APPLICATION OF BLOCKCHAIN TECHNOLOGY FOR MANGO TRACEABILITY MODEL IN VIETNAM

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ABSTRACT

Achieving sustainable agricultural development has always been Vietnam's goal. Today, with the rapid development of society, more and more new technologies appear, but their application in agricultural production is still limited and has not been widely implemented, mango is a typical product. With the progress of science and technology, many fruit sorters have been born, but in Vietnam, the mango classification process is still manual and the yield is very low. In addition, the traceability of mango is still opaque, reducing the competitive advantage of Vietnamese mango in the export market. In the face of these difficulties, this study aims to design a mango sorting machine that applies transparent traceability model applying blockchain technology, aiming at improving the quality and value of Vietnamese mango in the market.

Keywords: *Blockchain, Mango, Agricultural products, Traceability, Identification, IR 4.0, Economics, Innovation*

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1. INTRODUCTION

Applying technology to the goal of sustainable development is one of the trends in Vietnam today. In the economic field, especially in the agricultural sector, in order to toward sustainable development, it is necessary to ensure that the goal of establishing an ecologically sustainable system can meet human needs without destroying land and polluting the environment, and ensure the interests of future generations. In order to achieve the goal of sustainable agricultural development in Vietnam, it is necessary to solve the problem of reducing the labor force, especially in the stage of agricultural product classification, which is quite backward at present [1,2], Vietnam's food classification equipment productivity is low, lagging behind the overall situation of the world. Agricultural development not only focuses on improving the productivity and quantity of agricultural products but also must go hand in hand with the story of improving the quality of agricultural products. With the development speed of today's society, market demand is becoming more and more difficult, and the overall model has brought pressure to the agricultural sector. Therefore, one of the main priorities of agricultural production is to meet the needs of the export market and meet the current demand for a large number of high-quality agricultural products. In order to achieve this goal, the research of agricultural classification equipment has become the top priority of agricultural construction and development. Mango is the second most consumed tropical fruit in the world after bananas. According to data from the Ministry of Agriculture and Rural Development, Vietnam is the thirteenth country in the world in terms of mango production with an amount of about 893,000 tons (in 2020). The largest mango export market in our country is the Chinese market, which has experienced more or fewer fluctuations since the outbreak of the pandemic, leading to many economic losses. Therefore, to avoid being dependent on the Chinese market, agricultural products in general and mangoes in particular need to upgrade their qualifications to be able to meet demanding markets like Europe. From an economic perspective, it is difficult for Vietnamese mangoes to compete with other mango-exporting countries such as Japan, and Korea on factors of quality, preservation, and transparency in origin. This is partly due to the fact that the mango grading process is still done manually, leading to high costs and poor quality, and the annual cost of sorting can be up to about 100 billion VND/year. Before the development of the current era, the application and research of technology to apply to the design process of sorting machines is urgent to solve the problem of increasing output and reducing costs for the mango industry in Vietnam.

Currently, at home and abroad, there have been studies on the classification system of agricultural products such as mango, apple, tomato, etc., applying image processing technology [3]. However, it is necessary to use a distinct classification system for each type of agricultural product, particularly with mango because it makes the process more difficult. The rapid development of science and technology to design, calculate, model, and simulate systems operating

on specialized software has accelerated the process of designing and manufacturing classification and classification systems. As a result, an agricultural classification system has emerged and operates in major cities and key rural areas. Although classification systems have appeared for a long time in the agricultural field, up to now there is no specialized system for the classification of mangoes. The news that Cao Lanh mango (Dong Thap) was impersonated with the planting area code, causing the Chinese side to ban the import, is a wake-up call about the problem of origin confusion not only for mango products but also for the agricultural product industry. Recently, the EVFTA Agreement officially took effect, creating great opportunities for Vietnam's agricultural products to grow in exports to the EU, especially commodity groups such as vegetables, coffee, pepper, rice, and seafood with a tax rate of 0%. The EU will protect 39 geographical indications of Vietnam. The geographical indications of Vietnam are related to agricultural products and foodstuffs, creating favorable conditions for some types of Vietnamese agricultural products to build and affirm their brands in the EU market [4]. However, if the mandatory requirements on traceability, labeling, safety, and hygiene are not met..., Vietnamese agricultural products not only lose these opportunities but also affect the reputation of the brand in the EU and world markets. This shows that in the coming time, the implementation of traceability of agricultural products in the domestic market as well as for export is an urgent task. Because even in the domestic market, the problem of mixing the origin of agricultural products is also very complicated.

One of the tasks that require high precision but are still completed manually is the classification of agricultural products. Mangoes will be classified manually after being harvested and transported to the warehouse. This process requires a lot of labor, resulting in increased production costs and more problems related to the quality of agricultural products. Therefore, the use of an intelligent classification system can reduce production costs, improve labor costs, and improve the automation level of production models, with unlimited working hours. Product traceability refers to the ability to track and identify a product unit through each stage of the production, processing, and distribution process. It is a solution that allows consumers to directly collect complete information about the purchased item. The application of blockchain technology in the traceability of agricultural products is related to the issue of enhancing transparency in the traceability process. Blockchain can be understood as a distributed ledger technology, data is stored on the blockchain in a decentralized form, unlike traditional storage methods that only focus on storing data on a single database. certain institutions in a centralized form. These chains are linked together by a hash code. This means that any change to any data taking place in the chain is not possible due to the high security and characteristic one-way encryption of the code. This makes the data stored on the blockchain almost immutable except, only when the consensus is reached by 51% of the machines participating in the network. Therefore, in processes that require high transparency, trust, and security such as mango traceability, the application of blockchain technology can increase the efficiency of security in the process.

2. PROPOSING A TRACEABILITY MODEL OF MANGO USING BLOCKCHAIN TECHNOLOGY

Blockchain was first invented and designed by Nakamoto in 2008. In essence, blockchain is a distributed and decentralized electronic ledger technology that allows data to be stored on it. It can be regarded as a series of data blocks, which are linked together by chain. These chains in the blockchain are called hashes. Each block in the blockchain is identified by the corresponding hash, except that other blocks in the chain must carry the corresponding hash of the previous block [5-7]. Therefore, changing the data on one block will affect the entire other block. This is the feature of Blockchain. We usually learn about blockchain through Bitcoin, one of its most famous products. Bitcoin is essentially a form of blockchain 1.0 and exists in the form of digital currency. This is an early version of this technology, aiming to create a cryptocurrency superior to the existing legal tender. As an inevitable part of technological development, with the emergence of Ethereum platform and smart contract protocol, blockchain 2.0 was born. The main goal is to solve many key problems by providing decentralized applications and becoming a global grid. With the development of technology, blockchain 3.0 focuses on the field of "design and monitoring", which means that the technology is no longer limited to banking, but extends to many other fields including agriculture.

The problem of food of unknown origin is a headache that Vietnam's agricultural industry is suffering. Food of unknown origin contains potential risks to the health of consumers, and to large extent reduces the quality of the entire agricultural industry. Facing that status quo along with the current outstanding development of blockchain technology. The application of blockchain technology is one of the ways to solve the problem of unknown origin of food. The application of blockchain technology in agriculture allows us to check all information related to food such as: origin, packaging date,... in a transparent and clear way. The information provided can help improve performance in the supply chain while at the same time [8-12]. In the framework of the study, the proposed traceability model receives the data from the mango sorter mentioned above. Aiming to increase the value and quality of the mango industry in our country today, contributing to the goal of sustainable development of agriculture. Blockchain technology has many advantages for managing agricultural operations. It enables customers to trace the origin of their food, making them feel more secure using their own goods. Blockchain typically functions in the food supply chain in five ways: Data

record: A single blockchain can function as a distributed collection of units that transfer information. Blockchain allows for the tracking of purchases, receipts, delivery notifications, and other commercial activities. Verification: The blockchain can be used to confirm other food-related events or transparency, like the date and place of the harvest. Distributing goods and linking them to digital labels like barcodes, serial numbers, and RFID is possible with the help of blockchain technology. Blockchain can be used to send dealers details about assembly. Blockchain is a distributed, decentralized system that can be used to improve food traceability. Every link in the supply chain must function properly for it to be successful as a whole. The responsiveness and effectiveness of supply chain operations are two traits. The issue is that precise food traceability is necessary in order to reach the output for international exports. To obtain accurate data about food safety and quality, all participants in the food supply chain must guarantee traceability. This will allow them to respond quickly to problems and take preventative measures. The FAO rule of 2005 includes the traceability of food as a key component. All food and food businesses are required to adopt traceability, according to the Common Food Act of the European Union (EU). As a result, in order to inform the appropriate authority, business entities must clearly identify the origin and origin of goods. Two primary features make up the traceability system. The first is the capacity for motion tracking. The second is monitoring how a food product is handled throughout the food delivery chain. It's critical to understand the difference between monitor and traceability. A product's traceability refers to the capacity to establish a history of that product in the food supply chain and track its origin, movement, and information pertaining to units in the supply chain by referring to data logged from the beginning. While this is going on, tracking refers to the capacity to keep track of a product's location in the food supply chain as well as the path taken by a specific unit or product collection as it moves from one business or group to another. from one point of sale to another, and from one support location to another, etc.

The development of a traceability system applying Blockchain technology for agricultural products brings many benefits to agriculture in general, such as information security, and improving and enhancing the quality of cooperation with other parties. related issues in the supply chain, reducing economic losses due to minimizing counterfeiting, and enhancing sustainability, and transparency in traceability management. Operating a traceability system basically requires the participation and coordination of 4 main layers: Business layer, IoT, traceability layer, Blockchain layer, and Application layer. Business Layer: At this layer, is the involvement of the food supply chain. An export organic supply chain consists of many interdependent actors, so coordination among the chain stakeholders can be represented as a strategic response to problems occurring in the chain. There exists a coordination and cooperation mechanism between the parties in the supply chain that includes methods to manage the degree of interdependence between the parties. With the increasing importance of sourcing organic agricultural products, the role of coordination and relationship management among stakeholders is increasingly emphasized and considered an important issue. The supply chain plays many roles and is an important factor in determining the quality of the product that reaches the consumer. In the traceability system, the involvement of the business layer takes up most of the weight throughout the process.

IoT traceability layer: The term IoT refers to a network of smart devices and technologies that facilitate communication between the cloud and data. IoT technology applied in the traceability system acts as a cloud database that stores and manages information about the origin, etc., provided and authenticated data from stakeholders. importance in the supply chain. The cloud database system in the study accepts and manages related devices in the ecosystem such as temperature sensors in containers, transaction management information systems, etc. Blockchain layer: In the research that we propose, the blockchain network plays the role of ensuring data transparency through a distributed and decentralized network of data. Participants in the mango supply process will be granted the right to become nodes in the distributed network. Therefore, changing data on the main blockchain is almost impossible and only happens when there is the consensus of more than 50% of machines in the network. The application layer is the intermediary between the layers in the traceability system. This class manages and regulates how the classes play certain roles in the entire traceability system. This layer plays the role of maintaining the operation of the entire traceability system.

3. DESIGN THE MANGO SPPLY CHAIN

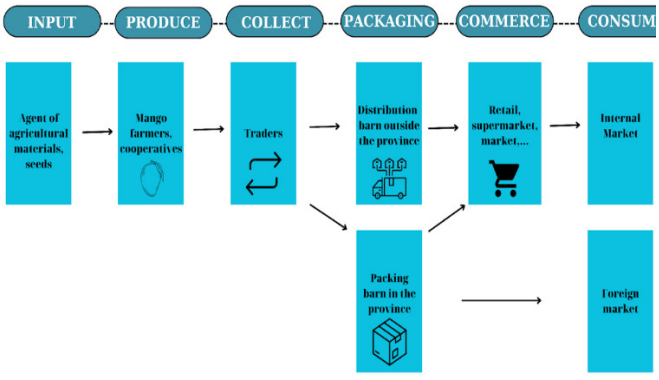

Fig. 1. Dong Thap's Mango supply chain

This research is based on Vietnam's Dong Thap Province's mango supply chain. (one of the largest mango planting provinces in our country). For most individuals here, food traceability is still not a major issue. There are still a lot of untraceable goods available in markets. One of the major agricultural products of the fortress is fruit in particular. There are six steps in the Dong Thap mango

supply chain (Fig. 1). Farmers are given raw materials, farming equipment, and seeds by agricultural agents during the first step. Mango planting by growers and cooperatives will begin in the second phase. Farmers and cooperatives must follow certain rules at this point to guarantee that the harvested mangoes meet GLOBALGAP and VietGAP requirements. The primary action of the third stage will be the traders visiting the gardener to purchase mangoes. Mangoes will be bought and then transported by merchants to two locations in the fourth level. The packaging warehouse is located inside the province, and the distribution location is located outside the province. At this stage, mangoes will be classified, packaged and sealed for traceability. We can categorize the process of data collection and identification into different phases based on how the mango supply chain is organized. Based on supply and the information provided, the traceability of the first supplier can help decide which growers will supply mangoes and how many mangoes will be supplied. Mango, however, has not yet been decided. Mangoes were properly sorted and packaged during transportation to the fruit warehouse in accordance with the requirements of each market, but it was still difficult to identify which gardeners planted the mangoes. The third customer traceability: the data confirms that the user bought mango, but at this stage, the seller or farmer does not know who the consumer is.

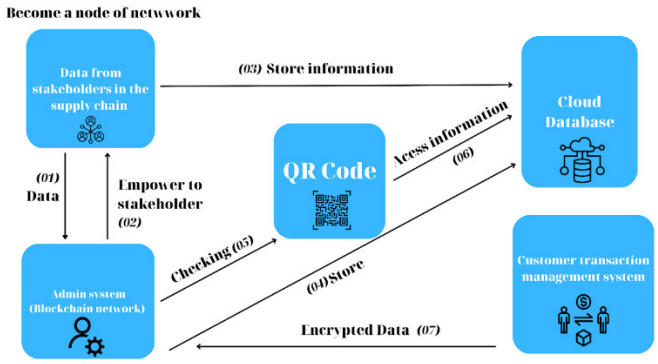

Fig. 2. Traceability system applying blockchain

The traceability system (Fig. 2) is developed with 5 modules: Module 1 plays the role of managing the entire system, and this module will receive and manage information transferred from other modules in the traceability system. This module contains an account that is granted admin rights to participate in the Blockchain network. Module 1 has a particularly important role as it is responsible for operating the entire Blockchain network, it will receive input data from module 2 and it also performs authorization to turn stakeholders into nodes in the blockchain network. Module 2 covers supply chain stakeholders, these include mango farmers, fruit growers, packers, transporters, etc. Stakeholders provide data and participate in the blockchain network as nodes. Several shipping stakeholders can easily access and trace food. The third module is a cloud database storage system, this system will store publicly allowed information for traceability purposes, and it will allow customers to access the information obtained from stakeholders. Module 4 is responsible for the product array and the actors that affect the product such as the QR code. Module 5 manages transactions, this module provides data to help stakeholders determine the condition and quality of the product through the stages. The food supply chain is a complex system with the participation of many parties and many processes taking place, so the development of the system needs to ensure the consensus and cooperation of the parties involved in the supply chain.

Three major parts make up the model traceability: data, a blockchain system, and a QR code. The diagram (Fig. 3) demonstrates how the blockchain system contributes to tracking. Private data and public data are the two categories of data that will be entered into the Blockchain system using the on-chain algorithm. Public data encrypted to hash value will be stored in both the blockchain system and database. The hash value is stored on the Blockchain with a very high level of security due to the distributed and decentralized nature of the technology. When consumers scan the QR code on the mango, they will be provided with the necessary information. Because this information has been encrypted with a hash code and stored in the database, the system will now compare the two codes if they are the same, then this information is real and not forged, however, if there is a difference between 2 values, the information provided is fake.

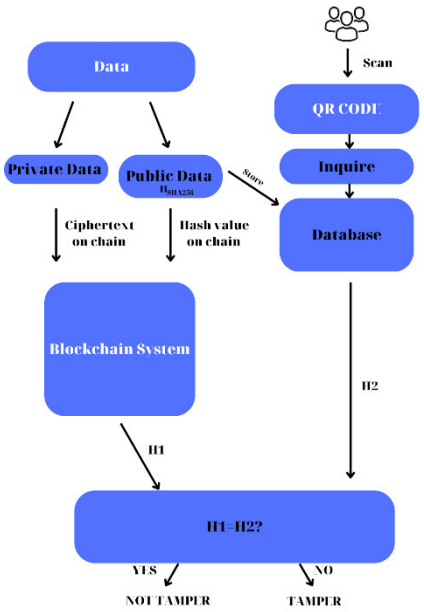

Fig. 3. Anti-tamper mechanism

We conduct research and offer standard classification based on the real test and circumstances in Vietnam. Before buying and transferring mango to the rack for classified supply market during the mango harvest stage, traders need information about the harvest date, mango variety, whether the grower complies with GLOBALGAP and VietGAP standards, etc. The supply chain's functionality depends heavily on these facts (Table 1). The mango bank sorts and

gathers information about mango quality after the mangoes arrive. Product packaging comes next after categorization. At this point, the system will be updated with information regarding packing date.

Table 1. Data in the process of classification

Actors	Composition	Information
Plants	Name	Types of Mango Fruit
	Display	Shape, Size
	Texture	Defects, impacts from insects
	Taste	Sweetness
	Weight	Weight of Fruit (Gram)
	Fruit Class	Classification based on mango fruit quality
	Fruit Class	Classification based on mango fruit quality
Standard		GLOBALGAP, VietGAP
	Harvest Date	The day when mango is picked
	Packaging Date	The day when mango is packed

Each stakeholder will be given a unique account to enter data into the system. It will be exchanged when the farmer purchases mango from the grower. In order to obtain the mango information, which includes the gardener's name, planting location, batch number, PLU code, PUC code, and resin name, the gardener must first log in to the system using the provided account. The garden will save and exit once all necessary information has been released. When the mango batch is placed on the supermarket shelf, the corresponding QR code will be generated and will remain with it. Participants who have bought mangoes from the previous party must log in and fill out all the necessary fields during the following stage. Customers can see the details they need about the products they are about to buy, enabling them to make the best possible purchase decision. This makes the data particularly useful. Organizations and stakeholders can also examine and confirm the mangoes' place of origin. The provision of data will also assist mango suppliers in analyzing the variables relating to the annual output of mangoes and in making the right choices.

4. BLOCKCHAIN SYSTEM

The traceability process is carried out using the permissioned blockchain system. Only those with permission to access the blockchain can use a permissioned blockchain. The management system, which is highly customizable, easier to change time to comply with regulations, better energy efficient, and better scalable, must first be approved by anyone who wants to verify transactions or view data online. In terms of traceability, the benefits of this model are consistent and sufficient. This study created a food traceability system based on smart contracts and solidity [13-15]. The database that stores the information provided, which receives and includes the information entered in modules 2 and 3, and the blockchain system for mango traceability will essentially be divided into these two major components (Fig. 4). In order to accomplish transparent retrieval, the hash of the order's public information is stored concurrently. Private information is encrypted and stored using the blockchain system. A QR code comprising the data kept in the database will be given to the customer. Check the hash number in this situation. The merchandise won't be tampered with if the two hash values in the database and blockchain system match. The product is forged if the two are distinct. The decentralized nature of the blockchain makes it nearly impossible to alter the data stored there, protecting the veracity of food sources. Blockhead and Blockbody are the two parts of every block in the blockchain. The block body contains information about the type, ID, information, private data key, and public data hash while the block header contains details about the block name and hash value of the preceding block.

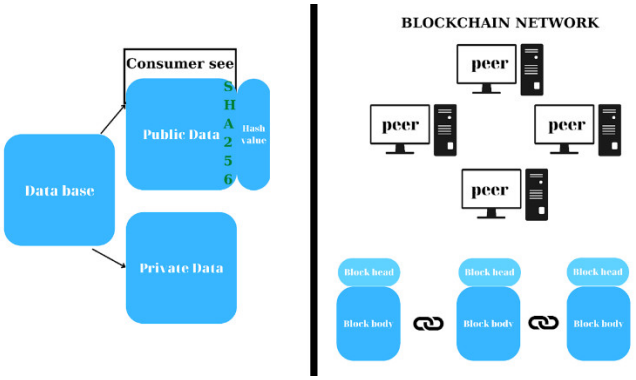

Fig. 4. Blockchain network and cloud database

SHA-256 encryption means a secure hashing algorithm for outputting encrypted data with 256 bits. This algorithm is mainly applied in the field of cryptocurrencies such as Bitcoin and has proved effective in terms of information safety and security (shown in Table 2). Applying the SHA-256 data encryption algorithm to research with the aim of increasing the performance of the entire system by reducing data storage capacity, through encrypting information, a long piece of information can be stored 1(MB can be encrypted to 256 bits). In addition, the algorithm also plays a core role in the anti-forgery model by taking advantage of the distributed and decentralized nature of the blockchain network (Fig. 5).

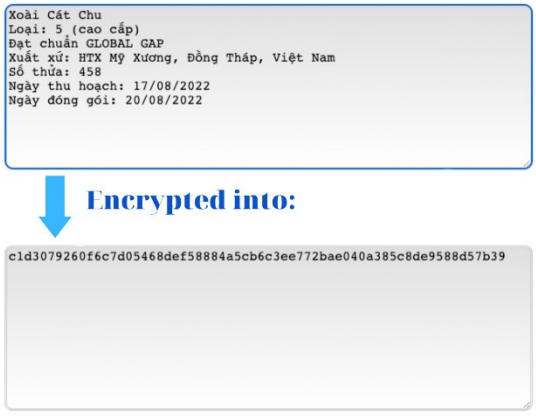

Fig. 5. Data encryption illustration

Table 2. Data is stored on the blockchain

Block number	Block Arrangement	Input Interrelationship	
		New input	Previous Block Input
Block 1	Supplier (Mango Farmers), when delivering to barn	Supplier name, planting place, Number of parcels, Harvest date	
Block 2	Barn owner, when the classification process is complete	Mango Type	Supplier name, planting place, Number of parcels, Harvest date
Block 3	Distributors, when delivering the mango fruits to distributors	Packing Date	Mango Type, Supplier name, planting place, Number of parcels, Harvest date

Data will be encrypted using the SHA 256 algorithm and simultaneously stored on two modules. Name, harvest date, and other supplier-related details will be included in Block 1 along with the supplier's plot number. Since this block is the first block, it will only contain its own hash and not the previous hash. Information about mango quality from the fruit barn will be found in block 2. The owner's personal hash and the hash of block 1 make up this block. Information about the date of packing provided by the distribution site will be included in the third block. This block will contain both its own hash and the hash of the preceding block.

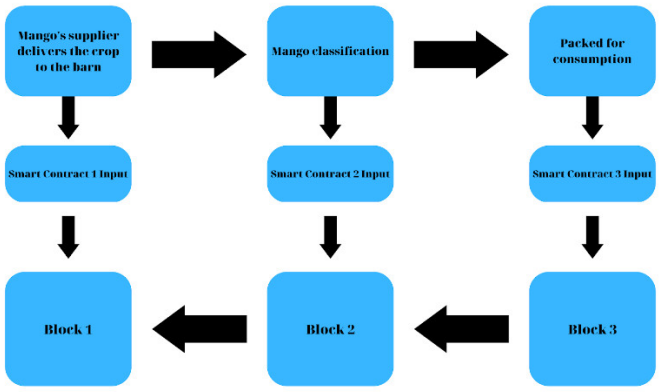

Fig. 6. Illustrated smart contract interacting with data

A smart contract is an infrastructure that appears in the blockchain network to execute control orders and regulate protocols between the participating parties, ensuring transparency without the need for 3rd party intervention. The smart contract traceability system is applied with the role of ensuring that the operation process is stable and automatic (Fig. 6). The smart contract acts as an intermediary in the interaction process between the stakeholders in the Blockchain network. Through the use of an interactive smart contract setup, data will be kept in blocks. The data will be virtually impervious to outside effects once it is entered into the blockchain system. That is also the main advantage that blockchain has for the identification and tracking of mangoes. The output component of the traceability procedure is the QR code. Each QR code belongs to a particular mango and it will be printed on the mango's label. With the use of this QR code, consumers will have a clear grasp of the mango's origin when it reaches them, boosting consumer confidence and the reputation of the Vietnamese mangoes.

After the mango has completed its journey through the automatic sorter, the sorter will record and save its length, width, volume, density, weight, class, and sweetness in the database. Based on the data collected from the mango sorting machine and the US commodity import requirements from the US Department of Agriculture (USDA) for Vietnamese mangoes, we determined that the QR code would contain the necessary information in Table 3.

Table 3. Data during traceability

Fruit information	Name of produce	**Storage information**	Name of company
	Net weight		Address
	Class		Storage temperature
	Standard	**Export information**	Name of company
	Expiry date		Address
	Farm address		Destination port
	Name of trader		Lot number
	Address		Billing lading code
	Packing date		Container code
	Price Look-up (PLU)		Seal code
	Production Unit Code (PUC)	**Certificates**	VietGAP/GlobalGAP Certificate
Packing information	Treatment Facility Code (TFC)		Phytosanitary Certificate
	Treatment Identification Number (TIN)		
	Packing House Code (PHC)		

5. RESULTS AND DISCUSSION

Following the research and testing phases, the mango evaluation and classification process is divided into five stages: Before being moved to the feed conveyor, where they are successively provided to the image processing chamber mounted on a roller conveyor, mangoes are washed and sprayed as necessary. When the mango enters the image processing chamber - stage 2, it is continuously rolled on the conveyor belt so that the camera can capture all sides of the mango, while the captured color images are processed to determine the defects in the fruit surface (blemish, bruise, black spot, wilting) and mango fruit size (length, width, volume, density). Mangoes that meet the shape and size requirements will continue to enter stage 3 labeling. To save accurate information for each mango and at the end of the cycle, the mango can be dropped on the

corresponding conveyor, then when passing through the image processing chamber, the system will number each mango, each number corresponds to a QR code, which is printed on the label of the mango, and this label is affixed to the corresponding mango. The tray containing the mango is brought to the loadcell as the process advances to stage 4. The loadcell will determine and return the actual weight of the mango and transmit a signal to the controller. Then, at stage 5, upon receiving information, the controller compares the existing data with the data on the established classification standards (VietGAP, GlobalGAP) before transmitting signals to the classification structure. Mangoes are divided into four types (maximum of five categories): type 1 is the highest quality, type 4 is a rejected product due to unsatisfactory quality, and type 5 is a supplement that can be used for a variety of other agricultural products or other classification standards.

The traceability system was created to ensure transparency about the origin of each mango, allowing consumers to feel confident in selecting and using the product. After completing the image processing process in the processing chamber, each mango will be assigned a different order number to make later evaluation and classification easier and more accurate. Based on this, each mango will go through the labeling step after assigning numbers to each mango. Each mango number will correspond to a QR code supplied by the server, which will then be printed on the label and attached to the corresponding mango. As with previous manual processes, the worker will label the mango after it has been sorted. The entire process was automated in this study. This reduces the worker's use of excessive force when labeling the mango, resulting in a change in the type of fruit. On the other hand, because the QR code for each of our mangoes includes the weight, precise manual gluing is difficult. After the mango is assigned a number in the image processing chamber, the server generates QR codes corresponding to each number. Based on the number of each fruit, the information about the size, weight, and type will be saved in the QR code after each implementation. When a customer scans the QR code on the mango label, they will be directed to a page with fruit-specific information. In addition to the fundamental information (weight, expiration date, country of origin, etc.), consumers are informed of the mango's export information and its journey from the time it is harvested to the time it reaches their hands.

The website is designed as shown in Fig. 7, with information displayed on a single page and organized in the order of the mango's path to assist consumers in tracking and looking up information in a quick and easy manner.

To increase consumers' trust and confidence in the product, we include a confirmation icon on each page. Here, users can determine whether the information displayed on-screen has been altered or fabricated. When the user presses this button, the data on the screen is immediately compared to the data on the server. If the codes match, the consumer's screen will be framed in green and a safety message will appear like as Fig. 8(a). When the server detects that the codes do not match, the consumer's screen is immediately covered by a red frame, indicating that the data has been tampered with Fig. 8(b).

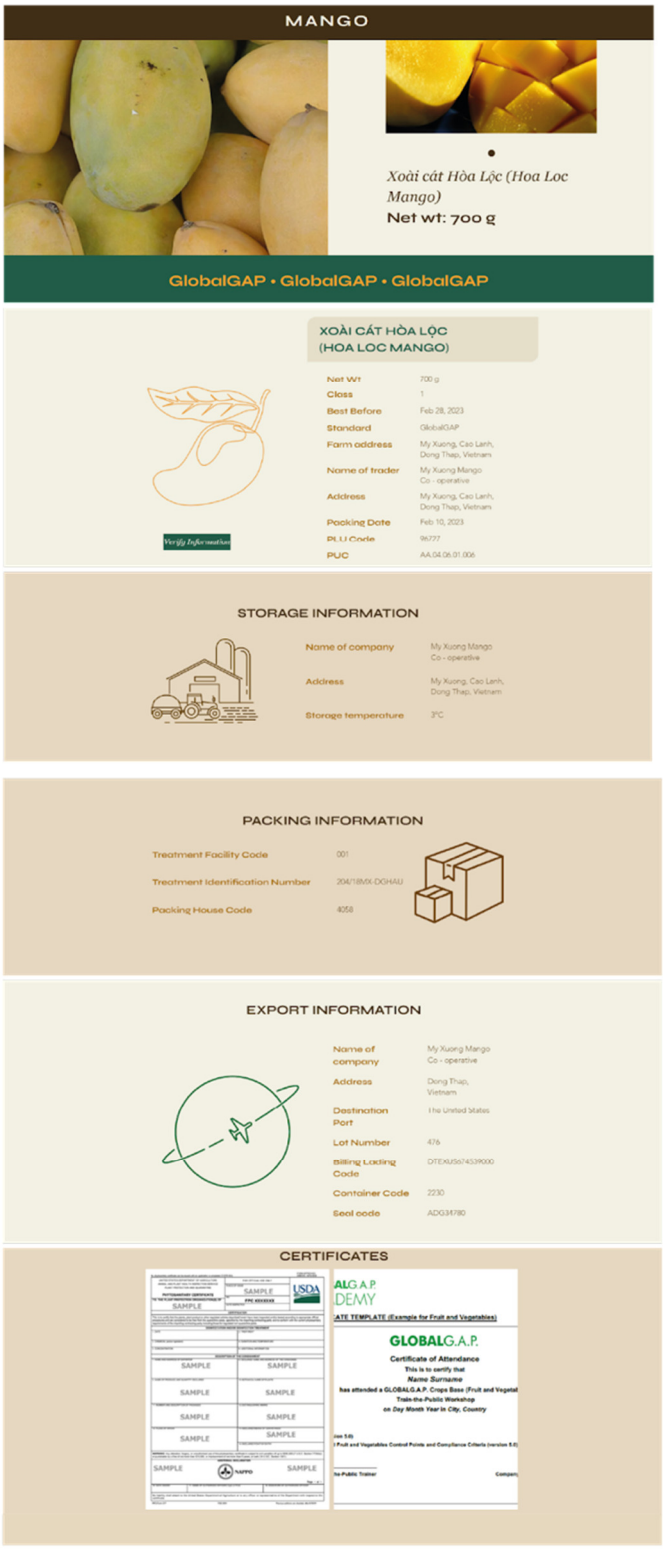

Fig. 7. Traceability page interface for consumers

a)

b)

Fig. 8. a) Interface when information is safe, b) Interface when information has tampered

6. CONCLUSIONS

This study has developed and implemented a high-precision and high-productivity process for the automatic classification of mangoes using computer vision and artificial intelligence. This method can classify up to three tons of mangoes per hour, based on their color, size, and weight. By utilizing image processing and machine vision technology, the study has analyzed various factors affecting the accuracy of image data collection and the capabilities and efficacy of artificial intelligence in mango classification. The study has also proposed an information retrieval method that aims to improve the transparency and authenticity of Vietnamese mangoes. This method utilizes blockchain technology, which is a decentralized and secure way of storing and sharing data, by using blockchain, the method can ensure the immutability and traceability of information related to Vietnamese mangoes. Future research will deepen and develop the blockchain-based agricultural product traceability model while also conducting experiments to evaluate the model's efficacy. Further research will be done on the use of Internet of Things technology to create equipment for tracking the production and delivery of agricultural goods. The research will be expanded to include other agricultural products in addition to mangoes in order to increase the efficiency and transparency of the supply chain as well as the level of agricultural products in Vietnam. The objective of sustainable agricultural development will be furthered as a result.

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