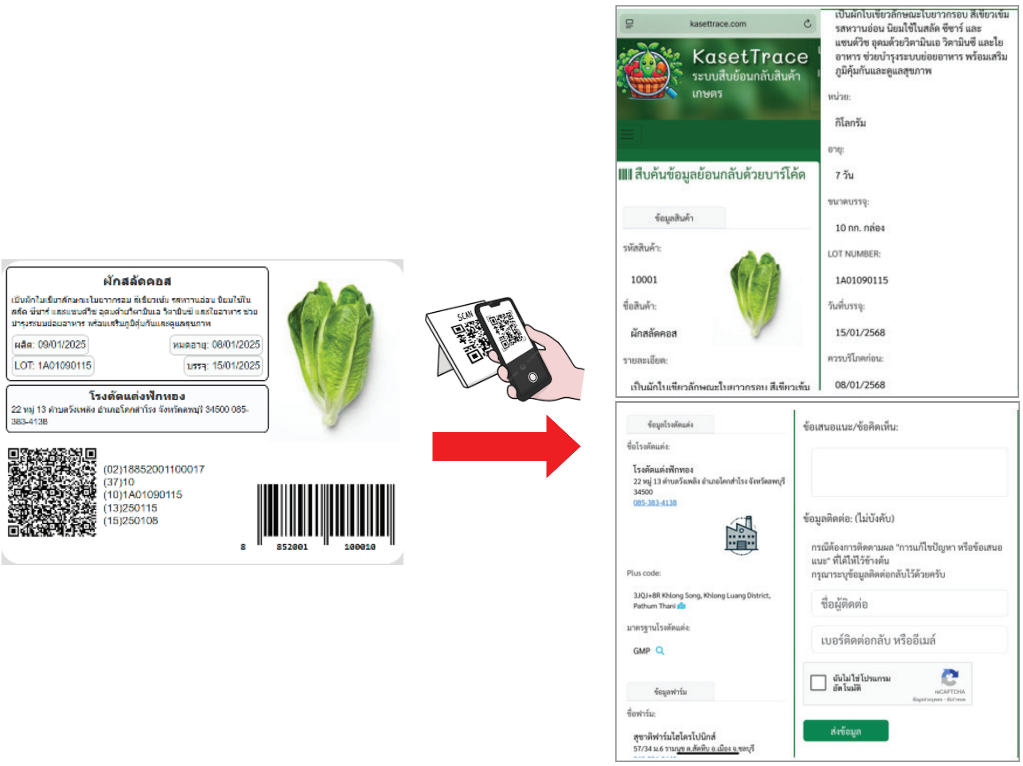

Figure 5. Consumer-End Traceability Access

10. Key Features of the System

- Supports international barcode standards (EAN-13 and ITF-14)
- Enhances transparency throughout the supply chain and builds consumer trust
- User-friendly interface compatible with desktop and mobile devices
- Automated data linkage reduces management errors
- Cost-effective through open-source platform development without licensing fees

System evaluations indicate a significant improvement in data transparency and operational efficiency within agricultural logistics. These outcomes demonstrate the system's potential for broader adoption in the future.

Results and Discussions

1. Data Collection on Traceability Time

In this study, a field experiment was conducted to evaluate the traceability time of agricultural products. The experimental design followed a repeated measures design, allowing for accurate comparison of traceability times across different product types while minimizing variability from confounding factors. Data collection was carried out in the form of quantitative data, focusing on five distinct agricultural products. For each product, five traceability trials were conducted under simulated customer request scenarios. The time taken (in seconds) for the system to complete each traceability operation was recorded. The collected data were then used to calculate the average traceability time and standard deviation for each product to assess the system's performance in terms of speed. The results of the experiment are presented in Table 3.

Table 3 Traceability Time Performance

Product Code	Experiment No.					Average (sec)	Standard Deviation (sec)
	1	2	3	4	5		
10001	38	40	42	48	39	41.4	3.97
10003	42	45	39	42	41	41.8	2.17
10005	39	41	44	43	40	41.4	2.07
10009	45	42	39	40	42	41.6	2.3
10012	47	45	42	47	41	44.4	2.79
Overall Average						**42.12**	**1.29**

Table 3 presents the results of traceability time performance for five agricultural product codes, with five repeated trials conducted for each product. The average traceability times ranged from 41.4 to 44.4 seconds. The standard deviations ranged between 2.07 and 3.97 seconds, indicating low variability within groups. The overall mean traceability time was 42.12 seconds, and the average standard deviation across all products was 1.29 seconds, reflecting the system's stability and consistent retrieval performance. Furthermore, a statistical power analysis was conducted at a significance level of α=0.05 to assess the adequacy of the sample size. Using an estimated effect size of approximately **f**≈0.5, which is considered large, and a sample structure of five groups with five observations each, the analysis yielded a statistical power of approximately 0.85–0.90. This exceeds the commonly accepted threshold of 0.80, indicating that the data set is sufficiently reliable and capable of detecting statistically significant differences in traceability time across product groups.

2. **User Satisfaction Assessment**

A total of 324 participants were involved in the user satisfaction survey for the traceability system, comprising 45 farmers, 9 intermediaries, processors, or distributors, and 270 consumers. This diverse sample of respondents reflects the key stakeholders across the agricultural supply chain, thereby enabling a comprehensive assessment of user satisfaction in terms of system usability, accessibility, and perceived effectiveness. User satisfaction was evaluated using a structured questionnaire developed based on established information system evaluation criteria. The instrument was designed following the Information System Success Model by DeLone and McLean (2003), which encompasses multiple dimensions of system performance and user experience. The interpretation of satisfaction scores was based on a five-point Likert scale, with the following thresholds: 1) 4.01–5.00 = Very high satisfaction 2) 3.41–4.20 = High satisfaction 3) 2.61–3.40 = Moderate satisfaction 4) 1.81–2.60 = Low satisfaction 5) 1.00–1.80 = Very low satisfaction

The results of the user satisfaction assessment for the agricultural traceability system are summarized in Table 4.

Table 4 User Satisfaction Assessment Results

Evaluation Criteria	Mean	Standard Deviation
1. Ease of Use	4.04	0.26
2. Accuracy and Reliability of Information	4.07	0.33
3. System Efficiency in Traceability	4.04	0.31
4. Accessibility and Reporting Capabilities	3.97	0.26
5. System Support and Services	4.17	0.38
6. Overall Satisfaction	4.04	0.37
Overall Average	**4.06**	**0.07**

As shown in Table 4, the overall average satisfaction score was 4.06 with a standard deviation of 0.07, indicating a high level of satisfaction. The highest-rated aspect was system support and services (mean = 4.17), followed by accuracy and reliability of information (mean = 4.07), and both ease of use and system efficiency (mean = 4.04). The lowest-rated aspect was accessibility and reporting (mean = 3.97). Nevertheless, all aspects scored above 3.50, indicating that the system effectively meets user needs and maintains a high level of reliability.

3. Discussion

The findings of this study align with previous research in several key areas. For instance, Tantidlatanes and Boonying (2018) developed a community-based traceability system for organic rice that emphasized transparency and consumer trust. Similarly, Lv, Zheng, and Huang (2021) highlighted the role of blockchain technology in enhancing transparency within agricultural supply chains, while Zhang, Zhang, and Liu (2020) proposed the integration of blockchain and the Internet of Things (IoT) to improve traceability and food safety, particularly for seafood products. These insights are consistent with the system developed in this study, which integrates modern information technologies and GS1 standards. As Fernández-Caramés, Suárez-Albela, and Fraga-Lamas (2018) suggested, combining these technologies facilitates real-time traceability, enhancing transparency, safety, and sustainability in agricultural production. Compared to existing systems, the traceability platform developed in this study offers advantages in accessibility and usability, especially for small-scale farmers, by enabling system use via smartphones without the need for additional specialized equipment. Notably, the system supports compliance with ten agricultural standards, a feature not commonly found in prior studies, and incorporates Plus Codes technology to pinpoint farm locations at the plot level, significantly improving traceability precision. From a cost-efficiency perspective, the platform was designed as a low-maintenance web-based system, with annual domain renewal costs ranging from 400 to 800 Thai Baht and server hosting costs between 2,000 and 10,000 Thai Baht, depending on service capacity and security needs—making it financially manageable for smallholders and SMEs. The system has also been tested in real field conditions over an extended period, during which a participating agricultural packing facility committed to ongoing technical support and maintenance. This field deployment demonstrates the system's stability, reliability, and user acceptance, thereby reinforcing its practical viability and long-term potential for supporting traceability standard compliance in diverse agricultural contexts.

Conclusions

This study aimed to design and develop an agricultural product traceability system that aligns with Thailand's national food safety policies and international standards, including ThaiGAP, GlobalGAP, Organic Thailand, ACT, ISO 9001:2015, ISO 22000:2018, Good Hygiene Practices (GHP), and BRC Global Standard for Food Safety Issue 8. The research process began with field studies, in-depth interviews, and focus group discussions involving stakeholders across the supply chain to analyze the current ("As-is") processes and guide the development of a context-appropriate system. The resulting system integrates barcode technologies—ITF-14, EAN-13, GS1-128, and QR Code—and is implemented through the KasetTrace.com platform, which supports both business operators and consumers, with public access available without requiring login. Trial implementation with five agricultural products demonstrated successful retrieval of complete and accurate traceability data within an average time of 42.12 seconds. The system also incorporates Google's Plus Codes geolocation technology to enhance the precision of source identification and accelerate data access, thereby strengthening transparency and supporting food safety objectives. A user satisfaction survey conducted with 300 participants yielded an average score of 4.06 out of 5, reflecting high levels of satisfaction with system usability, data accuracy, and overall reliability. To support nationwide scalability, the database architecture was designed to accommodate large volumes of data and concurrent users. The growing availability of high-speed internet across rural areas, increased smartphone penetration, and a user-friendly interface that requires minimal technical expertise enhance accessibility among stakeholders. Personal data security is addressed through role-based data classification, and long-term system maintenance is planned under the supervision of agricultural processing facilities, ensuring sustainability and continued adoption in Thailand's agricultural sector.

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