LOW-COST IoT AND WEB APPLICATION SOLUTION WITH NETWORK SECURITY FOR FOOD SAFETY IN VIETNAM

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Abstract: Food safety is a scientific field that involves various practices and analyses at every stage of the food chain. As we have faced several food crises that heavily impacted human health, food safety should be widely adopted to prevent dangerous wellness risks. With the help of the Internet of Things (IoT) and web applications, food quality can be monitored at any point in the supply chain. Moreover, it is now possible to interconnect food producers, transporters, and retailers. Since the quality of food products must be ensured throughout the supply chain, an IoT based low-cost solution and web applications for real-time food tracking and monitoring are presented. In order to enhance protection, a HTTPS connection between the hardware and software will be established and SQL injection is prevented.

Keywords: Food safety, IoT, network security, Vietnam, food production, VietGap.

I. INTRODUCTION

Looking at the food history, the world as we know today has advanced through hunter-gatherer, agricultural and industrial phases to the stage of goods suppliers and services. How far food manufacturing and supply chains have progressed throughout the years is remarkable. This field of study that is dedicated to the subject of food is defined as food science. It consists of engineering, nutrition, analytical chemistry, biotechnology, quality supervision, and food safety administration. The food safety system comprises food production, processing, packaging, distribution or transportation, depository, and preparation. Each stage of the food chain ought to be executed and audited thoroughly to complement food safety.

Regardless of what kind of food products are being produced and shipped, it is required to adopt multiple procedures from the point of origin to the point of use for ensuring safe foodstuffs shipment and avoiding any contamination. By applying new technologies and techniques like IoT, it is now possible to connect food makers, transportation, and retail enterprises with each other. Generally, RFID technology is regarded as a critical facilitator of the IoT due to its capability to trace a large number of uniquely classified items with cost-effective labels. RFID electronic tags keep standard and interoperability-utilized IoT information, which can be accessed by a central information system via a wireless communication network for object identification [1]. Fadable ink is also widely used in printing labels on food packages for time-temperature control and indicating freshness. The principle of the fadable ink is straightforward; as time passes, the ink will lose its color stating that the food is no longer fresh [2]. Big data can provide up-to-date and innovative solutions to food safety problems. It yields a technological breakthrough that can build up suitable measures and improve the system sustainably [3]. Another feasible solution in food monitoring is to use wireless sensing technology for building an IoT architecture. If there are any problems related to the foodstuffs like temperature, humidity, or air pressure, the wireless tracking system will send alarms to computers, smart-phones, or tablets. This helps speeding up time-consuming and pricey HACCP processes and reports. The essential advantage of this method is its ability to collect data continuously and automatically. It can respond swiftly and can be located almost anywhere.

The communication between the hardware and software will be over HTTPS. It stands for HTTP over SSL or HTTP Secure, which is the use of Secure Socket Layer (SSL) or Transport Layer Security (TLS) [4] as a sublayer under usual HTTP application layering [5–6] . That means the data that is sent back and forth between the device and the server is encrypted and secured. HTTPS websites require a certificate, which is issued by a certification authority (CA). When an HTTPS request to a website is made, the browser will check and validate the certificate. A secure connection can be started only when it is verified that the certificate is indeed issued by a credible CA.

To communicate with the server, the web application uses SQL language. SQL, which stands for "Structured Query Language," is the most common standardized language used to access databases [7]. Since SQL is used to interact with the database, the system must be protected from SQL injection. SQL injection is a web security vulnerability that allows an attacker to interfere with the queries that an application makes to its database. A web page or web application that has an SQL Injection vulnerability uses such user input directly in an SQL query. The attacker can create input content. Such content is often called a malicious payload and is a crucial part of the attack. After the attacker sends this content, malicious SQL commands are executed in the database, and all the hidden and confident information is exposed [8]. To prevent SQL injection, each input value is going through a validation stage and being parametrized. And all database error is hidden on production sites since database error can be used

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with SQL injection to gain information about the database [9].

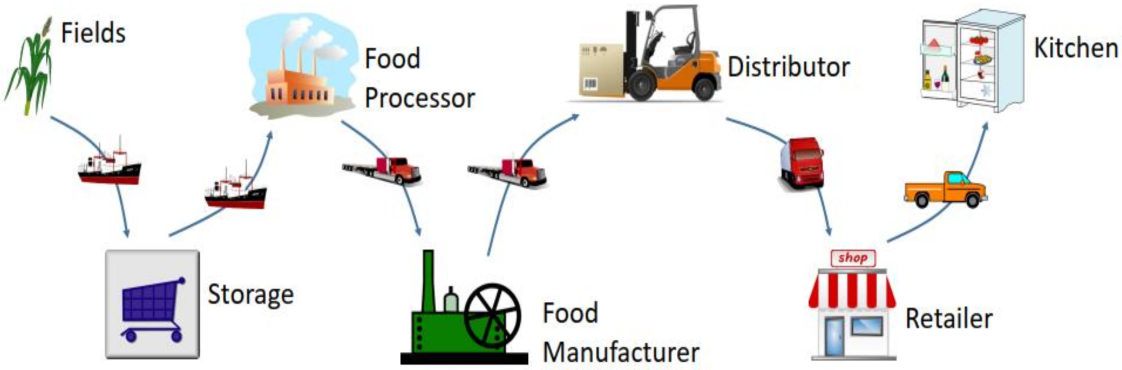

Figure 1. An example of the food supply chain.

II. A PROPOSITION OF LOW COST IoT AND WEB APPLICATION SOLUTION

A system architecture will be proposed to examine the environmental conditions under which the food items are stored and transported. The proposed solution measures and records the values of temperature, humidity, dust density, and location of the encircling environment. The reason those numbers are taken into account is they directly affect the nutritional values of food items. The collected data are then compared to standard values serving as threshold values for respective parameters. They can also be plotted as graphs for easy observing and analyzing. In case any reading goes beyond the preset threshold, the administrators will be notified immediately. With a GPS module, users can be alerted with the location of the shipment should an emergency happen. The introduced solution is designed to cover two elements, which are traceability and monitoring. The first one provides information on the product that is being monitored. The other presents the state of that product and its environmental conditions. The primary responsibility of this food traceability and monitoring system is to provide information and record relevant data of a unit or a group of products through all steps along the supply chain.

To sum up, a module that consists of a group of sensors will be designed and constructed. The types of sensors are temperature, humidity, pressure, dust level, and GPS. Then, a database is established and put online. The sensor module is programmed to periodically collect and send data to that designated database and ThingSpeak. For convenient interaction, a website will be created. Sensors data, along with food transportation and delivery information are shown on the site.

A web server is used for the storage of data values sensed in real-time and analysis of results. The database can be accessed remotely with laptops or mobile phones. The objective is to develop a universal platform that can be interfaced with third-party applications to enable easy access for all the collaborators involved in the processes.

The front-end of all the web pages is created by the combination of Bulma framework and JavaScript coding languages. PHP, MySQL, and SQL languages are used to develop the back-end or the brain of the project.

TABLE I
SENSORS USED IN THE SYSTEM

Sensors	**Specifications**
Temperature sensor	BME280
Humidity sensor	BME280
Air pressure sensor	BME280
Dust sensor	PM2.5 GP2Y1010AU0F
GPS module	GY-NEO6MV2

III. IMPLEMENTATION OF THE IoT PART

This sensor subsystem includes the sensing components that continuously check the temperature, humidity, pressure, dust density, and GPS location. Not only do they monitor, but they also send those values to the processing subsystem at regular intervals.

Data from the sensors is then collected and analyzed by a processing subsystem. These data are compared with their respective threshold values. If abnormality happens, a notification will be sent via a communication system. The implementation of the processing subsystem is based on the ESP8266 Node MCU, which is a low-cost open-source IoT platform. As it is engineered for IoT applications, mobile devices, and wearable electronics, the chip possesses low power consumption. The power-saving design presents three modes of operation: active mode, sleep mode, and deep sleep mode. These features allow battery-powered modules to run longer. It initially included firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems and hardware which is based on the ESP-12 module. This ESP8266 module allows microcontrollers to connect to wireless networks and establish a TCP/IP connection based on the Hayes commands. The ESP8266 chip is capable of operating consistently in industrial environments due to its broad functioning temperature range. With highly-integrated on-chip features and minimal quantity of external discrete components, the chip provides reliability, compactness, and power [10].

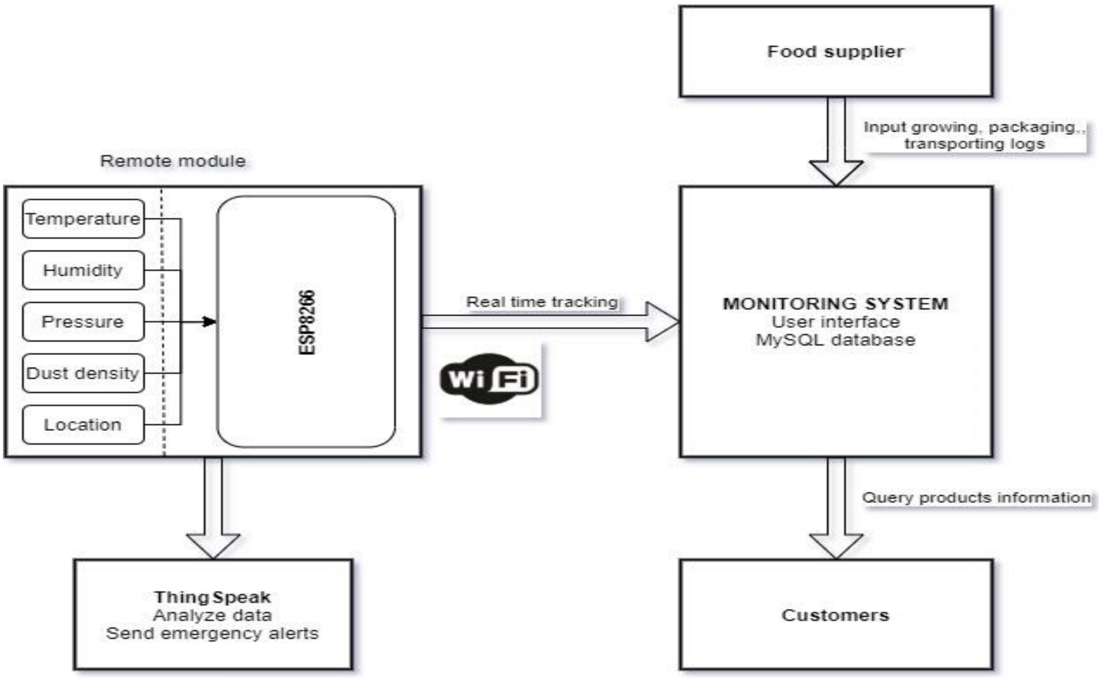

Figure 2. The system diagram.

A case is designed and will be 3-D printed to contain the sensors, battery, and PCB. By using Fusion 360, the module case is modeled and extracted to be 3-D printed. The next step is to program the board with Arduino Software. For setting a connection over HTTPS, the proposed method is to extract the fingerprint of a site's certificate and store it in the code. A fingerprint is a hash function of the certificate. Whenever the module communicates with the website, it checks the site's fingerprint to see if it matches the saved one. If it does, the module knows that the website can be trusted. The BearSSL library is used to execute all cryptography and TLS operations. Note that the ESP8266 has to be updated to the latest version in order to operate with the BearSSL library properly [11]. At the point of writing, the used version is 2.7.4. Boards with lower versions have problems executing the sketch. The final stage is to design and make a printed circuit board (PCB). EAGLE will be used for this task.

IV. IMPLEMENTATION OF THE WEB APPLICATION PART

The front-end of all the web pages is created by the combination of Bulma framework and JavaScript coding languages. PHP, MySQL, and SQL languages are used to develop the back-end or the brain of the project. The web system is divided into 2 different parts.

- The system before the user logged in. This system consists of the main page, which is the home page, the login modal, the sign-in modal, and the product information searching page.

- The system after the user has logged in. This part is used for the supplier to update the information about the quality of the food, such as chemicals, fertilizers used, the time when these chemicals are used, and so forth. The manufacturer also used this part to track and monitor all the present indicators like temperature, humidity, pressure, and air quality during production, transportation, and distribution stages.

To monitor and control the quality of food, six pages with different functions and purposes are created. Firstly, the Adding Lot ID and Barcode generator page is designed to generate and insert into the database the Lot ID (Lot ID is the number used to identify the products, and the manufacturer defines it). Also, a barcode will be generated based on the Lot ID. After being created, the Lot ID is sent to the suppliers. Secondly, For easily monitoring the chemicals, fertilizers used for food products before transfer to the manufacturers, the supplier updates this information on the Food growth information page daily or weekly. This page captures all the data related to the cultivation stage such as chemicals, fertilizers used, how much they are used, and so forth. Thirdly, the food is transferred to the factory and processed, the manufacturer will update all the information such as Lot id of the product, product types, number of products in one lot, etc, on the Export information page before the products are transferred and distributed. Fourthly, during the transportation phase, the temperature, humidity, pressure, air quality, and GPS location of the delivery vehicles are sent to the Sensor data page for quality' monitor. These sensor's data can also download and export as CSV files for thorough analysis.

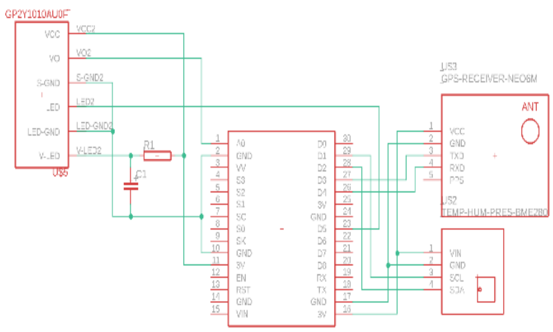

Figure 4. The complete schematic.

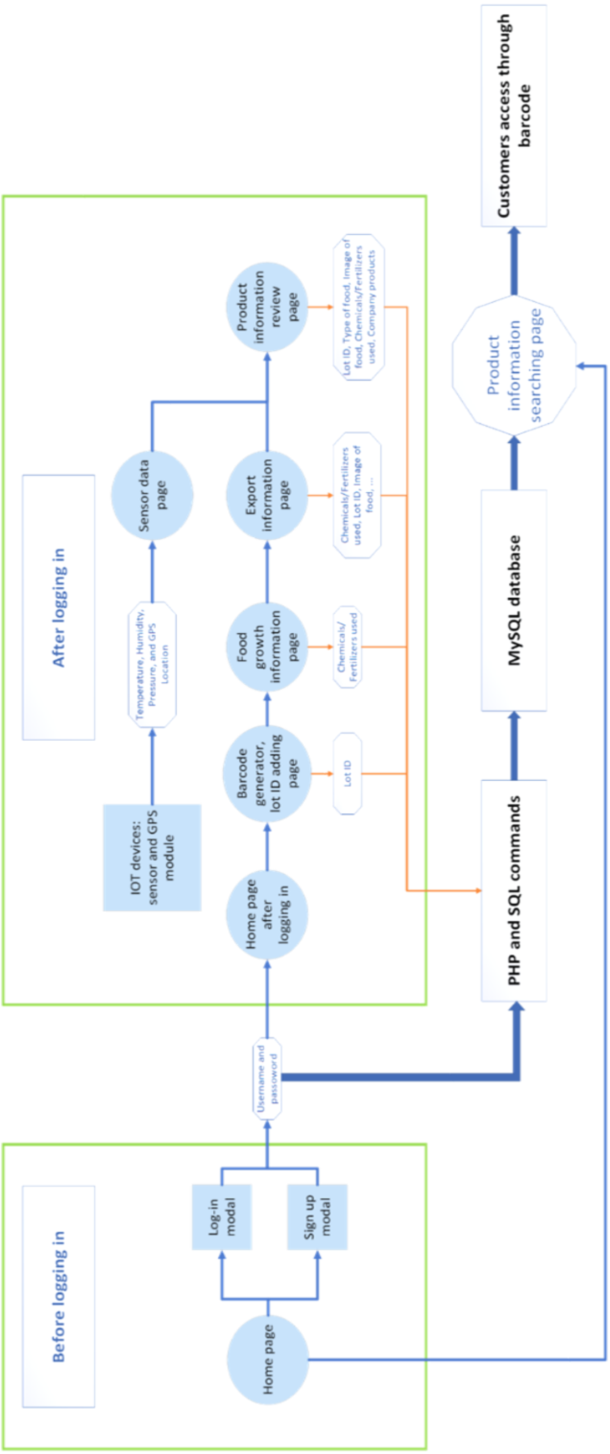

Figure 3. Work-flow of the system.

Fifthly, all the data related to the quality, safety factors are reviewed on the Products information review page. After being checked and analyzed, the data is then inserted into a new database. This database is developed to store all the information about the products. Thus, when the users scan the barcode label, all the info as the Lot ID, name of products, the chemicals, fertilizer used, the company process, and delivery of the products are shown. Finally, The Products information searching page is created to help the customers to check the info related to the quality and safety of the products. The customers can use the barcode scanner to scan for the products ID, which is labeled on the packaging of the products. After scanning, all the data describes Lot ID, the name of products, fertilized and chemicals used, and so forth, is shown.

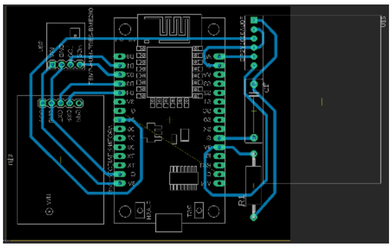

Figure 5. The complete board layout.

V. TESTING AND MEASUREMENT

A PCB is made based on the EAGLE design as shown in Fig. 6 and 7. The case is 3-D printed out of the designed sketch. It contains the PCB, sensors, and battery as shown in Fig. 8, 9, and 10.

Once the module is powered, it begins to get data and post them to the database. The optimum carrying temperature of durian is between 13 and 15 Celsius degrees, and of jackfruit is between 2 and 12 Celsius degrees as shown in Fig. 11. In addition, their optimum carrying humidity is between 85 and 95 percentage. Whenever there is a breach of environment parameters, administrators are notified immediately via mail.

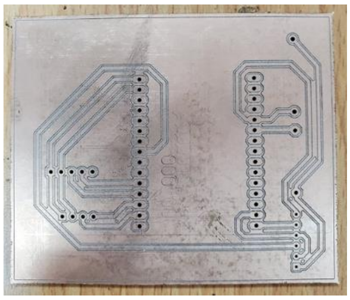

Figure 6. The complete PCB.

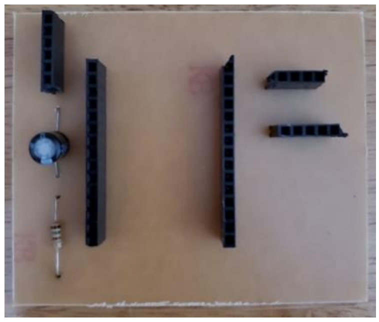

Figure 7. The PCB with soldered pin header.

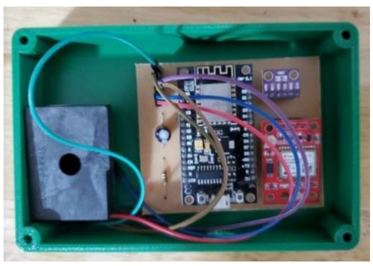

Figure 8. Bottom half of the modul.

Figure 9. Top half of the module.

Figure 10. The assembled module.

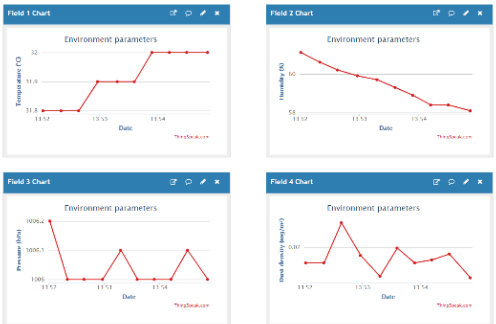

Figure 11. ThingSpeak uploaded data.

The accuracy of the GPS module is up to 2.5m, which is acceptable for tracking vehicles that travel over significant distances. Although the stock antenna coming with the GPS module works well, it is quite short and unstable sometimes. For improved performance, it could be upgraded with a better signal detection one. Note that when using a GPS module, the antenna should always be pointed upwards. Furthermore, avoid putting it in a metal case or tall buildings as they will significantly weaken GPS signals. When powered on, it may take up to one minute for the module to establish a fix to satellites. The front-end of six pages is created using the Bulma framework.

VI. CONCLUSION

Food safety and quality is a significant problem that raises concern across the community, not only in Vietnam but also around the world. Food poisoning, or also called as food-borne illness, can occur at any phase of the supply chain. Standards and rules are created to prevent the food from being contaminated and ensuring safety as well as quality. Therefore, having a system that enables the ability of tracking, tracing, monitoring, and ensuring the quality during the whole food chain process is crucial. In this paper, standard and rules, existing systems, problem statements, and novel techniques are presented. IoT devices combined with web applications will create a fast, efficient, and effective communication environment that helps to ensure the food quality throughout the supply chain. Web application and IoT devices provide remarkable, and extraordinary opportunities for food tracking and tracing with the combination of smart devices, smart tags, sensors, and real-time data monitoring. Hence, the system also helps to gain trust from customers by ensuring the food quality throughout the food supply chain. Moreover, this paper presents and demonstrates novel techniques and proposes an IoT system and web application for monitoring and tracing food safety and quality. The proposed system has advantages of low cost, small size, portable flexibility, real-time access, and productive communication environment. Future research will be focused on interconnecting vehicles, sensors, and mobile devices into a global Internet of Vehicles network, which will enable a variety of services to be brought to vehicular and transportation systems, and to people in and around vehicle.

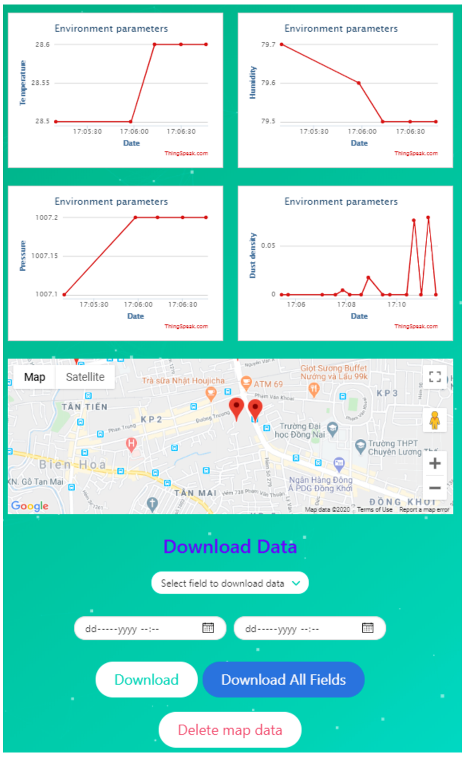

Figure 12. Sensor data page.

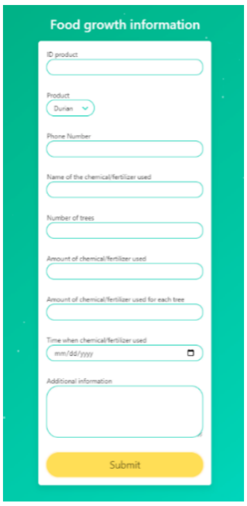

Figure 13. Food growth information page.

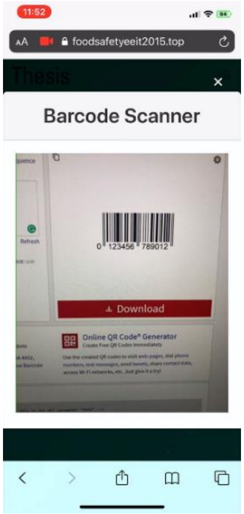

Figure 14. The barcode scanner.

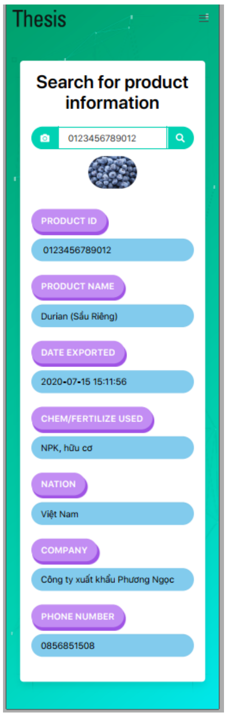

Figure 15. Data shown after scanning barcode.

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GIẢI PHÁP ỨNG DỤNG IoT VÀ WEB CHI PHÍ THẤP VỚI AN NINH MẠNG CHO AN TOÀN THỰC PHẨM TẠI VIỆT NAM

Tóm tắt: An toàn thực phẩm là một lĩnh vực khoa học bao gồm thực hành và phân tích khác nhau ở mọi giai đoạn của chuỗi thực phẩm. Vì chúng ta đã phải đối mặt với cuộc khủng hoảng lương thực ảnh hưởng nặng nề đến sức khỏe con người, nên an toàn thực phẩm cần được áp dụng rộng rãi để ngăn ngừa những nguy cơ cho sức khỏe. Với sự trợ giúp của Internet vạn vật (IoT) và các ứng dụng web, chất lượng thực phẩm có thể được giám sát tại bất kỳ điểm nào trong chuỗi cung ứng. Hơn nữa, hiện nay có thể kết nối các nhà sản xuất, vận chuyển và bán lẻ thực phẩm với nhau. Vì chất lượng của các sản phẩm thực phẩm phải được đảm bảo trong toàn bộ chuỗi cung ứng, nên một giải pháp chi phí thấp dựa trên IoT và các ứng dụng web để theo dõi và giám sát thực phẩm theo thời gian thực được trình bày trong bài báo này. Để tăng cường khả năng bảo vệ, kết nối HTTPS giữa phần cứng và phần mềm được thiết lập và SQL injection bị ngăn chặn.

Từ khóa: An toàn thực phẩm, IoT, an ninh mạng, Việt Nam, sản xuất thực phẩm, VietGap.

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