# INGREDIENTS TRACING USING BLOCKCHAIN FOR RAPID PRODUCT RECALL

BY

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A REPORT

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BACHELOR OF COMPUTER SCIENCE (HONOURS)

Faculty of Information and Communication Technology

(Kampar Campus)

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# REPORT STATUS DECLARATION FORM

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# FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

## UNIVERSITI TUNKU ABDUL RAHMAN

Date:＿＿28 April 2023＿＿

### SUBMISSION OF FINAL YEAR PROJECT

It is hereby certified that ＿＿＿＿＿***LEOW PEI YI***＿＿＿＿＿＿＿＿＿＿＿ (ID No: ＿*19ACB03957*＿) has completed this final year projectentitled "＿＿＿＿INGREDIENTS TRACING USING BLOCKCHAIN FOR RAPID PRODUCT RECALL＿＿＿＿＿_" under the supervision ＿＿＿Dr. Aun Yichiet＿＿＿(Supervisor) from the Department of＿＿＿Computer and Communication Technology＿＿, Faculty of＿＿＿Information and Communication Technology＿＿＿＿＿.

I understand that University will upload softcopy of my final year project in pdf format into UTAR Institutional Repository, which may be made accessible to UTAR community and public.

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*puy*

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# DECLARATION OF ORIGINALITY

I declare that this report entitled "**INGREDIENTS TRACING USING BLOCKCHAIN FOR RAPID PRODUCT RECALL**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.


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# ABSTRACT

Food security plays an important role in the food supply chain because contaminated food products may contain viruses that can threaten human health. The manufacturer and government noticed the consumers' concern towards the food's quality. Hence, in the event of food contamination, product recall must be conducted rapidly to minimise the likelihood of contaminated products reaching consumers. However, it is difficult and time-consuming for the manufacturer to recall the contaminated products that have been distributed around the world or used by other manufacturers to produce other products. This induces a health risk as some consumers have consumed the contaminated product before they notice the recall announcement on the news. Therefore, this project aims to develop an application system of ingredient tracing using blockchain to ensure that the manufacturer can rapidly recall contaminated products from the market and consumers while the consumer can check the status of the product through a QR code. In this project, blockchain technology is used to ensure that all the product information is transparent and immutable. The main focuses of this project are to develop a decentralized application to allow the manufacturer to add product information, trace the ingredient status, set predefined rules using the smart contract, generate the QR code for each product batch, and alert the merchants and consumers who have received or registered the contaminated product while allowing the consumer to view the product information through the QR code. In conclusion, this project will provide the necessary information to the consumer to assist the manufacturer to recall the contaminated product from the consumer within a short time.

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# LIST OF SYMBOLS

Ω               Ohm (resistance)
*%*             Percentage

# LIST OF ABBREVIATIONS

| | |
|---|---|
| *QR* | Quick Response |
| *ETO* | Ethylene Oxide |
| *HACCP* | Hazard Analysis Critical Control Point |
| *IoT* | Internet of Things |
| *IPFS* | InterPlanetary File System |
| *OS* | Operating System |
| *EVM* | Ethereum Virtual Machine |
| *NFC* | Near Field Communication |
| *PO* | Purchase Order |
| *SDLC* | Software Development Life Cycle |
| *ERD* | Entity Relationship Diagram |
| *DOUT* | Data Output |
| *SCK* | Serial Clock |
| *IP* | Internet Protocol |
| *AI* | Artificial Intelligence |

# CHAPTER 1
# Introduction

This chapter defines the problem statement of this project to ensure the proposed system is developed with the intent to enhance the existing system while the motivation is discussed to justify the existence of this proposed system. This chapter will also describe the project scope to highlight the functionality of the proposed system while the objective will mention the estimated goal to be achieved from this project. Then, the contribution will describe how this project benefits society while the background information will be described to provide a brief overview and define a few key terms related to the proposed project.

## 1.1    Problem Statement and Motivation

In the traditional tracing system, there is the existence of a tracing problem when multiple raw materials combine into a new product. For example, the dairy industry found out that one of the refrigerators is not working properly and the batch of milk that was stored in this refrigerator previously has been distributed to the customer. The bad case is that the contaminated milk has been used by other food industries to process other food products. The manufacturer may face difficulties in recalling all the contaminated products from the market as the contaminated milk might be processed by more than one food industry. In the dairy industry, the temperature used to store the dairy products is important because the inappropriate temperature of the refrigerator would spoil the dairy product and cause foodborne illness. Therefore, the system application of ingredient tracing using blockchain for rapid product recall will be developed to store every single piece of information about the product as well as the ingredients used in the blockchain. The information will be stored in the blocks and linked to a chain to ensure that if there is an issue exists in one of the ingredients, the manufacturer can trace their product by identifying which batch of products contained this particular ingredient and terminate the distribution of the contaminated product. This would increase the efficiency of the product recall as all the consumers and merchants can scan the Quick Response (QR) code on the food package to check if the bought item is being affected since the information of the ingredient used is transparent to the public. At the same time, the manufacturer can immediately notify the merchant who has purchased and received the contaminated product to stop distributing the contaminated product to the market.

Another problem is the information is not transparent which required the authorities to perform product testing on all imported products to ensure that the product quality is met. As mentioned in [1], the Chinese milk sandal in the year 2008 involve the usage of melamine in the milk-containing product. This action killed six infants, struggled 14 infants from kidney stones, and caused 300, 000 infants and children to have problems in the kidney and urinary tract. The core function of melamine is to make plastics, kitchenware, laminates, etc. However, melamine is added to infant formula to boost the protein content and it caused illness in infants. This has raised the concern of society toward food safety since the products have been exported to many countries such as Malaysia, Hong Kong, Taiwan, etc. Therefore, some countries conduct testing on all China products while some countries perform testing on suspicious or involved products. Hence, the motivation of this project is to reduce the risk of importing low-quality products from foreign countries by viewing the ingredients used in the product and quickly recalling the batch of products once the suspicious ingredient was found. The authority just needs to perform random testing on the imported products instead of performing testing on all the imported products.

Moreover, the consumer who is unclear about the criteria mentioned in the newspaper or news would throw away all the products from that particular manufacturer as they do not know whether the other products are having issues or not. Therefore, this project is to ensure that the consumer can get instant results on the status of the product using blockchain technology to minimise food wastage. The information about food is not hidden from the consumer or the public because blockchain technology is a decentralised digital ledger that distributes the data among multiple nodes that are located at various locations. The transparency of the product information increases the trust of the consumer towards the manufacturer since the product information from the ingredient collection phase until the distribution phase is transparent to the consumer.

Lastly, lack of tracing when distribution to all merchants from all around the world. According to the reported case in [2], the Health director-general of Malaysia, Tan Sri Dr Noor Hisham Abdullah has made an announcement to recall all the Haagen-Darz vanilla flavour ice creams that are imported from France and contain vanilla extract from Madagascar from the consumer because European Union Rapid Alerts Systems for Food and Feed has found out that the levels of Ethylene Oxide (ETO) have exceeded the acceptable level. Besides, six types of

instant noodles manufactured by the Mie Sedaap are also being recalled due to the existence of the ETO in the chilli powder [3]. ETO is a chemical compound that can be used for making pesticides and detergents. Therefore, the Health Ministry is concerned about the health of the public since long-term exposure to ETO could put human health in danger. However, the contaminated products have been distributed to all states around Malaysia as well as all around the world. Hence, the motivation of this project is to assist with the task of the Hazard Analysis Critical Control Point (HACCP). HACCP is an internationally recognized system that is responsible for food safety. With the help of a smart contract, any abnormal data will be mentioned in the blockchain transaction to alert the manufacturer. The abnormal data could be the overuse of certain ingredients in a food, overheating or supercooling of a product, etc. Therefore, when the value retrieved from the Internet of Things (IoT) is not within the scope of the HACCP regulations, the smart contract will reject the product by updating the status to the blockchain since the smart contract has zero tolerance for outliers. Thus, the consumers can file reports and return the contaminated product with valid evidence that the items they purchased are not in good condition.

In short, the problem faced by the manufacturer, merchant, and consumer will be solved by implementing blockchain technology in this project so that the ingredients used in a product are traceable and the contaminated product can be recalled within a short period of time.

## 1.2 Objectives

The main objectives of this project are listed as follows:

1. To develop a blockchain-based ingredient tracing system for rapid recall of food hazards.
2. To visualize the blockchain data for consumers to view the supply chain information.
3. To develop the smart contract on the blockchain-based system to ensure that the proposed system has zero tolerance for outliers.
4. To integrate the IoT device and dashboard to enable automation of readings entry and real-time monitoring.

## 1.3    Project Scope and Direction

The scopes of this project are listed as follows:

- Develop a decentralized application to record the details and conditions of the ingredients and products throughout the food supply chain using blockchain
  - This includes three processes: ingredient collection, production, and distribution.
  - The manufacturer is allowed to upload the certificate to the InterPlanetary File System (IPFS) as proof of certification.
  - The manufacturer is allowed to add the batch and generate a QR code if all the processing steps have met the predefined standards and all the ingredients used are free from contamination.


- Connect the IoT devices with Raspberry Pi 4B to simulate real industry environments
  - As a proof of concept, two sensors will be used namely DHT22 and HX711 amplifier with 10kg load cell.
  - The readings of the IoT device such as temperature (DHT22), humidity (DHT22), and weight (HX711 amplifier with 10kg load cell) will be pushed to Ubidot.
  - Ubidot will generate a dashboard and embed it in the Flutter application that can be used by the manufacturer for monitoring.
  - The smart contract will auto-reject the food product if the real-time data retrieved from the IoT devices are not within the acceptable range approved by an internationally recognised system such as HACCP.


- Develop a decentralized application to generate a QR code that allows the consumers to check for the full details of the products
  - The system will generate QR codes containing information about the product and ingredients involved as well as the product's status.
  - The consumer is able to determine whether the product is contaminated by using the mobile phone to scan the QR code.

- Develop a mobile-based alerting system to alert the consumer and merchant when the product is contaminated
    - The system will send an email to the merchants when the contamination issue is found so that the merchant can terminate the sales of that product.
    - This system will also send an email to the consumer when any of their registered product is contaminated.
    - The system will send an email to the manufacturer regarding the reason for rejection.

## 1.4     Contributions

As mentioned in the problem statement, one of the challenges in the food supply chain is the distribution of contaminated products in the market. In the event of food contamination, the related parties would require more effort and time to recall all the contaminated products from the market and consumers. Hence, this project would implement an ingredient tracing system using blockchain technology to help society to identify the contaminated product. By having this ingredient tracing system, the consumers can check the status of a product themselves by scanning the product's QR code using their mobile devices. This will increase the efficiency of the product recall as many of the consumers are unclear about the descriptions that are mentioned in the newspaper or news. Besides that, this project also eases the task of the manufacturer and related parties to recall the contaminated product since the consumer can check the status of the products by themselves.

On the other hand, this project uses a smart contract to set a predefined condition in the blockchain to alert the manufacturer if any of the actual values are not within the acceptable range. This is to stop the manufacturer from distributing the batch of contaminated products to the market. The smart contract is implemented since it will just follow the condition stated in the code and update the status accordingly because the smart contract will not tolerate outliers. Due to the immutability feature of the blockchain, no one dares to tamper with the information of the product and data integrity can be ensured since the hash of the new block will always compare with the hash of the previous block. Therefore, if there is any modification in any block, the blockchain will detect it and notify the manufacturer to conduct the investigation. Hence, this will also help the manufacturer to detect the bad actor who is trying to modify the data without permission. This project will also increase the trust of the consumer as there is no

way for the manufacturer or merchant to modify the product label since all the ingredients used will have a unique address attached to the chain of the product.

In this project, IoT integration contributed significantly to improving product traceability. The IoT devices such as DHT22 and the HX711 amplifier with 10kg load cell have the capability to retrieve real-time data on product quality parameters, such as temperature and weight, thereby reducing the possibility of human error in manual data entry. The real-time data provided by the IoT devices can be securely stored in the blockchain, creating an immutable and transparent system that allows manufacturers to track product movement throughout the supply chain. The use of IoT in this project reduces the need for manual monitoring and manpower, resulting in efficient and cost-effective product recall management.

## 1.5    Background Information

The author of article [4] mentioned that food traceability refers to the action of tracking and connecting the movement of the food product and all of its ingredients throughout the production, processing, and distribution phases in the food supply chain. Food traceability is applicable in both backward and forward movements since it's crucial to understand where the food went after completing each phase as well as where it came from and where it has been. Food traceability has the ability to assist the authorised person to locate the origin of the contamination and respond to it effectively to ensure the contaminated products can be returned and terminated from distribution so that the outbreaks of foodborne illness can be minimised.

According to [5], there is a batch of eggs imported from Linggi Agriculture, Malaysia has been returned by Singapore after it had been detected that the eggs were contaminated with a bacteria called Salmonella enteritidis that could result in food illness. With the assistance of stamping the farm code on the eggshell, the involved agencies can suspend the distribution of the affected egg and advise the affected consumer to cook the egg thoroughly as the heat has the capability to kill Salmonella enteritidis. In addition to that, the contaminated eggs that had been distributed out to the market can also be recalled since there is a traceable stamping that allows the agencies to identify the source of the eggs. Hence, the related agencies can identify and recall the contaminated product through stamping.

In recent years, blockchain technology just started to be implemented in the food industry although it has been utilised in supply chain management for a long time [6]. According to [7], a blockchain is a distributed digital ledger that is made up of a "chain" and "blocks" where the new data would be added to the new block and linked up as a chain. This structure improves the security of the data as the credibility of a new block must be checked and agreed upon by the majority of nodes in the network. Besides that, blockchain also allows the public to track assets and record transactions in a corporate network. Blockchain is different from the database as it is completely decentralised. In blockchain technology, the data is stored in peer-to-peer devices (nodes) over the network instead of only being stored in one place, controlled by a single database administrator. Therefore, it had the advantage of each node having identical copies of data which allows the data to be accessible by all members. Specifically, the ownership of the transaction is not limited to one stakeholder.

Moreover, immutability is one of the features of the blockchain. Immutability means that the transaction of blockchain cannot be modified and concealed easily since every modification is monitored, logged, and transparent to the internet users who have access to the data [6]. The cryptographic hash concept is applied in blockchain technology by notifying the administrator when the hash of the new block does not match the hash of the previous block. Hence, if the previous block is being modified by an unauthorised person, then the next block onwards will be having different previous hash values and cause an invalid hash. This brings the advantage of trustworthy and tamper-proof transactions [8].

Furthermore, blockchain offers an environment that is extremely transparent where the requirement for trust is fully eliminated, and there is no need for a centralised authority to act as a mediator between parties [6]. This feature has benefited the authorities by increasing the efficiency and speed to investigate contaminated food. Due to the transparency of the blockchain, the disruption of the intended person who modified the record to clear the faulty record will be minimized and hence blockchain can act as a stopper for the investigation. To put it another way, the blockchain is having complete records of all the previous transactions over the network so that the authorities can keep track of the data that had been written in the blocks easily.

According to [9], a smart contract refers to a simple program in the blockchain that will be executed once the predefined condition is matched. It is just a simple "if…else" or "while" statement inside the code which are developed by the programmer or developer. This is the most essential part of the blockchain as the smart contract will not be able to be modified once it has been deployed. Therefore, it is zero tolerance for missed reading or minor outliers throughout the processing step. This can avoid the ignorance of the manufacturer towards this issue and continue to allow the low-quality product to be distributed to the market. Thus, low-quality products can be noticed by the related party through blockchain and recalled from the market.

Following the outbreak of E.coli, Walmart is concerned about the safety of the food they sell to the consumer. Food safety is essential in the food supply chain because contaminated food that contains poisonous viruses and bacteria would cause the consumer to be infected by more than 200 diseases, including cancer [10]. Thus, Walmart started to utilise blockchain technology to modernise its supply chain and speed up the process of identifying the source of food contamination. Walmart requests all suppliers of leafy green veggies to upload the data onto the blockchain to enable the production of ingredients to be traced back to the farm where it was grown [6]. By using the blockchain-based system in Walmart, the person in charge can assess and determine which types of vegetables and which batches of vegetables are contaminated, within a few seconds. This is because every production detail and even the use of ingredients are recorded in the blockchain. Moreover, due to the immutability and transparency features of the blockchain, the intended person will not be able to change any details that might benefit them.

In short, the implementation of the blockchain in the food industry is extremely important to ensure all the food being bought is able to be traced back and forth so that the information of the ingredients used is traceable and can help in the rapid product recall.

**1.6      Report Organization**

This report was divided into 7 chapters. Chapter 1 was regarding the introduction of this project which covers the problem statement, project scope, project objective, contribution, and background information.

Next, chapter 2 focused on the literature review to review the related technologies and evaluate, review, and compare the existing similar systems and existing related research papers. This provided the idea for the user requirements by comparing and contrasting the previous works to adapt the strengths and evaluate the weakness of the previous works.

Then, chapter 3 was related to the methodology and design of the proposed system. This chapter briefly describes how the proposed system is being developed. Moreover, chapter 4 discussed how the proposed system is being developed in detail. This chapter illustrates the system's functionality and flow in the diagrams.

Chapter 5 focused on system development to present the system's graphical user interface design and system functionalities to the user. In addition, the file configuration is mentioned in this chapter as well. Chapter 6 focused on the evaluation of the proposed system. Finally, chapter 7 was about the conclusion for the entire proposed system.

# CHAPTER 2

# Literature Reviews

The society requires an ingredient tracing system to assist them in a product recall. Hence, this chapter will review the related technologies and discuss the related work on the tracing system using blockchain to identify how the other existing systems apply blockchain technology in the ingredient or component tracing system as well as how rapid product recall can be achieved through blockchain technology. Besides, the strengths and weaknesses of each related application will be listed and compared to provide suggestions for better features of the proposed system.

## 2.1    Review of the Technologies

Table 2.1 Review of the technologies

| Type | Name | Description |
|------|------|-------------|
| Hardware | Raspberry Pi 4 Model B | A tiny and low-cost single-board computer that can run on various operating systems. |
| | DHT 22 Sensor | A digital temperature and humidity sensor that used to measure the temperature and humidity of the surrounding environment. DHT22 offers a wide humidity measurement range, which is 0 to 100%. |
| | HX711 Amplifier with a Load Cell | The combination of the HX711 amplifier and the load cell is used to measure the weight and is suitable for a project that requires accurate weight measurement. The load cell will convert the force into the signal while the HX711 amplifier will amplify the signal of the load cell. |
| Operating System (OS) | Macintosh OS | An operating system developed by Apple Inc and is used in Apple devices. |

| | Raspberry Pi OS | A Linux-based operating system that is specifically used in the Raspberry Pi single-board computer. |
|---|---|---|
| Database | Firebase | A software platform that supports various platforms, such as Andriod, IOS, and web. It provide a range of features such as authentication, cloud storage, real-time database, and others. |
| | Ubidot | A cloud-based platform that is able to connect with IoT devices and display the data in the dashboard. |
| Programming Language | Solidity | A high level programming language that is used to write smart contracts on the Ethereum network. |
| | Python | A simple and versatile programming language that can be used in many applications, including running on the Raspberry Pi. |
| | Dart | A client-centric programming language that used for the development of the mobile and web applications in the Flutter. |
| Emulator | Ganache | A local blockchain emulator that allows the developer to test the smart contract on the local environment. |
| Programming Framework | Truffle | A development framework that allows the developer to compile, deploy, and test the smart contract. |
| | Flutter | An open-source development framework that allows the developer to create responsive user interface for the mobile application. |
| Blockchain | IPFS | A decentralized file system that utilized unique content-addressing to identify and distribute files across a distributed network of nodes. |
| | Metamask | A mobile application that supports both Andriod and IOS device. It allows the user to interact with |

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| | | their Ethereum-based dApp by connecting the Metamask wallet to the dApp. |
|---|---|---|
| | WalletConnect | An open-source protocol that allows the secure communication between the dApp and mobile cryptocurrency wallet such as Metamask. |

## 2.2    Review of the Existing Systems/Applications

### 2.2.1    Tracing manufacturing process using blockchain-based token composition

The research paper [11] proposed a blockchain-based system to improve the traceability of the supply chain by using solidity contracts on the Ethereum Virtual Machine (EVM) blockchain. The ingredient will be inputted into the system and then will be generated with a token contract which holds the information of the ingredient such as the batch identifier for each and every ingredient in the contract. To ensure the quality of the ingredients fulfilling the standard defined in the token contract, the certifier will approve it and issue a certificate. The certificate is on hold in the blockchain and when it is passed to the next department for the next process, the certificate will also pass to the next department by triggering the event "transfer" which is one of the functions of the contract. For the processing department, when more than one ingredient is used to manufacture a new product, the "add-batch" function is triggered and this function will check for the certificate of the ingredients before the processing step is started. During the processing step, if the certificate is applied, the contract will update the amount used and all the ingredients with their previous respective information. This is to allow the consumers to trace all the details.

To provide better visualisation of the workflow of the contract, the author of the paper developed a mobile and web application so that consumers were able to interact with the contract explained above. As shown in figure 2.1, the web-based application allows authorised users to create a token contract for the new product by filling in the required information while the existing product will be used as the component of the new product. The proposed system also printed the QR code on the physical product to allow the consumer to retrieve the information from EVM.

Figure 2.1 Interface of creating a token contract for the new product

**Strengths:**

1. With the help of a QR code, the consumer can quickly search for the product information because they do not require to manually enter the product identifiers.

2. Creates unique tokens for every stage and component involved in the production of products that aid the identification of bottlenecks in the supply chain.

**Weaknesses:**

1. The visualisation of raw material is not user-friendly as the details are not shown but the address is shown which may not be informative enough to the consumer.

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### 2.2.2 Blockchain recall management in pharmaceutical industry

Research paper [12] applies the blockchain smart contract in the pharmaceutical industry. The paper mentioned there are 3 smart contracts and they are measures based on the severity of the effect on the human. By using the contracts mentioned, the system will automatically update the recall status that applied to the same batch or same ingredient used once the authorities found the affected medicine. This brings the benefit of fast stopping the selling and distribution of the related products.

The flow of the system mentioned by the author is initially the product's details will be listed in the contract such as batch number, the number of sales and inventory and the materials involved in the recall. Once the material is marked as alert status, all the products with the related content will be marked as dangerous. This is able to stop the selling and distribution. To further increase the speed of the recall, the system is also able to send a notification to the customers who had purchased and started to consume via the contact information saved in the blockchain. The main reason for the system proposed by the author is to ensure that every consumer can get the alert as fast as possible instead of waiting for the announcement in the news that may have a delay. This system is also able to show the ingredient used to produce the products and hence able to allow faster recall as the contract can automatically update all the related products to alert status by not requiring the staff to update one-by-one manually.

**Strengths:**

1. Make use of smart contracts to automatically update all the products that contain materials with alert status so that any delay in news and human error during the manual update can be avoided.
2. Send a notification to the consumer when the purchased product is marked as alert status or recall status.

**Weaknesses:**

1. The contact information of the consumer might be leaked and privacy will not be protected due to the contact information being stored in the blockchain that is open to the public.

### 2.2.3 Blockchain-based food supply chain traceability: a case study in the dairy sector

A research paper [13] proposed an Ethereum-based blockchain system for the dairy sector. In the development of the system, the tools of node and ganache-cli as well as truffle were used to code and deploy the smart contract that defined the functionalities of the whole system. The graphical interface was also developed to ease the stakeholder to have better visualisation of the data in the blockchain.

In this system, the author made use of three smart contracts which are to keep track of the ingredients or raw materials, the interaction of stakeholders such as supplier and merchant as well as tracking the condition of the internal characteristic such as temperature. All the information is stored in the blockchain throughout the whole process of the supply chain. All of the stakeholders will get real-time notifications for all the related information updated via the "trigger" function coded in the smart contract. In addition to that, the stakeholder can get the information via the "get/retrieved" function that had been implemented in the blockchain's smart contract.

This system can further ensure the privacy of the trade secret and information of the stakeholder as it has roles in the smart contract and the content can be able to be created, updated, read and deleted by the authorised roles. In addition, the internal characteristics are automatically updated by the IoT device and it can avoid human error during the data entry. Therefore, this guarantees a fast recall process as the issue of careless mistakes in data entry is avoided and the persons who modified the data to block or stop the investigation of authorities can be identified, especially if there is a case of food poisoning. This is because the roles are able to allow the authorities to check who is the person who changes the data or destroys the evidence that causes the incidents.

**Strengths:**

1. There is a real-time notification for all the stakeholders so that everyone will instantly receive updated news.

2. Avoid human error when data entry as the internal characteristic value is automatically read by the IoT device.

**Weaknesses:**

1. The delivery route of the final product to the merchant is not recorded. This could delay the process of a product recall as the manufacturer needs to check the order record to contact the merchant who has bought the contaminated product.

## 2.2.4  AUTHENA PROTECT AUTHENTICITY– Food and beverages

This system uses Near Field Communication (NFC) technology and sensors in the manufacturing industry to trace the status of the products in the production, storing and distribution phases so that any tampering that could affect the quality of the products can be detected. This system also attached a unique tamper-proof digital passport to every packaging of the food and beverages to allow the consumers to view the product authenticity through a single tap from their mobile devices. The user can either use the NFC connection or the free consumer application to retrieve the product information. Figure 2.2 shows the information retrieved by the users once the users put their mobile devices near the bottle. As shown in figure 2.3, the user can also retrieve the product information by using their mobile application to scan the unique number that is sticked on the bottle [14].
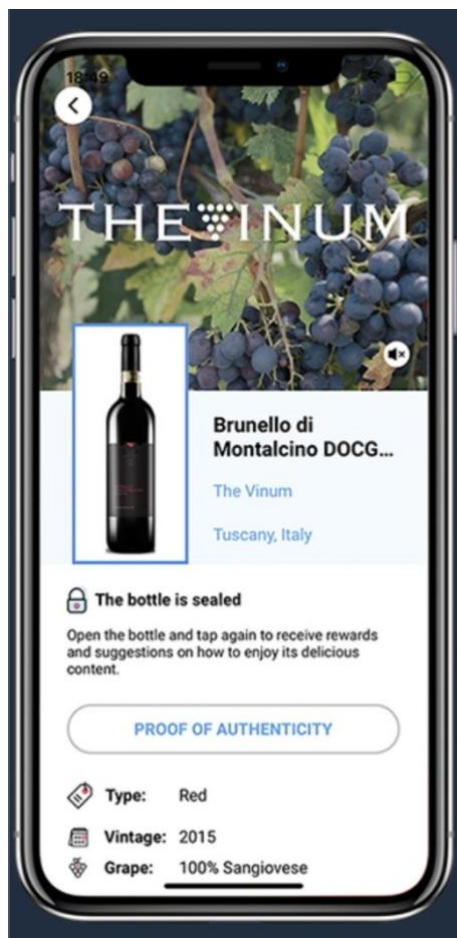


Figure 2.2 Product information retrieved by the user

Figure 2.3 Interface of the mobile application to allow scanning of the unique number

**Strengths:**

1. Allows the consumer to get instant results with just a simple tap on their mobile devices.
2. The consumers can know if the packaging is open so they can avoid buying the swapped product.

**Weaknesses:**

1. NFC is not suitable to be used in daily used products and affordable products because the NFC tag is pricey.

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### 2.2.5 TraceX Technologies

TraceX provides a blockchain-based tracing system to digitalise the agriculture supply chain so that the consumer can view the information of a product starting from the farm. This system will connect all the stakeholders to one platform to ensure that the other stakeholder can trace the root cause of the problem and recall the specific product batch based on information updated by the source. For example, if there is an outbreak of E.coli, the farmer can update the status of the vegetables on the blockchain while the manufacturer can recall the products based on the status of the ingredient used. Besides that, this system also attached the QR code to the product packaging to allow the consumer to view the product history. Last but not least, real-time data analytics and reports will be generated to allow the stakeholder to monitor the deviations from the package approaches and assess the performance in terms of yield [15].

**Strengths:**

1. All information will be shared among the stakeholders to ensure that the details of the ingredients used in one product can be traced.
2. The QR code is attached to the product packaging so that the consumer can view the product information.
3. Each stage will be having a unique identifier which ease the product recall.
4. The growth of crops can be monitored in real-time value because the value is retrieved from the IoT device.

**Weaknesses:**

1. Does not make full use of a smart contract to avoid any potential breaches in the contract execution.

### 2.2.6 IBM Food Trust

IBM food trust provides a blockchain-based food safety system that digitalizes the information about the food supply chain and ensures the information is searchable and indelible so that the users can have access to their encrypted data. The authorized user can search for the source of a product in real time by entering the product's identifiers, name, or purchase order (PO) number. Figure 2.4 shows the supply chain information (real-time location and status) of the whole grain Margherita pizza according to the phase, starting from production to the store. The user can click on any of the ingredients to view the date range that the ingredient consumed at a specific phase. Figure 2.4 shows that the organic whole milk was in the distribution centre starting from 8th October 2020 until 16th October 2020. Moreover, the consumer of this system can add the product details as well as upload the certificate of registration to this system to allow their customers to view the source and journey of the ingredients used by scanning the QR code that is attached to the product label. Figure 2.5 shows the ingredient sources of the milk to produce the mozzarella cheese on the pizza [16].
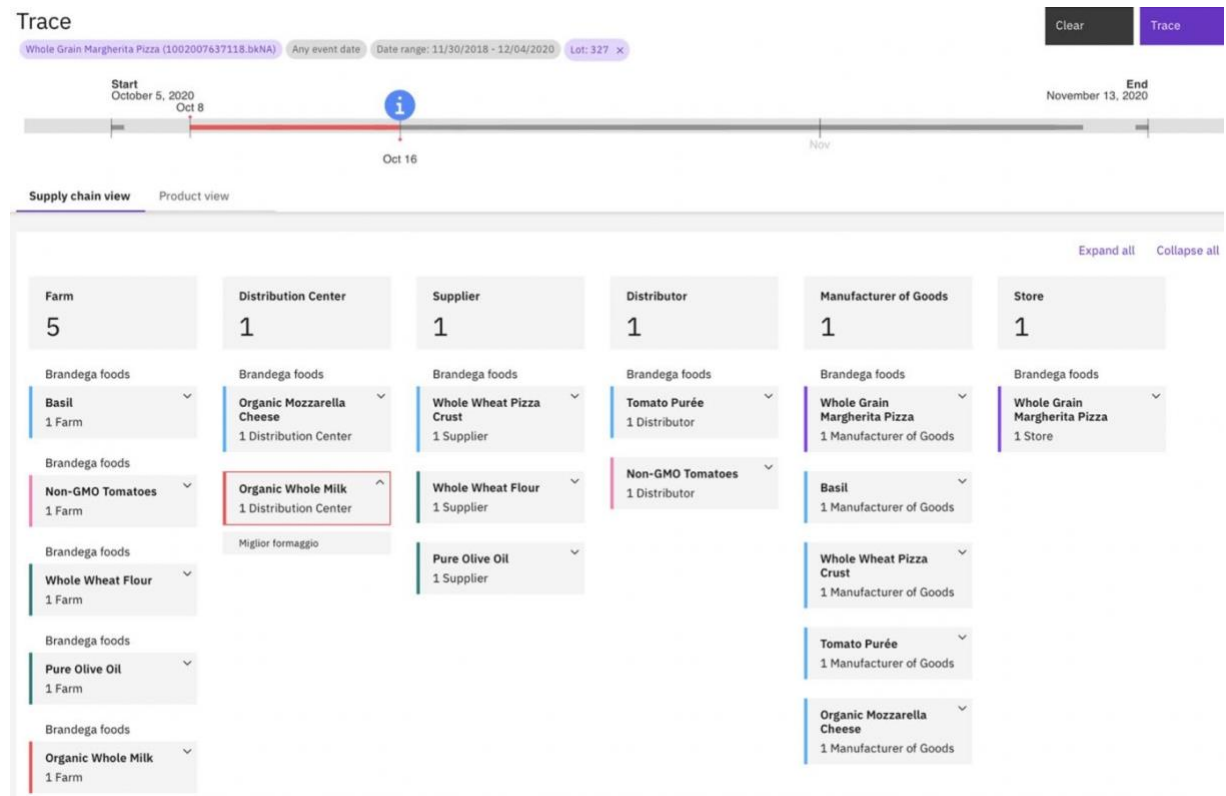


Figure 2.4 Overview of the supply chain view

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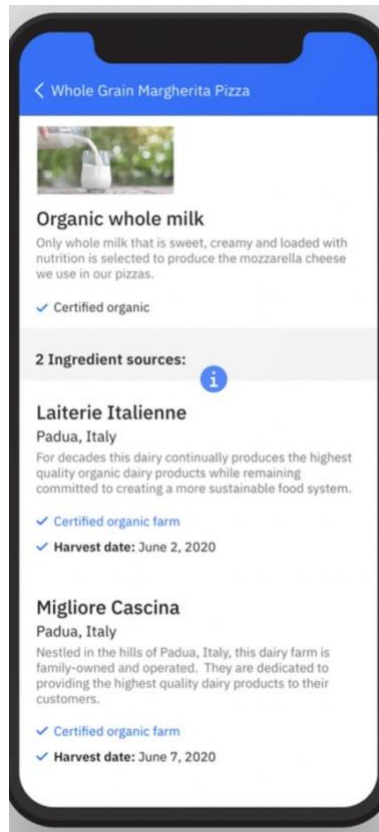
Figure 2.5 Interface to view the source of all ingredients in a product

**Strengths:**

1. Provide the feature of downstream tracking to track the destination of the processed product that contains the contaminated ingredient.

2. Provide the feature of allowing the manufacturer to upload the certificates as proof of certification.

**Weaknesses:**

1. There is no feature that sends a real-time notification to the merchant who has purchased the contaminated product.

### 2.2.7 Summary of the Existing Systems

Table 2.1 illustrates the comparison of features present in the existing system. The numbering below represents the subsection.

Table 2.2 Features comparison of the existing system with the proposed system

| Application / Features | 2.2.1 | 2.2.2 | 2.2.3 | 2.2.4 | 2.2.5 | 2.2.6 | Proposed system |
|---|---|---|---|---|---|---|---|
| Make use of QR code | √ | | | | √ | √ | √ |
| Make use of NFC | | | | √ | | | |
| Privacy protection | √ | | √ | | | √ | √ |
| Record the processing standard | √ | √ | √ | | √ | √ | √ |
| Send alert message | | √ | √ | | | | √ |
| Ability to trace ingredients used | √ | √ | √ | √ | √ | √ | √ |
| Low chance for data entry error | | | √ | | √ | | √ |
| Show the opening status of the product | | | | √ | | | |
| Upload certificate | | | | | | √ | √ |

## 2.2.8   Proposed Solutions

This proposed project will include the features of retrieving the product information via a QR code, tracing ingredients or components used, performing quality detection, retrieving data from the IoT device, performing privacy protection, sending alert messages, and uploading the certificate. However, since this proposed project only involves daily used products, NFC technology will not be applied to this product because the NFC tag is pricey. Besides that, the feature of showing the opening status of the product will not be applied in this proposed project because the consumer can easily identify the opening status of the packaging by themselves. For example, the consumer will not buy the milk if the packaging is unsealed.

This proposed project will enable consumers to trace the status of the product and the ingredients used via a QR code, allowing them to return the product to the manufacturer if the status is in an alert state. The proposed system even adds value by enabling the consumers to scan the product prior to purchase, ensuring that the product is not contaminated and thus increasing safety and quality control. Besides, each of the ingredients collected in the information-collection phase and the ingredients used in the production phase will be having unique identifiers so that the manufacturer can link them together and use them in the product recall. Moreover, the smart contract will be used to update the product status in the event that the readings of the IoT devices fail to meet the predefined standard that is approved by the internationally recognised system. This feature ensures that any product that does not meet the required standards is quickly identified and triggers the necessary actions, such as sending alert emails and refusing to distribute the product. By preventing manufacturers from distributing products that are contaminated due to substandard ingredients or processing, this feature not only increases customer satisfaction but also protects customer health and safety. Furthermore, the IoT devices will be connected to Raspberry Pi 4B and used in this project to collect real-time data and create a simulation of the industry environment. In this project, a DHT22 sensor is used to act as the digital temperature and humidity sensor while an HX711 amplifier with a 10kg load cell is used as the weight measurement. The real-time data will also be pushed to Ubidot to embed the dashboard into the proposed system for real-time monitoring.

In addition, the privacy protection feature is responsible for ensuring that consumer information is not stored on the blockchain. This is to ensure that consumer details are not accessible to the public, which could lead to financial and legal consequences. Thus, the

consumer details will be stored in the Firebase database instead of the blockchain to increase the privacy of the consumer. For consumers, the product registration in the proposed system is used as an alert function to send emails to consumers if any of their registered products are contaminated. The proposed system would also send emails to merchants alerting them to stop selling contaminated products to consumers if they receive them. Lastly, the proposed system allows the manufacturer to upload the certificate to the IPFS, which serves as proof of certification for the products and allows them to be sold in the market.

# CHAPTER 3
# System Methodology/Approach

This chapter will explain what methodology is used in this project and what are the reasons for choosing it. This chapter will also present the architecture diagram, use case diagram, and activity diagram to demonstrate the system flow. Besides that, the entity relationship diagram will also be illustrated in this chapter.

## 3.1    Methodology
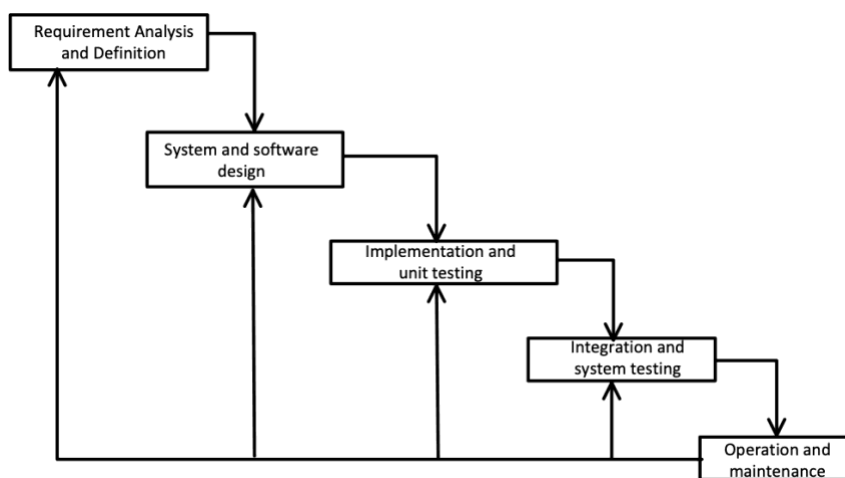


Figure 3.1 Waterfall Model

The methodology that will be used for the ingredients tracing system using blockchain for rapid product recall is the waterfall model. The waterfall model illustrated in Figure 3.1 is one of the models in the Software Development Life Cycle (SDLC) and it proceeds in sequence, which means a step must be finished before proceeding to the next step. The waterfall model is chosen to be applied in this system is due to several reasons. The first reason is that the requirements of this system are identified thoroughly before the deployment starts. This will bring an advantage to the project as there will be only minor changes to the requirements when the project proceeds. Hence, the loss of gas fees can be minimised, as deploying a smart contract will certainly incur costs. Upfront analysis of each phase is conducted to ensure the requirements of the entire system are well understood so that the wastage of resources can be decreased, and the project can be done on time. Besides that, the structured design of this model allows the identification of the possible risk at the early stage to avoid the unpredicted risk that

might cause the project to fail in the future. Thus, the following section will discuss each phase in the waterfall model in detail.

The first phase in the waterfall model is the requirement analysis and definition phase. This phase is the key step of this project since there will be no project when there is no problem. Hence, the problem statement and motivation are identified in this phase to figure out the targeted user of the project and the problems that happen in this particular domain. Moreover, the background information will be studied in order to discuss the brief information on the technology that is related to this domain. After that, the project scope and objective will be defined to present the expected outcome of the final project as well as the goal of the project. Then, the contribution of this project will be determined as well. Furthermore, the user requirements are gathered by reviewing multiple existing systems and research papers. With this, the user requirements will be listed by gathering the strengths of the existing systems as well as the enhancement of the weaknesses.

After the analysis mentioned above is completed, the proposed system is defined with the assistance of strengths and weaknesses of the existing system and research papers. The tools and technologies such as blockchain, Ganache, Metamask, Raspberry Pi 4B, and others are being used to develop the proposed system. In addition, the core functionalities such as saving the data to the blockchain to provide transparency and temper-proof, using the smart contract to automate the step of rejecting the product if the actual value retrieved from the IoT devices is not within its threshold, and alerting features are defined. Lastly, the QR code will be generated for the consumer to scan so that the status and details of the product can be obtained.

The second phase is the system and software design phase. During this phase, the unstructured user requirements are converted to the conceptual model to avoid any misunderstanding issues regarding the user requirement. Hence, in this phase, the first and foremost step is to draw out the flowchart of the proposed system to further illustrate the system flow. After that, the use case diagram is drawn to illustrate the functionalities of the consumer and the manufacturer in the proposed system. The activity diagrams are then provided to show the relationships and interactions between each actor and system as well as the blockchain, Firebase, IPFS, and Python. Then, the architecture diagram is designed to present the components of the proposed system. After the image of the whole system is clear, the SDLC

is designed with the entities and their respective attributes. The relationship of each and every entity is also joined in the Entity Relationship Diagram (ERD) diagram. The proposed system utilizes various software and tools, including Visual Studio Code, Ganache, Truffle, Metamask, IPFS, and others. In addition to these, the proposed system also uses various hardware components such as Raspberry Pi 4B, DHT22 sensor, HX711 amplifier, 10kg load cell, breadboard, jumper wire, and 10k ohm resistor. Solidity is the programming language used for blockchain development in the proposed system, Dart is used for mobile development and Python is used for IoT and Raspberry Pi development.

The third phase is implementation and unit testing. In this phase, the implementation will develop the smart contract with all the logic and variables for data storage. After that, the Ganache is used to develop, deploy, and test the smart contract to verify it works as intended. Then, the user interface is developed without any integration into the smart contract. In other words, the user interface developed in Flutter is developed by passing dummy data for ensuring the parameters passed to each page are correct and fulfilling the process flow of the proposed system that is generated in the previous steps. This is to ensure the user interface is suitable for data processing and data retrieving in the smart contract. In addition to the smart contract and user interface development, this phase also involves the connection of Raspberry Pi 4B with the IoT devices. Python was then used to read and print the sensor data to ensure the load cell was properly calibrated.

The fourth phase is integration and system testing. In this phase, the integration is done with system testing to ensure all particular integrations have been properly coded and functional. As for the manufacturer, the integration process will proceed with the integration of Metamask for login purposes and the integration of the smart contract for data storing purposes. As for the consumer, the integration process will proceed with the integration of Firebase Authentication for the authentication module. Each new integration requires testing of the entire system to prevent the latest updates from conflicting with previous code and causing hard-to-detect errors. During this phase, the sensor data is sent to both the smart contract for quality detection as well as to the Ubidot for real-time monitoring via the Ubidot dashboard. In addition, a test environment was created and tested using test case data to verify that the expected results were achieved.

The last phase is operational and maintenance. During this phase, the system will be deployed to the iPhone XR. Since the final year project does not involve any of the real consumers, merchants and manufacturers, therefore, the testing will be done by following the flow diagram and use case diagram as well as activity diagram to ensure it is fit to the real-world scenario.

## 3.2 System Design Diagram

### 3.2.1 Architecture Diagram
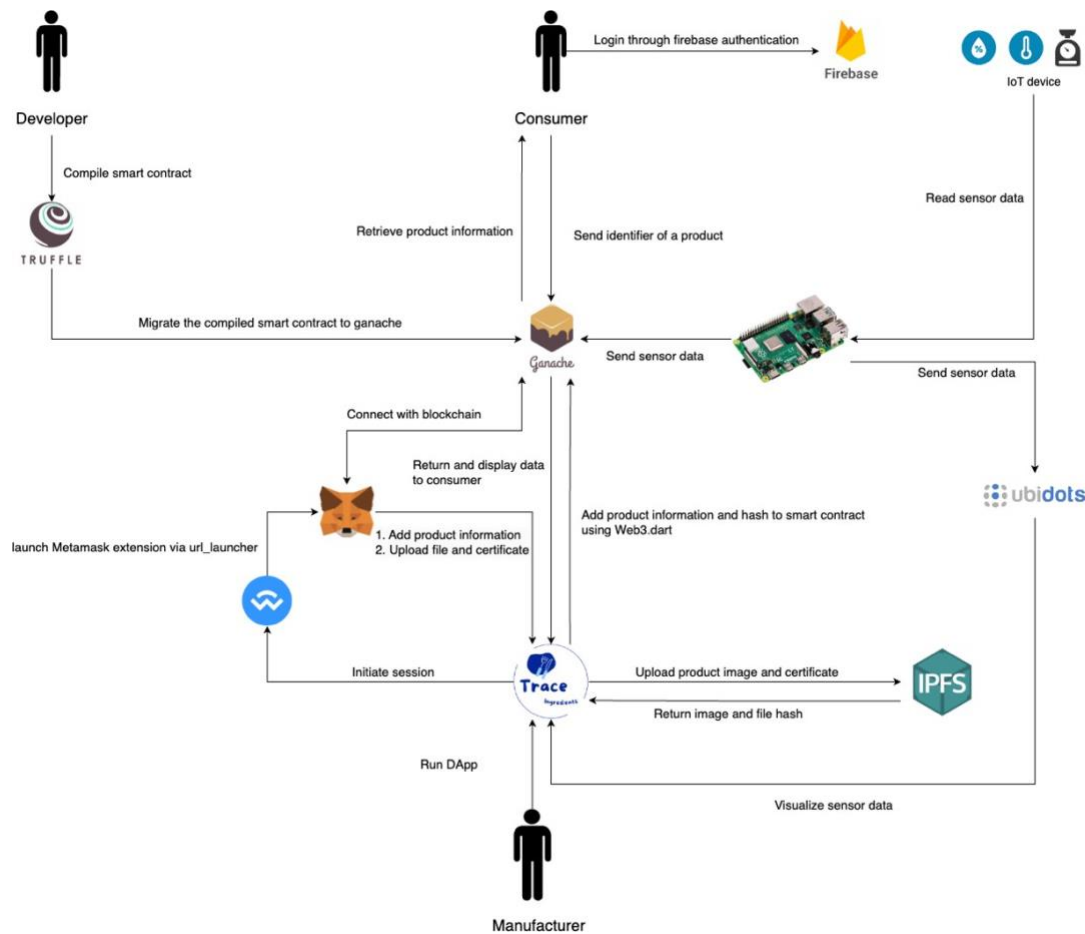


Figure 3.2 System architecture diagram

Figure 3.2 shows the architecture diagram of the proposed system to show the interaction of the components and illustrate how the information is stored in the blockchain. The developer will first compile the smart contract using Truffle and migrate it to the Ganache. When the manufacturer executes the proposed system, the system will start a WallectConnect session with the manufacturer's Metamask account and launches the Metamask extension to request the manufacturer to connect their Metamask account to the proposed system. Web3.dart allows the proposed system to interact with Ganache, send and retrieve data from the blockchain and execute smart contracts. Besides that, the product image and certificate uploaded by the manufacturer will be uploaded to the IPFS and the hash value will be returned to the application and added to the blockchain along with the product information.

Moreover, the Raspberry Pi 4B reads the temperature, humidity, and weight data from the IoT devices and sends them to the blockchain for transparent data storage and Ubidot for data visualization. The smart contract will then mark the product status by comparing the value retrieved from the sensor with the threshold whereas the flutter application is used to add the product information as well as display the data in a visually appealing manner on the dashboard. On the other hand, the consumer's account is authenticated through Firebase authentication and the identifier obtained from the QR code that is scanned by the consumer will be sent to the Ganache. Ganache will then return the product information to the consumer, providing the consumer with secure and transparent access to the product details.

### 3.2.2 Supply Chain Diagram
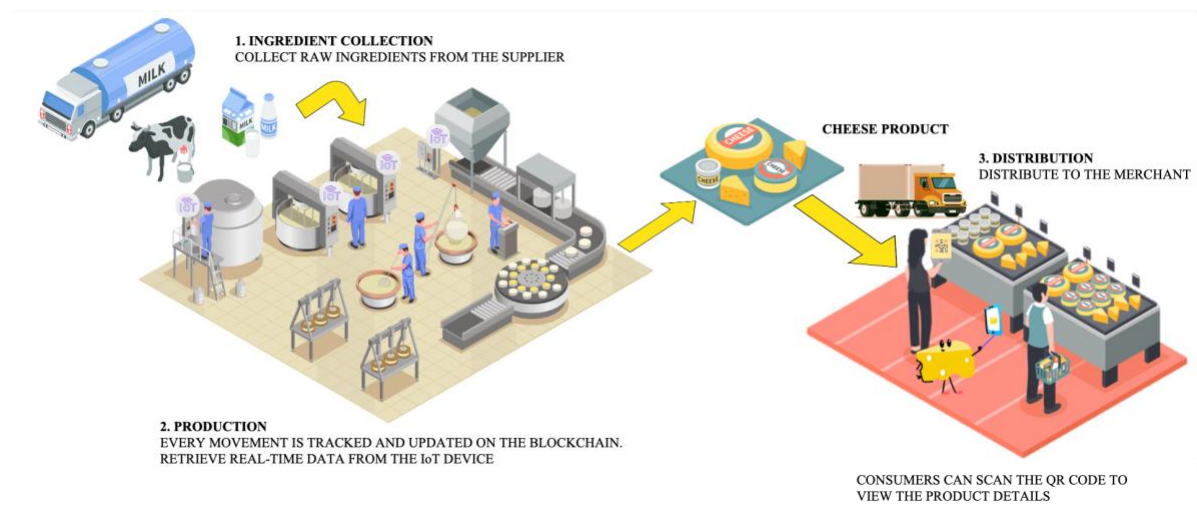


Figure 3.3 Food supply chain process

Diagram 3.3 illustrates the three stages of cheese production, namely, ingredient collection, production, and distribution. The ingredient collection stage involves sourcing the raw ingredients necessary for the products such as milk, from various sources and belonging to different batches. Then the production stage transforms the raw ingredients into a completed food product, i.e. cheese. Quality control is aided by the application of IoT devices that monitor the production process. In the final stage, the uncontaminated food product is distributed to the merchants who can start selling the product to the consumers. Consumers can scan the QR code on the product packaging to view the product information and ensure the safety of the product before purchase.

### 3.2.3   Use Case Diagram and Description



Figure 3.4 Use case diagram of the proposed system

Figure 3.4 shows the use case diagram of the proposed system. The proposed system contains 2 actors which are the manufacturer and the consumer.

In the proposed system, the consumer can register for a consumer account and sign in to the system by entering their email addresses and password. Once successfully signed in, the consumer can scan the QR code on the product packaging with their phone's camera to view information about the product and the ingredients used in that product. The consumer can then receive email notifications if any of the ingredients used in their registered products are flagged as contaminated.

On the other hand, the manufacturers can connect their Metamask account to the proposed system so that the manufacturer can interact with the proposed system without having to reveal their private key. Once successfully connected to the Metamask, the manufacturer can add company details, as well as other necessary information for the product recalls such as details of suppliers, merchants, ingredients, products, standards, and batches. The manufacturer can upload the product image and certificate to the system, select the ingredients from a list of previously added ingredients, and add the processing standard to the system to record the threshold value. Furthermore, the manufacturer can also view the dashboard to monitor the real-time data retrieved from the sensors. The manufacturer can add the sensor data retrieved from the IoT device to the system by starting production and then receive an email message when the actual value is outside the range of the predefined threshold. Then, the manufacturer can update the ingredient status if any of the ingredients is detected contaminated. The product status is updated when the manufacturer starts production or updates the ingredient status. Lastly, the manufacturer can add the batch details and select the merchant from the merchant list and then save the QR code if all the processing steps do not violate the processing standard.

### 3.2.4 Activity Diagram
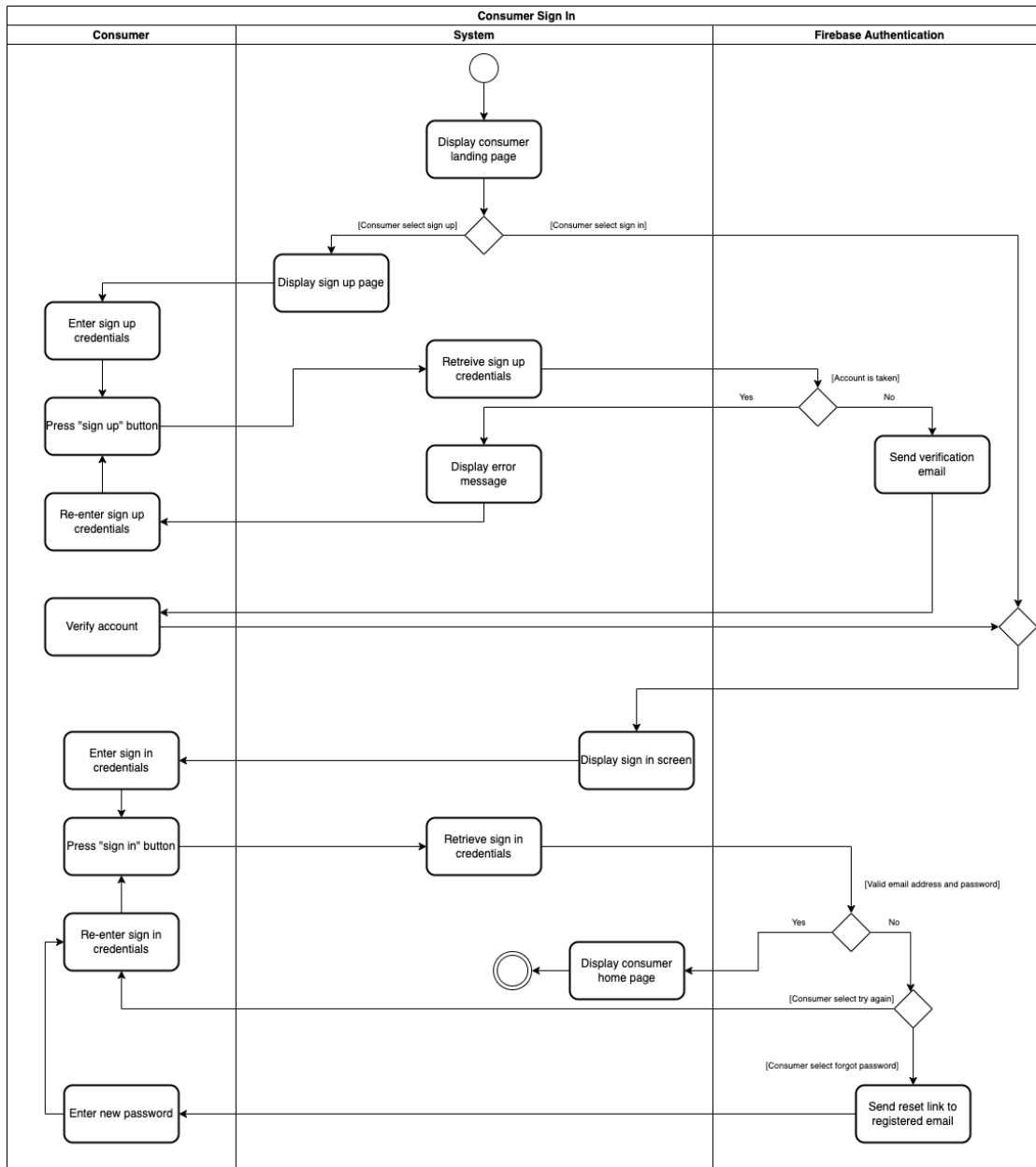


Figure 3.5 Activity diagram for consumer login
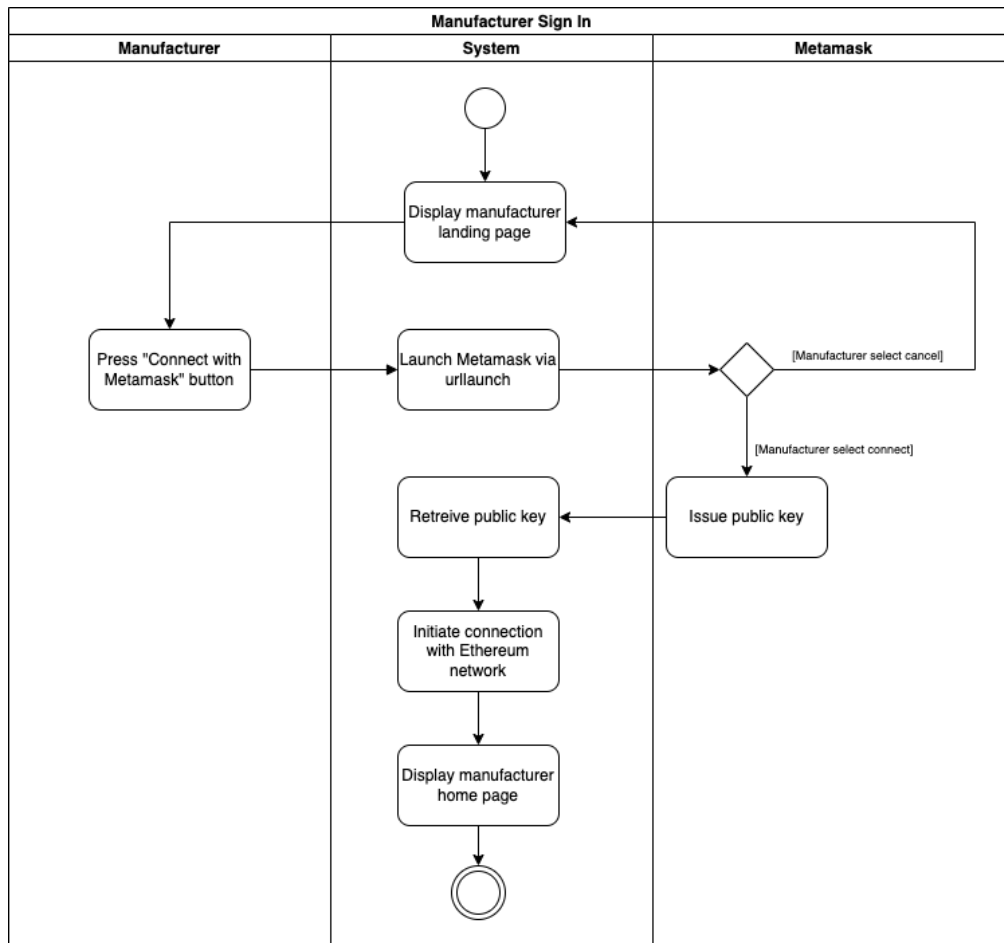
Figure 3.6 Activity diagram for manufacturer

Figure 3.5 and figure 3.6 are the activity diagram of the authentication of the consumer and manufacturer.

For the consumer, the activity starts with displaying the consumer landing page, allowing the consumer to choose whether to sign-in or sign-up. If the consumer chooses to sign-up, the system will display the sign-up page and allow the consumer to enter their sign-up credentials, which are the email address and password. After the consumer presses the "sign up" button to proceed with the sign-up process, the system will retrieve the sign-up credentials from the user input and send them to Firebase Authentication to check whether the account is already taken. If it is taken, the system will display an error message and request the consumer to re-enter the sign-up credentials. On the other hand, if the account is not taken, Firebase will send a verification email to the email address that the consumer input previously and allow the consumer to verify the account by clicking on the verification link.

After the consumer validates the account, the system will display the sign-in page and allow the consumer to enter their sign-in credentials, which are the email address and password. After the consumer presses the "sign in" button to proceed with the sign-in process, the system will retrieve the sign-in credentials from the user input and send them to Firebase Authentication to check whether the input email matches the input password. If it matches, the system will display the consumer's home page. However, if it does not match, the consumer can choose to re-enter the sign-in credentials or reset the password. If the consumer chooses to reset the password, then Firebase will send a reset link to the consumer's email and request a new password from the consumer. The consumer can then re-enter the sign-in credential after resetting the password.

The same goes for the manufacturer, but the only difference is the manufacturer is required to connect their Metamask account to the proposed system so that the public key retrieved from the Metamask account can be used to initiate the connection with the Ethereum network and sign transactions.
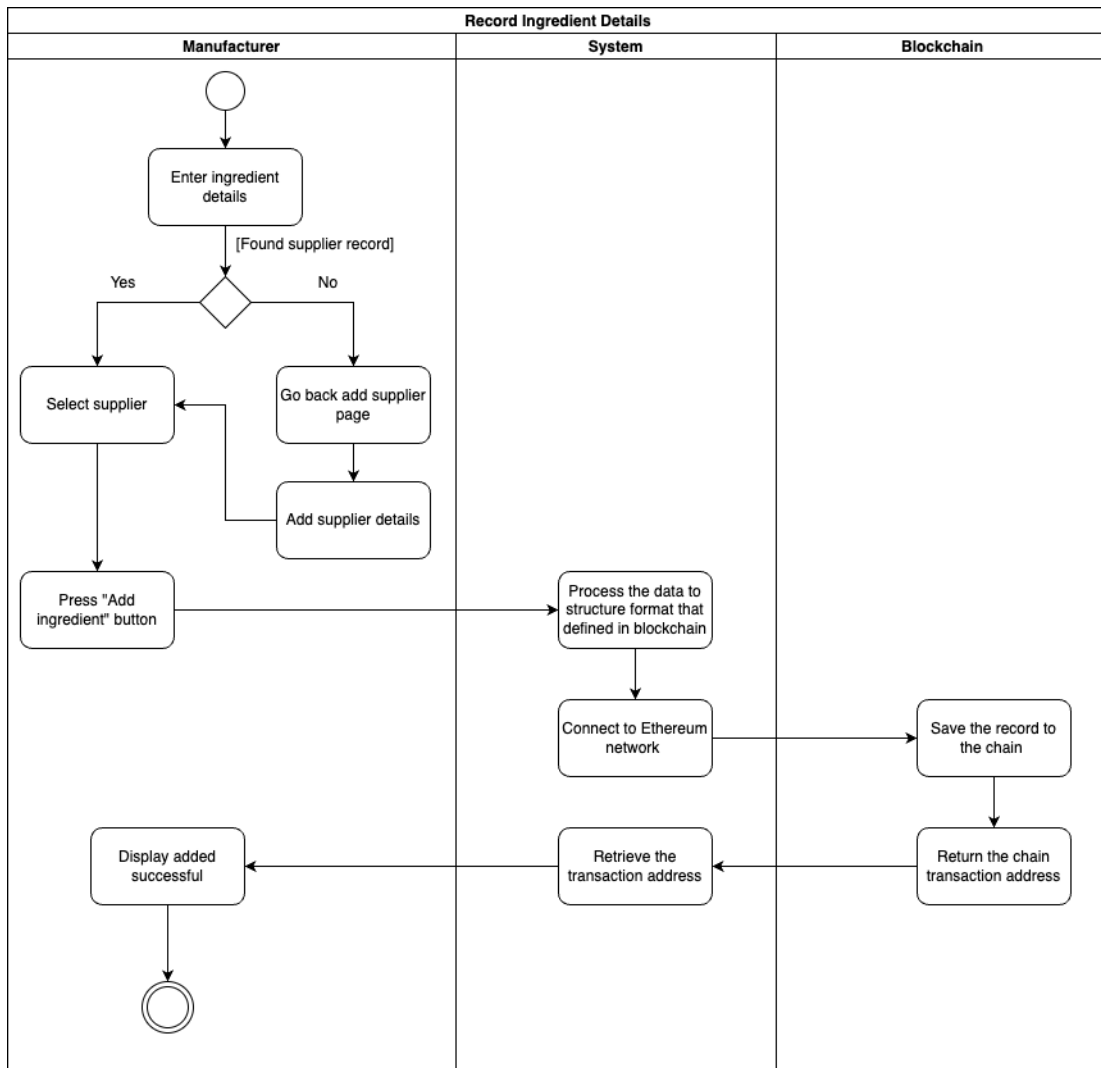
Figure 3.7 Activity diagram for record ingredient details
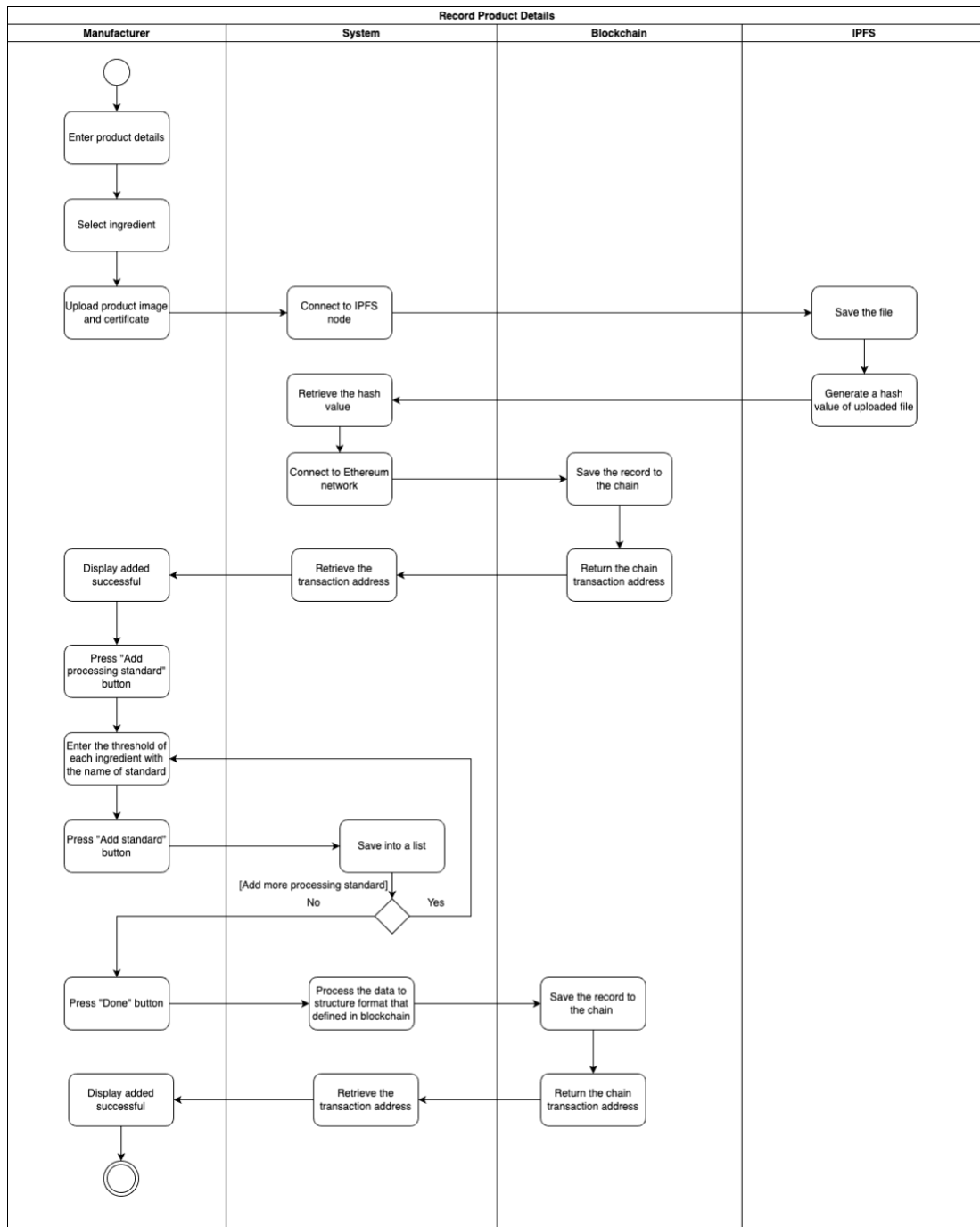
Figure 3.8 Activity diagram for record product details

Figures 3.7 and 3.8 show the activity diagrams for data entry. The process of recording the ingredient and product information is similar, which is involving data entry for recording the related details to the blockchain. The data will be stored in the blockchain, and the dart backend will process the data by restructuring the data to the structure that can be stored in the blockchain as well as displayed in the user interface. This step is necessary to ensure a better user experience without requiring the consumer to wait while the data is processed on the backend. However, recording the ingredient details involved an additional step, which is checking whether the supplier information is found in the blockchain. If the supplier record is not found, the manufacturer can go back to the add supplier page to record the supplier details. Meanwhile, recording the product details involved an additional actor, which is IPFS. During the process of recording product details, the manufacturer can store the product image and certificate file in the distributed file system, which is IPFS and the system will retrieve the hash value of the file from the IPFS and send it to the blockchain for storage purposes. For each ingredient in a product, the manufacturer can add more than one processing standard. The data of the processing standard will be used in the production steps to control the quality of the product.
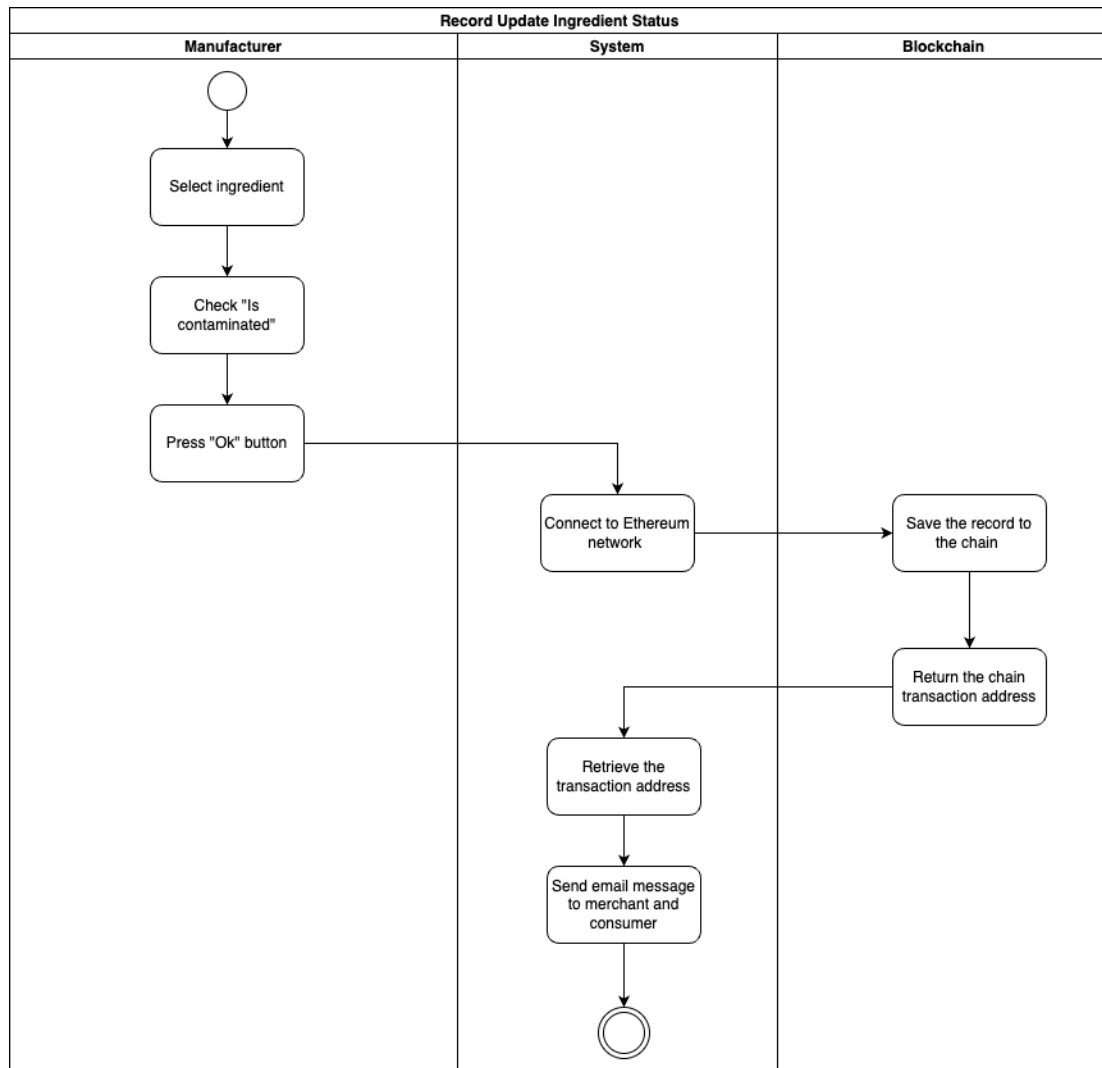
Figure 3.9 Activity diagram for update ingredient status

Figure 3.9 shows the activity diagram for updating the ingredient status. The manufacturer can mark the ingredient as contaminated if the manufacturer receives a notification from the supplier about a contaminated batch or ingredients. Blockchain will then update the ingredient status from "Safe" to "Alert". Moreover, the merchants and consumers who registered the product containing this contaminated ingredient will receive an email message reminding them to stop consuming or selling the product and return it to the manufacturer as soon as possible.
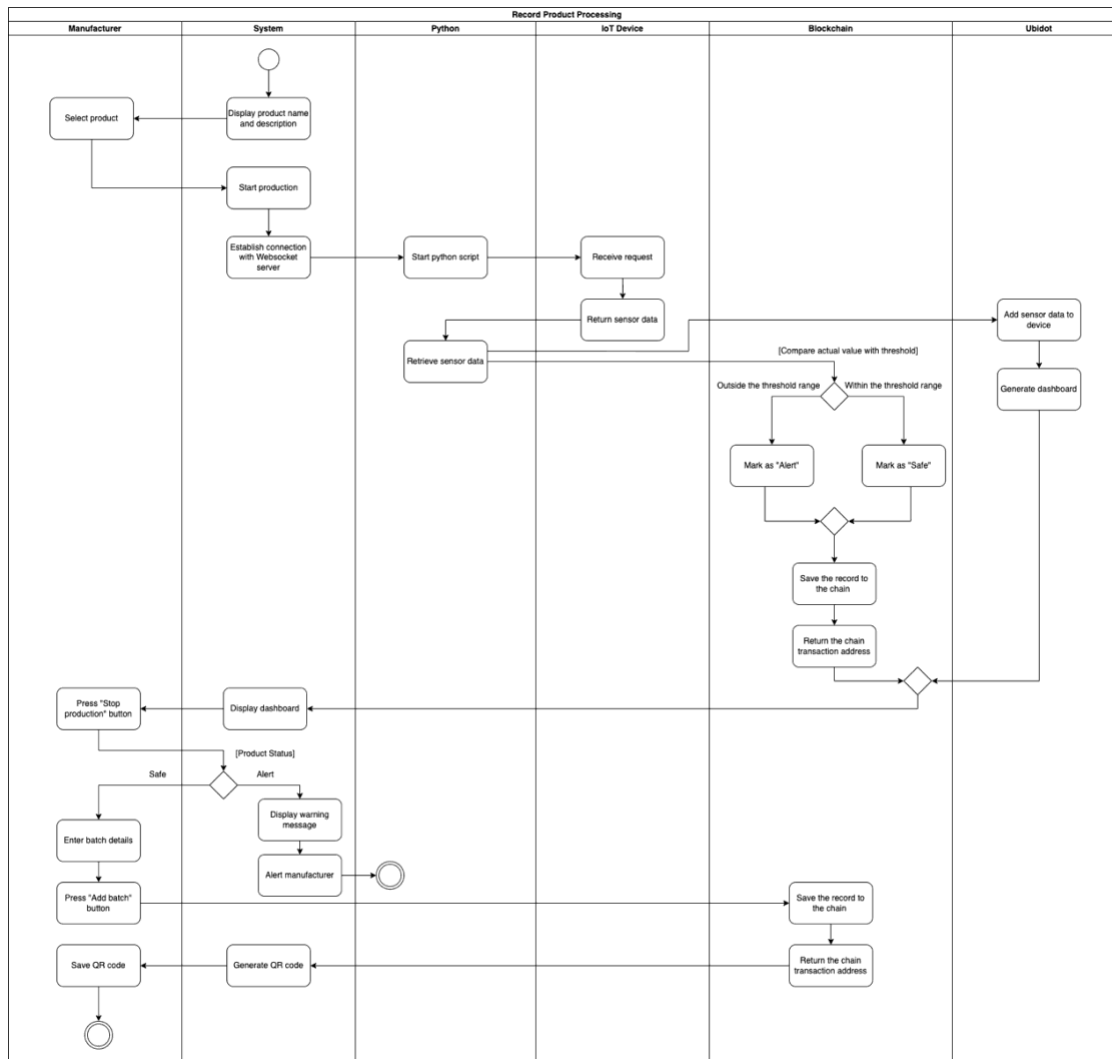
Figure 3.10 Activity diagram for record product processing

Figure 3.10 shows the activity diagram for product processing. In this stage, the manufacturer can start the production of a product and the system will establish a connection with the WebSocket server in order to communicate with the Python script. Once the connection is established, the Python script will start running the program and retrieving the sensor data from the IoT device. Then, Python is responsible for sending the sensor data to the Ubidot to generate the dashboard as well as to the smart contract to verify and validate the processing standard of a product. If the actual value entered during the processing steps is outside the range of the predefined standard value, then the smart contract will update the product status as "Alert"; otherwise, it will mark it as "Safe". Meanwhile, the system will display the dashboard that is generated by the Ubidot to allow real-time monitoring. The manufacturer can press the "Stop production" button to indicate the processing step is ended. The system will then check the status of the product during this processing session. If any of

the ingredients used in this product is contaminated or if any of the processing standards are violated, the system will display a warning message, send an alert email message to the manufacturer regarding the reason for rejection, and will not allow the manufacturer to distribute this batch of product. Otherwise, the manufacturer can enter the batch details and the system will generate a QR code that can be saved by the manufacturer and attached to the product packaging.
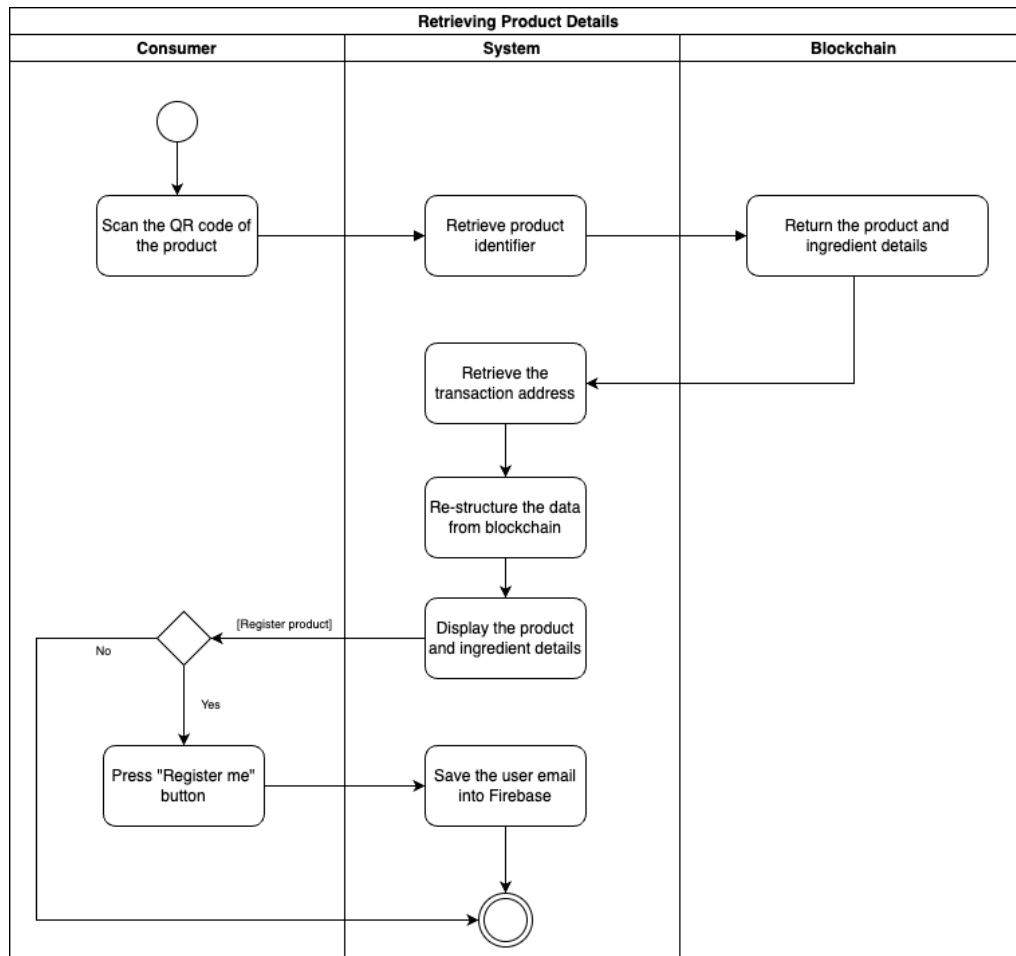


Figure 3.11 Activity diagram for retrieve product details

Figure 3.11 illustrates the activity diagram for retrieving product details for the consumer. The system will retrieve the product identifier from the QR code that the consumer has scanned and display the product and ingredient information to the consumer. If the consumer wishes to receive an email message if the product is detected as contaminated, they can press the "Register me" button and the system will save their email address to the Firebase.

**3.2.5   Entity Relationship Diagram (ERD)**
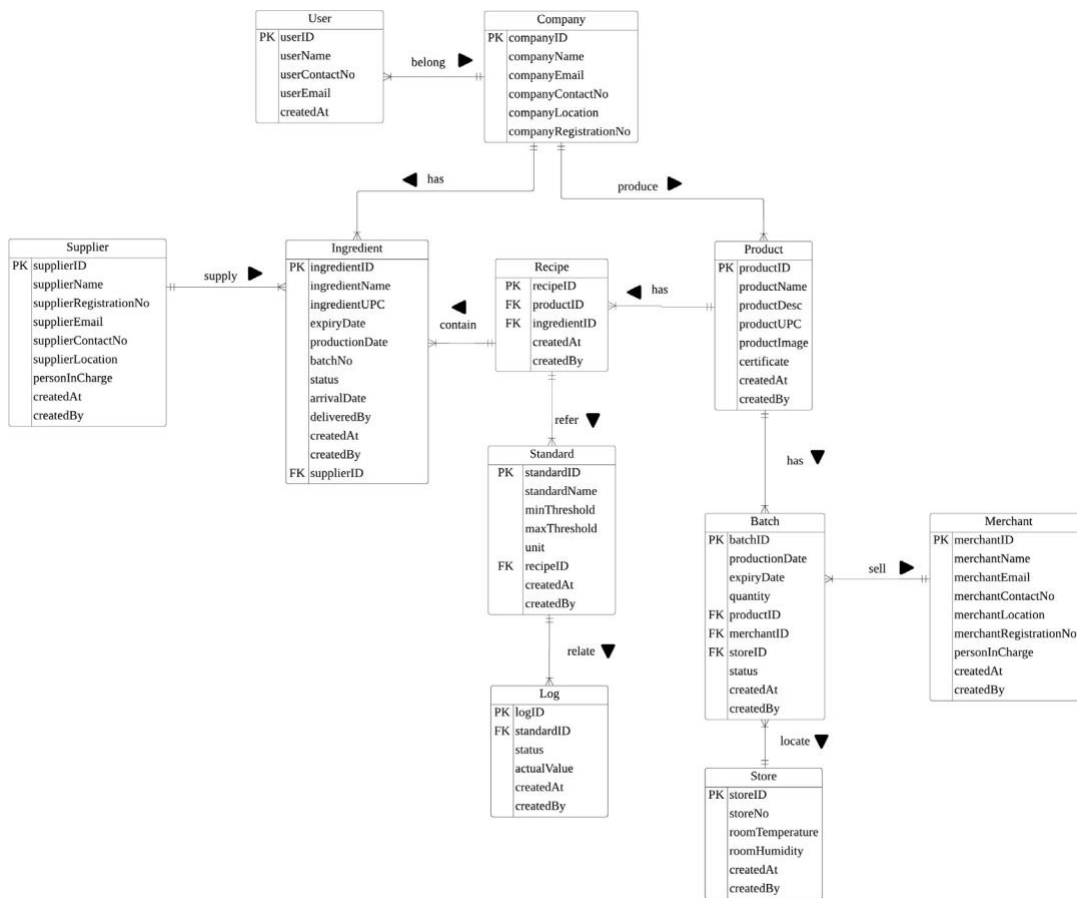


Figure 3.12 ERD for the proposed system

Figure 3.12 illustrates the entity relationship diagram of the proposed system. The details of each entity and attribute will be further discussed in section 3.2.6.

### 3.2.6 Database Design

The relationship type and the details of the attributes are illustrated in the tables below. The relationship between the entities is illustrated in table 3.1 whereas the data type and description for each and every attribute in the entities are described in the following tables (table 3.2 to table 3.12).

Table 3.1 Relationship type of the ERD

| Entity Name | Multiplicity | Relationship | Entity Name | Multiplicity |
|---|---|---|---|---|
| User | 1..* | belong | Company | 1..1 |
| Company | 1..1 | has | Ingredient | 1..* |
|  | 1..1 | produce | Product | 1..* |
| Supplier | 1..1 | supply | Ingredient | 1..* |
| Recipe | 1..1 | contain | Ingredient | 1..* |
|  | 1..1 | refer | Standard | 1..* |
| Standard | 1..1 | relate | Log | 1..* |
| Batch | 1..* | sell | Merchant | 1..1 |
| Product | 1..1 | has | Recipe | 1..* |
|  | 1..1 | has | Batch | 1..* |

Table 3.2 Entity User

| Attribute Name | Data Type | Description |
|---|---|---|
| userID | address | Transaction ID |
| userName | string | Record the full name displayed on the home page |
| userContactNo | string | Record the contact number of the company staff |
| userEmail | string | Record the email address of the company staff |
| createdAt | uint | Record the timestamp of user creation |

Table 3.3 Entity Company

| Attribute Name | Data Type | Description |
|---|---|---|
| companyID | address | Transaction ID |
| companyName | string | Record the business name of the company (manufacturer) |
| companyEmail | string | Record the email address of the company |
| companyContactNo | string | Record the contact number of the company |
| companyLocation | string | Record the address of the company |
| companyRegistrationNo | string | Record the registration number of the company. (12 digits for the new format and 6 digits with one business entity for old format) |

Table 3.4 Entity Supplier

| Attribute Name | Data Type | Description |
|---|---|---|
| supplierID | address | Transaction ID |
| supplierName | string | Record the business name of the supplier |
| supplierRegistrationNo | string | Record the registration number of the supplier |
| supplierEmail | string | Record the email address of the supplier |
| supplierContactNo | string | Record the contact number of the supplier |
| supplierLocation | string | Record the address of the supplier |

| Attribute Name | Data Type | Description |
|---|---|---|
| personInCharge | string | Record the name of person in charge |

Table 3.5 Entity Ingredient

| Attribute Name | Data Type | Description |
|---|---|---|
| ingredientID | address | Transaction ID |
| ingredientName | string | Record the name of the ingredient |
| ingredientUPC | uint | Record the universal product code of the ingredient |
| expiryDate | string | Record the expiry date of the ingredient |
| productionDate | string | Record the production date of the ingredient |
| batchNo | string | Record the batch number of the ingredient |
| status | string | Record the status of the ingredient (Safe or Alert) |
| arrivalDate | string | Record the arrival date of the ingredient |
| deliveredBy | string | Record the name of the delivery rider |
| supplierID | uint | Record supplier id (referene supplierID in supplier) |

Table 3.6 Entity Product

| Attribute Name | Data Type | Description |
|---|---|---|
| productID | address | Transaction ID |
| productName | string | Record the name of the product |

| productDesc | string | Record the product description |
|---|---|---|
| productUPC | uint | Record the universal product code of the product |
| productImage | string | Record the hash value of the image |
| productCertificate | string | Record the hash value of the file |

Table 3.7 Entity Recipe

| Attribute Name | Data Type | Description |
|---|---|---|
| recipeID | address | Transaction ID |
| productID | uint | Record product id (referene productID in product) |
| ingredientID | uint | Record ingredient id (referene ingredientID in ingredient) |

Table 3.8 Entity Standard

| Attribute Name | Data Type | Description |
|---|---|---|
| standardID | address | Transaction ID |
| standardName | string | Record the name of the processing standard |
| minThreshold | uint | Record the minimum threshold of a ingredient in a product |
| maxThreshold | uint | Record the maximum threshold of a ingredient in a product |
| standardOption | uint | As a flagged to determine IoT device |

| recipeID | uint | Record recipe id (referene recipeID in recipe) |
|---|---|---|

Table 3.9 Entity Log

| Attribute Name | Data Type | Description |
|---|---|---|
| logID | address | Transaction ID |
| standardID | uint | Record standard id (referene standardID in standard) |
| status | string | Record the status of a ingredient in a product (Safe or Alert) |
| actualValue | uint | Record the actual value of a ingredient in a product during the processing step |

Table 3.10 Entity Merchant

| Attribute Name | Data Type | Description |
|---|---|---|
| merchantID | address | Transaction ID |
| merchantName | string | Record the business name of the merchant |
| merchantEmail | string | Record the email address of the merchant |
| merchantContactNo | string | Record the contact number of the merchant |
| merchantLocation | string | Record the address of the merchant |
| merchantRegistrationNo | string | Record the registration number of the merchant |
| personInCharge | string | Record the name of person in charge |

Table 3.11 Entity Batch

| Attribute Name | Data Type | Description |
|---|---|---|
| batchID | address | Transaction ID |
| productionDate | string | Record the production date of a batch of products |
| expiryDate | string | Record the expiry date of a batch of products |
| quantity | uint | Record the total amount of products in a batch |
| productID | uint | Record product id (referene productID in product) |
| merchantID | uint | Record merchant id (referene merchantID in merchant) |
| status | string | Record the status of the batch (Safe or Alert) |

### 3.2.7   Overview of Mobile Application
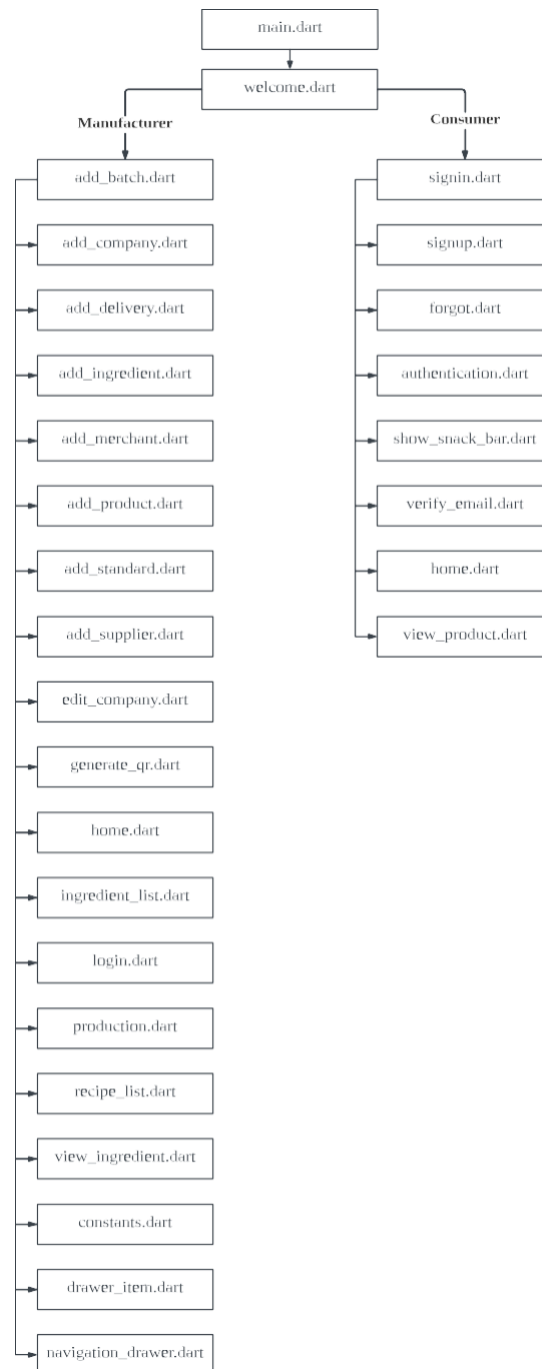


Figure 3.13 Overview of the mobile page

Figure 3.13 shows the overview of the mobile page for the proposed system. The master page called main.dart stores the navigation route of the page so that the application can navigate accordingly based on the navigation path. Chapter 5 will discuss the details of each page in detail.

## 3.3 Timeline
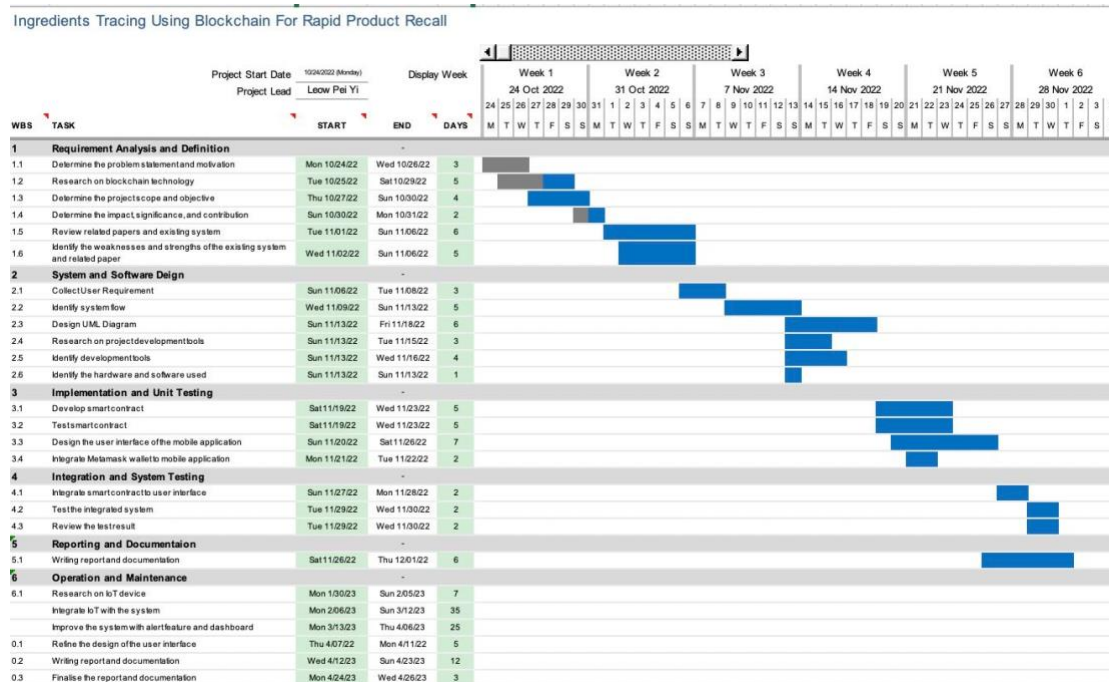


Figure 3.14 Timeline (Part 1)
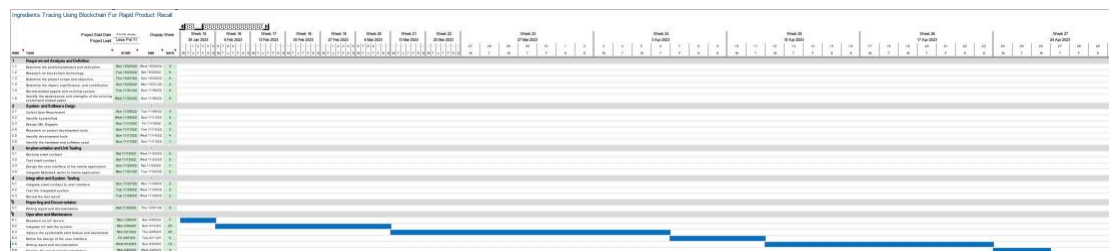


Figure 3.15 Timeline (Part 2)

Figures 3.14 and 3.15 show the timeline of the proposed system. This proposed project is estimated to be done within two trimesters, which include one short trimester (7 weeks) and one long trimester (14 weeks).

## 3.4 Discussion

Traditional ingredient tracing methods, such as centralized databases, typically rely on manual data entry and paper-based records which are more difficult to cross-check, easily tampered with, slower and less accurate than blockchain. This may result in delays in the recall process and a greater likelihood of contaminated products reaching consumers. In contrast, blockchain provides a more transparent, efficient, accurate, and secure method for tracking the source and flow of ingredients throughout the food supply chain.
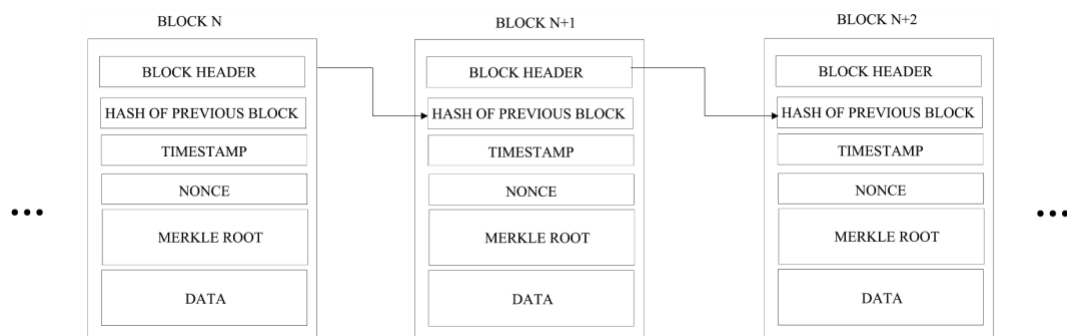


Figure 3.16 Structure of Blockchain

Blockchain is a distributed digital ledger that has the ability to create an immutable record of all transactions, helping to build trust and enhance transparency and traceability in the supply chain. This can be accomplished through the use of smart contracts, where the terms of the buyer-seller agreement are predetermined before distributing the product to the market. Therefore, quality control checks can be performed so that any product batches that do not meet the predefined terms will be rejected and not allowed to be distributed to the market to avoid costly recalls. In addition to this, each transaction will be stored in a block and linked as a chain. If any block is modified by a third party, then the following blocks will have different hash values, resulting in invalid hash values which fundamentally prohibits data tampering (as shown in figure 3.16). In addition, due to its decentralized nature, blockchain records every transaction in a shared and tamper-proof ledger where each transaction is secured and verified by the computer network. As a result, the changes are visible to all participants in the network, and they are broadcast to all other computers in the network since each computer keeps a copy of the ledger and all network participants have equal access to the transaction in the ledger to make sure there is no room for disputes.

However, without a decentralized ledger, the process of conducting product recalls and determining the source of contamination is more challenging because the flow of ingredients is more difficult to track, and the manufacturer can insist on distributing contaminated products to the market, resulting in increasing the risk of fraud. Furthermore, traditional ingredient tracing methods will delay the recall process because it is more difficult to identify contaminated products in paper-based records and conduct cross-checking.

In conclusion, blockchain technology offers several benefits to the ingredient tracing system over traditional methods. It enhanced transparency, traceability, and efficiency, and enabled rapid product recall, ultimately minimizing the risk of widespread contamination, protecting consumers' health, and increasing confidence in the food supply chain.

# CHAPTER 4

# System Design

This chapter illustrated how the proposed system is being developed and how the IoT devices are connected to the Raspberry Pi. Besides that, this chapter also provided the steps to configure the system.

## 4.1    Flowchart
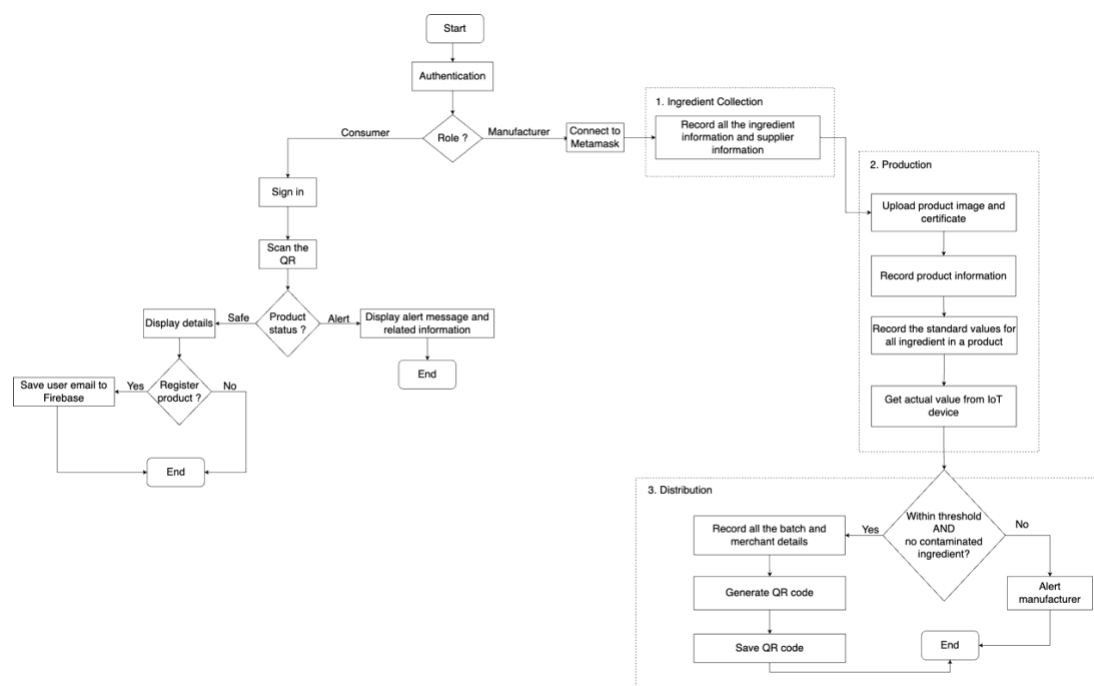


Figure 4.1 System flowchart

Figure 4.1 shows the flowchart of the proposed system, which illustrates the business flow from the manufacturer's perspective, starting with the ingredient collection, followed by production and distribution. Additionally, it showcases the consumer's perspective. The system will start with the authentication process to determine the role of the user. This is imperative as the system will be identical for both consumers and manufacturers. However, access control is fixed during the development phase of the system.

For the consumer, the system's functionalities are as simple as signing in to the system using the email address and password. Firebase authentication will be used here to authenticate the user account, and allow for the creation of the consumer account. Once successfully signed

in, the consumer can scan the QR code to get the product and ingredient information as well as their perspective status. Additionally, the system includes an alert feature which sends an email to the registered consumers in the event of contamination in their registered product. This could occur if any of the ingredients used in that particular product is contaminated. However, this function does not require any effort from the consumer because the notification of the alert is automated and only can be triggered by the manufacturer so it can be said transparent to the consumer.

On the other hand, the manufacturers first connect their Metamask account to the proposed system via WalletConnect. Upon successful connection, the system proceeds to the ingredient collection phase, allowing the manufacturers to store the information about the ingredients, and their respective suppliers on the blockchain. This is followed by the production phase, where the manufacturer can upload the product image and certificate file into the IPFS. Blockchain will be used to store the hash values returned by the IPFS as well as the product details. When creating new recipes for a product, an additional data entry step is required to enter standard processing steps, such as minimum and maximum temperature to heat up the ingredient. This step is critical because the smart contract ensures zero tolerance for outliers. Therefore, the value of each processing step will be taken from the IoT device, while the smart contract strictly adheres to the predefined standards to check if the actual value is within the range of safety and if the product contains contaminated ingredients. In case of any violations, the smart contract will update the status of the product to "Alert" and will not allow the manufacturer to add a new batch. The manufacturer will also receive a notification email explaining the reason for refusing to distribute the product. On the other hand, for the product that does not violate any rules, the manufacturer can enter distribution information, such as batch and merchant details, and generate and save the QR code to be included in the product for consumers to scan.

## 4.2    System Components Specification

Table 4.1 Raspberry Pi Specification

| Description | Specifications |
|---|---|
| Model | Raspberry Pi 4 Model B |
| SOC Type | Broadcom BCM2711 |
| CPU | Cortex-A72 (ARM v8) 64-bit |
| CPU Cores | 4 cores |
| RAM | 2GB |
| Storage | 16GB |
| Operating System | Raspberry Pi OS |
| Power | 5V DC via USB-C connector (Lowest acceptable 3A)<br><br>5V DC via GPIO header (Lowest acceptable 3A) |

Table 4.2 DHT 22 Specification

| Hardware | DHT 22/ AM2302 |
|---|---|
| Power Supply | 3.3-6V DC |
| Sensing Element | Polymer capacitor |
| Operating Range | Humidity 0-100%<br>Temperature -40-80 Celsius |
| Accuracy | Humidity 2-5%<br>Temperature <+-0.5 Celsius |
| Sensitivity | Humidity 0.1%<br>Temperature 0.1 Celsius |

Table 4.3 HX711 Amplifier Specification

| Hardware | HX711 Load Cell Amplifier Module |
|---|---|
| Power Supply | 3.3-6V DC |
| Input Resistance | 405+-10 Power Supply |
| Output Resistance | 350+-3Ω |
| Insulation Resistance | ≥5000MΩ (100VDC) |
| Excitation Voltage | 5VDC – 12VDC |
| Operating Current | <10 mA |
| Sensitivity | 1.0+-0.01mv/v |

CHAPTER 4

## 4.3 Circuits and Components Design

### 4.3.1 Raspberry Pi 4 Model B
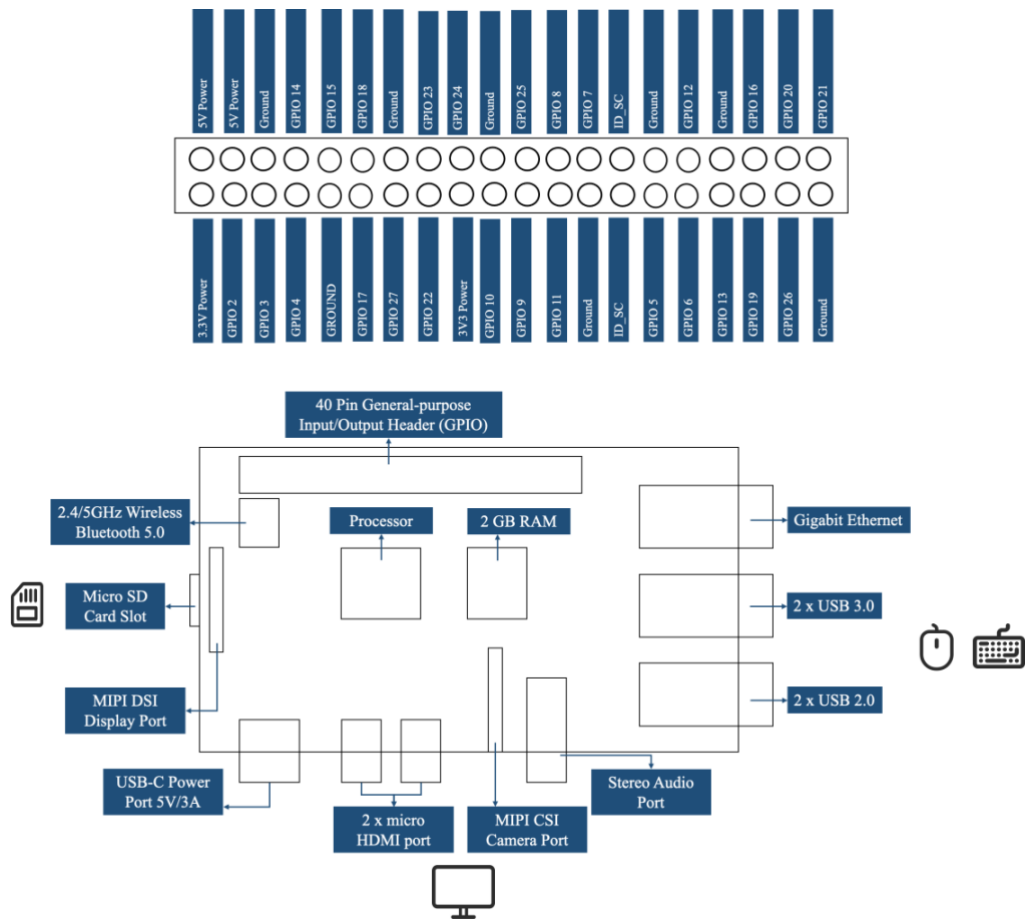


Figure 4.2 Raspberry Pi 4B (1)



Figure 4.3 Raspberry Pi 4B (2)

The pin layout and Raspberry Pi 4 used in this project are shown in figures 4.2 and 4.3.

### 4.3.2 DHT22 Sensor
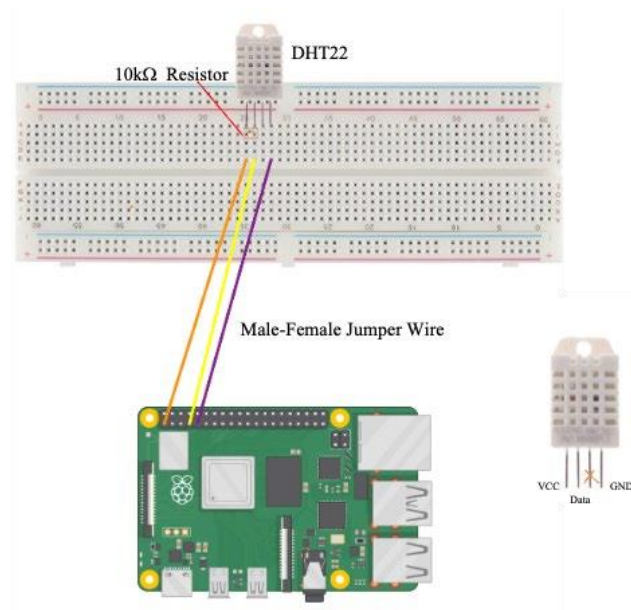


Figure 4.4 Wiring diagram of connecting the DHT22 sensor to the Raspberry Pi (1)
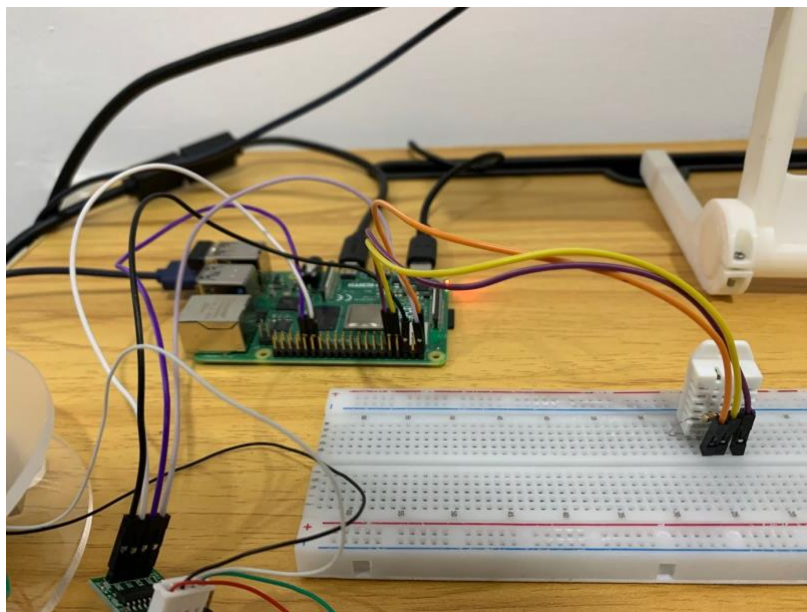


Figure 4.5 Wiring diagram of connecting the DHT22 sensor to the Raspberry Pi (2)

To connect the DHT22 sensor to the Raspberry Pi, the first thing to do is to connect the Raspberry Pi to the breadboard using the male-female jumper wires. Then, connect the VCC pin of the DHT22 sensor to the 3.3V rail on the breadboard, the data pin to a GPIO pin, and the GND pin to the ground rail on the Raspberry Pi (as shown in figure 4.4). As shown in figure 4.5, this project connects the data pin to the GPIO 4.

### 4.3.3  HX711 Amplifier with a 10kg Load Cell
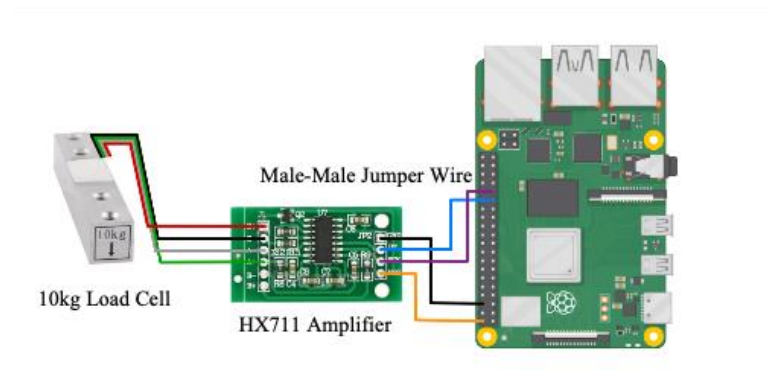


Figure 4.6 Wiring diagram of connecting the HX711 amplifier with a 10kg load cell to the
Raspberry Pi (1)
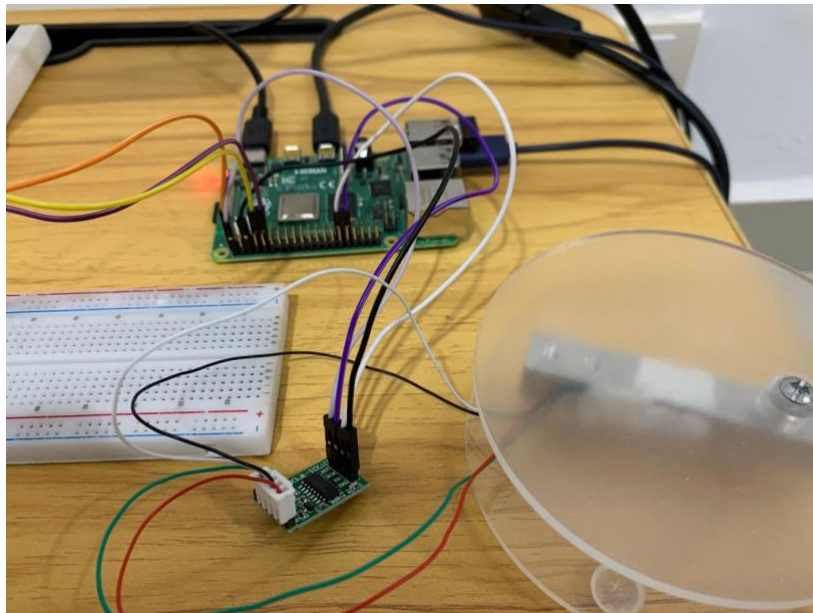


Figure 4.7 Wiring diagram of connecting the HX711 amplifier with a 10kg load cell to the
Raspberry Pi (2)

To connect the HX711 amplifier to the Raspberry Pi, the first thing to do is to connect the GND pin of the amplifier to the ground rail of the Raspberry Pi, the DT pin to the GPIO pin, the SCK pin to another GPIO pin, and the VCC pin to the 5V rail. Then, connect the load cell to the HX711 amplifier by connecting the red wire of the load cell to the E+ pin on the HX711 amplifier, black wire to the E-, white wire to the A-, and green wire to the A+ pin (as shown in figure 4.6). Figure 4.7 shows this project connects the DT pin to GPIO 5 whereas the SCK pin is connected to GPIO 6.

## 4.4    System Components Interaction Operations

### 4.4.1    System Components Interaction with IoT Device

```python
from adafruit_dht import DHT22
import board

# Set sensor type and pin number
DHT_SENSOR = DHT22(board.D4)


temperature = DHT_SENSOR.temperature
humidity = DHT_SENSOR.humidity
```

Figure 4.8 Code snippet of DHT22 sensor

```python
import RPi.GPIO as GPIO
from hx711 import HX711

# Set the HX711 pins and calibration factor
# dout pin = 5, sck pin = 6

hx = HX711(5, 6)
referenceUnit = 235
hx.set_reference_unit(referenceUnit)

hx.reset()
hx.tare()

weight = hx.get_weight()
```

Figure 4.9 Code snippet of HX711 amplifier with load cell
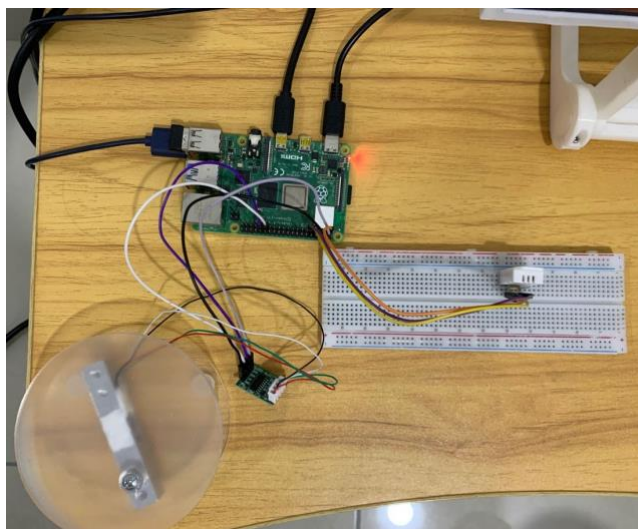


Figure 4.10 Wiring diagram of connecting all sensors to the Raspberry Pi

Referring to the code snippet shown in figure 4.8, the first thing to do is to import the DHT22 class and board module to read data from the DHT22 sensor and define the GPIO pins on the board. Then, set the sensor type to DHT22 with the specific pin number where the sensor is connected. In this example, the pin number is set to 4 and the DHT22 is set to a variable called DHT_SENSOR. Lastly, DHT22_SENSOR object will retrieve temperature and humidity from the sensor.

Referring to the code snippet shown in figure 4.9, the first thing to do is to import the hx711 and PRI.GPIO libraries to read weight data from the HX711 amplifier and the load cell. Then, identify the data output (DOUT) and serial clock (SCK) pins (refer to guideline shown in figure 4.6) and sets up the HX711 pins. In this case, the DOUT pin is connected to GPIO pin 5 and the SCK pin is connected to GPIO pin 6. The calibration factor is also set to 235, which is used to convert the HX711 output readings to weight values. After initialising the HX711 object and taring the weight, hx.get_weight function will retrieve the weight from the HX711 amplifier and load cell.

Once the Raspberry Pi has successfully retrieved the sensor data from the sensors, this project saved the sensor data into a JSON and sends it to the Flutter application through Websocket while sends to the Ubidot through an HTTP POST request. The flutter application will save the sensor data to the blockchain and perform quality detection. The program will start running when the command "python3 filename" is run in the Raspberry Pi terminal. Replace the filename with the file name of the Python file where the code is placed. In this example, the filename is sensors.py. The wiring diagram of connecting the HX711 amplifier with a 10kg load cell and the DHT22 sensor to the Raspberry Pi is shown in figure 4.10.

**4.4.2   System Components Interaction with Dashboard**

```
child: WebviewScaffold(
  url: url,
  withZoom: false,
  withLocalStorage: true,
  withOverviewMode: true,
), // WebviewScaffold
```

Figure 4.11 Code snippet of WebviewScaffold

Referring to the code snippet shown in figure 4.11, the proposed system uses the WebviewScaffold widget to integrate the Ubidot dashboard into the Flutter application. The url is set to 'https://stem.ubidots.com/app/dashboards/<dashboard_id> where the <dashboard_id> can be found in the URL link of the dashboard in the Ubidots platform. This seamless integration of the Ubidot dashboard into the Flutter application provides the manufacturer with a user-friendly way to monitor and analyze sensor data, without the need for switching between different interfaces to view different data.

Figure 4.12 Actual weight of the objects          Figure 4.13 Dashboard data
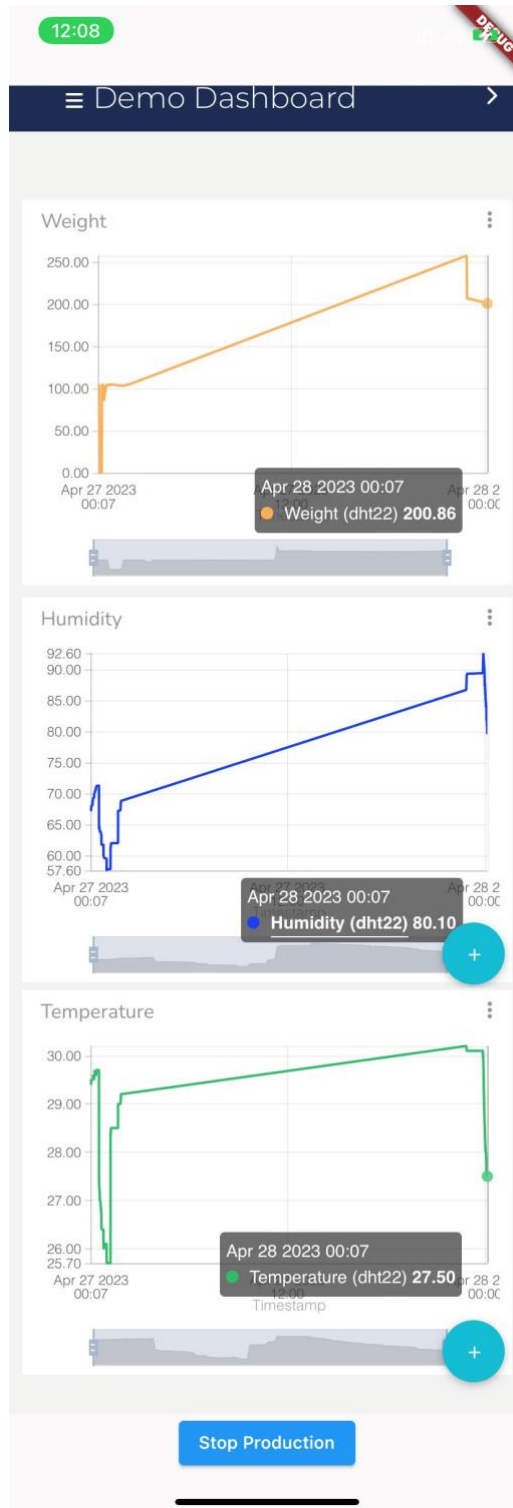
As shown in figures 4.12 and 4.13, the actual weight of the objects is around 200 grams (120 grams and 80 grams) and the weight value shown in the dashboard is also around 200 grams. This shows that the system is able to capture the real-time data accurately.

# CHAPTER 5

# System Implementation

The features of the proposed system and the configuration of the proposed system are shown in this chapter. The system features will be divided into two sections, which are the manufacturer's view and the consumer's view.

## 5.1    Hardware Setup

Table 5.1 Laptop Specification

| Description | Specifications |
|---|---|
| Model | Apple MacBook Air M1 2020 |
| Processor | Apple M1 chip with 8-core CPU, and 16-core Neural Engine |
| Operating System | macOS Monterey |
| Graphic | Retina display with True Tone, 8-core GPU |
| Memory | 16GB unified memory |
| Storage | 512GB SSD |

Table 5.2 Mobile Specification

| Description | Specifications |
|---|---|
| Model | iPhone XR |
| Processor | A12 Bionic processor |
| Software Version | 15.2 |
| RAM | 3GB |
| Storage | 128GB |

## 5.2    Setting and Configuration
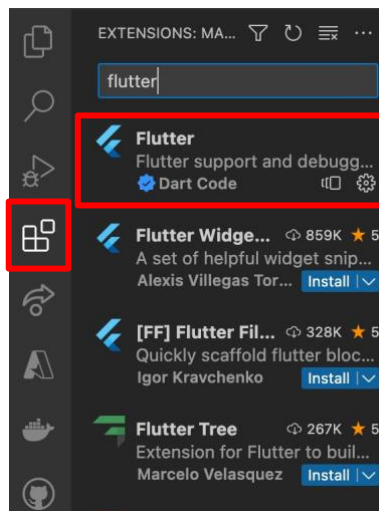


Figure 5.1 Extensions panel of the Visual Studio Code
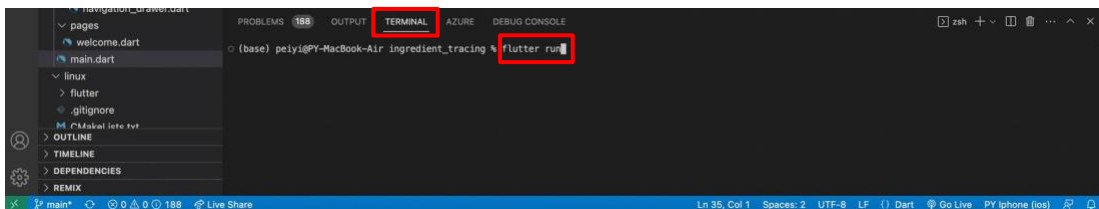


Figure 5.2 Run command in the terminal

To run the proposed system on Visual Studio Code, the first step is to install the latest version of Visual Studio Code, Flutter SDK, and Dart SDK on the computer. Then, install the Flutter and Dart plugins from the Extensions panel of the Visual Studio Code (shown in figure 5,1). In order to run the proposed system on the mobile device, it is necessary to connect the mobile device to the computer using the lightning cable. Lastly, it is recommended to run the command "flutter devices" in the terminal to ensure that the device is recognized by the flutter environment before running the command "flutter run" to launch the flutter application on the mobile device (shown in figure 5.2).
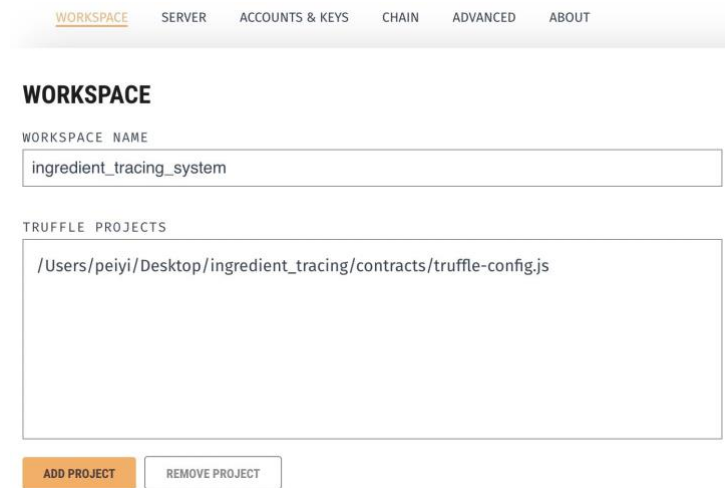
Figure 5.3 Add project to Ganache

To set up the Ganache on the proposed system, the first thing is to install the Ganache from the official website. After installation, launch the Ganache and create a new workspace and add the configuration file of the Truffle project in order to connect the deployment environment to the Ganache network (shown in figure 5.3).
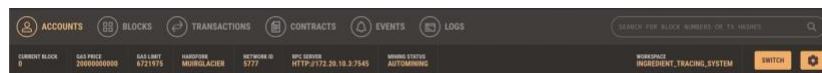


Figure 5.4 Server of the Ganache
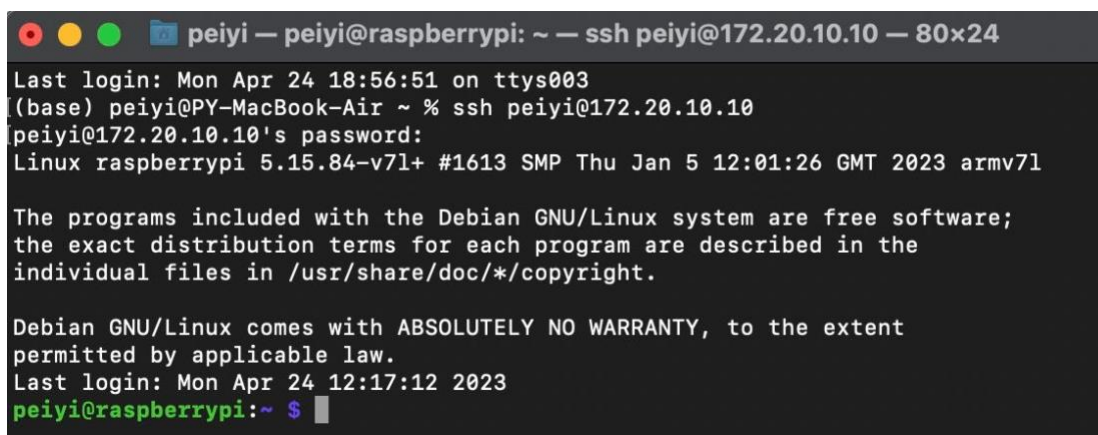


```
module.exports = {
  networks: {
    development: {
      host: "172.20.10.3",
      port: 7545,
      network_id: "*"
    },
  },
  contracts_directory: "./contracts",
  compilers: {
    solc: {
      version: "0.8.17",
    },
  },

  db: {
    enabled: false,
  },
};
```

Figure 5.5 Content of truffle-config.js

To create a new Truffle project, first, install the Truffle on the system by running the command "npm install -g truffle" in the terminal. Then, navigate the project directory and run the command "truffle-init" on the terminal to create a basic project structure with the necessary files and folders, such as the contracts folder for writing the smart contracts. In the "truffle-config.js" file, change the host to the BPC server of the blockchain, set the port number to 7545, and set "contracts_directory" to the directory where the smart contract is placed (as shown in figures 5.4 and 5.5). Lastly, navigate to the directory of the smart contract and run the command "truffle migrate" in the terminal in order to deploy the smart contract on the Ganache network and run "truffle compile" to compile the smart contract code.



Figure 5.6 Establish SSH connection to the Raspberry Pi

To establish an SSH connection to the Raspberry Pi, enable SSH on the Raspberry Pi by running the command "sudo raspi-config" in the terminal of the Raspberry Pi. Then, connect the Raspberry Pi to the same network as the computer and run the command "ssh raspberryPiUserName@raspberryPiIPAddress" in the terminal by replacing the raspberryPiUserName with the username of the Raspberry Pi user account and raspberryPiIPAddress with the IP address of the Raspberry Pi (shown in figure 5.6). Lastly, enter the password for the Raspberry Pi account. Once successfully connected, use the "cd" command to navigate to the directory where the sensors.py is placed and run the command "nano sensors.py" to modify the content of the Python script. Before running the command "python3 sensors.py" to execute the Python script, run the command "sudo pip3 install Adafruit_DHT" and "sudo pip3 install hx711" to install the Adafruit_DHT module and hx711.

## 5.3    System Operation

### 5.3.1    Manufacturer View
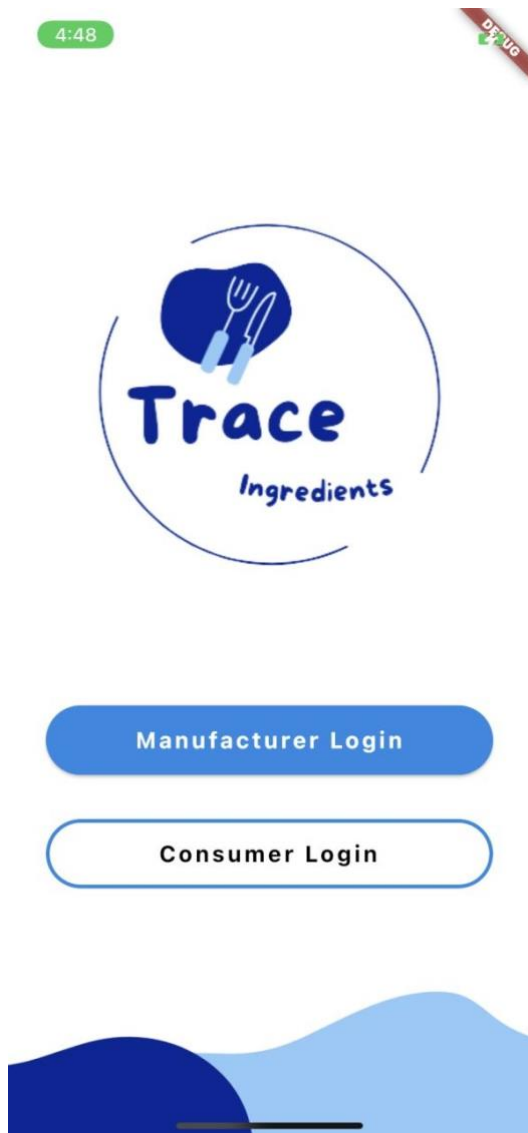


Figure 5.7 Main page of the proposed system
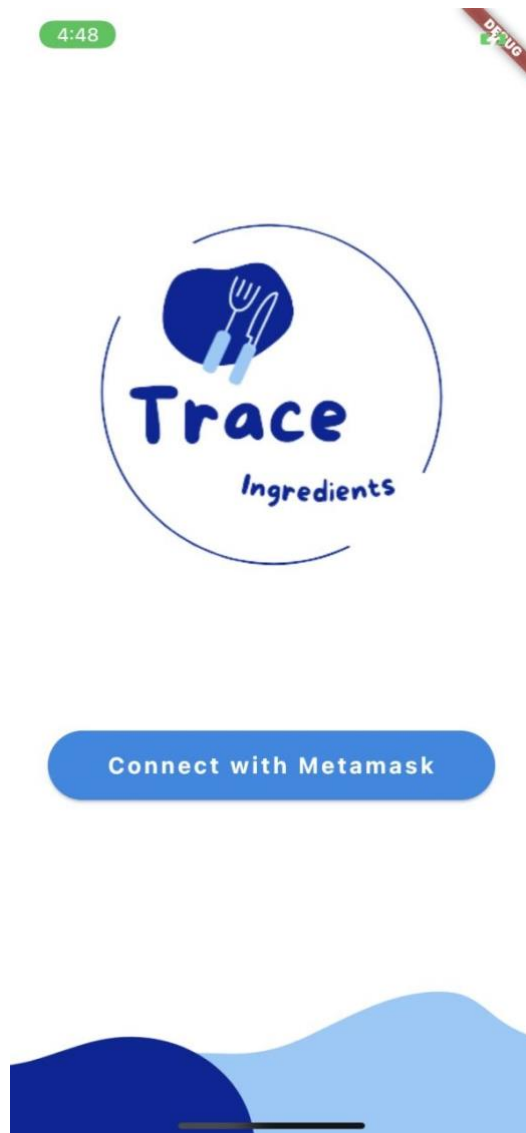
Figure 5.8 Connect to Metamask
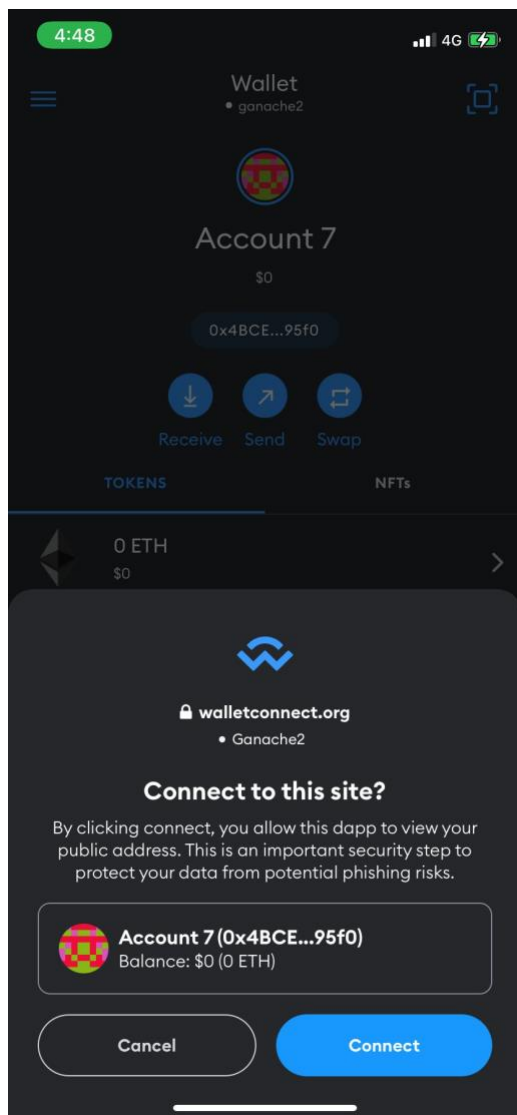
Figure 5.9 Metamask home page
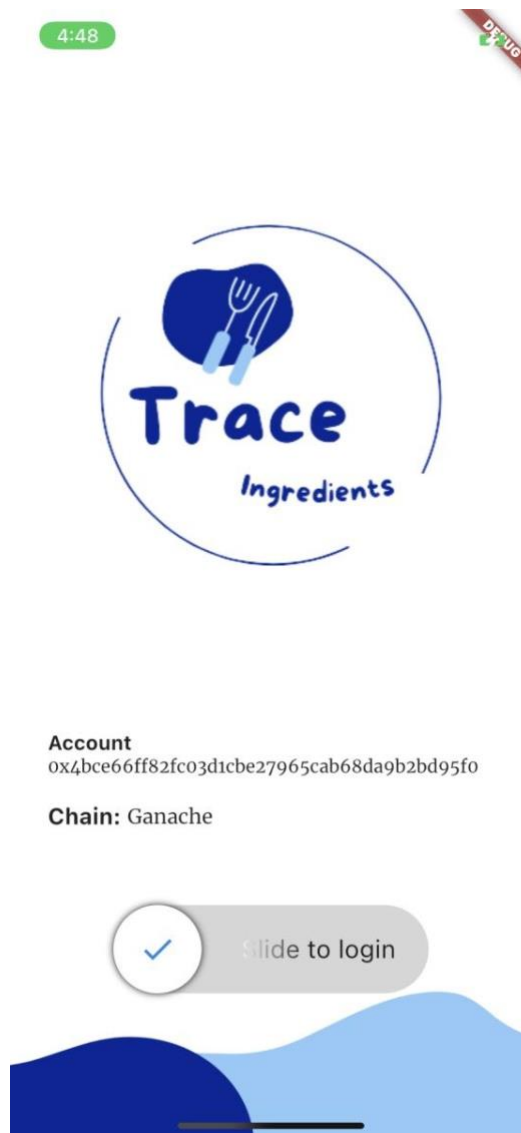


Figure 5.10 Display account details

Figure 5.7 shows the main page of the proposed system. This page will allow the user to choose whether to log in as a manufacturer or consumer. If the user clicks on the "Manufacturer Login", they will be navigated to the login page of the manufacturer, as shown in figure 5.8. Once the user clicks on the button called "Connect with Metamask", the system will open the Metamask application (figure 5.9) that has been installed on the mobile and let the users connect their Metamask wallet to the proposed system. If the Metamask wallet is successfully connected to the proposed system, the system will navigate back to the page of the proposed system, as shown in figure 5.10  to display the account address and chain name of the connected account.

Figure 5.11 Add company information form

Figure 5.12 Dialogue message (add company)

Once the user slides the slider, the user will be navigated to the add company information page if the company information has not been registered to the account yet, as shown in figure 5.11. The dialogue message displayed in Figure 5.12 will be shown after the company information has been added successfully. Then, the user will be navigated to the home page of the proposed system.

If the company information is already registered in the account, the user will be navigated to the home page immediately after the slider is swiped.
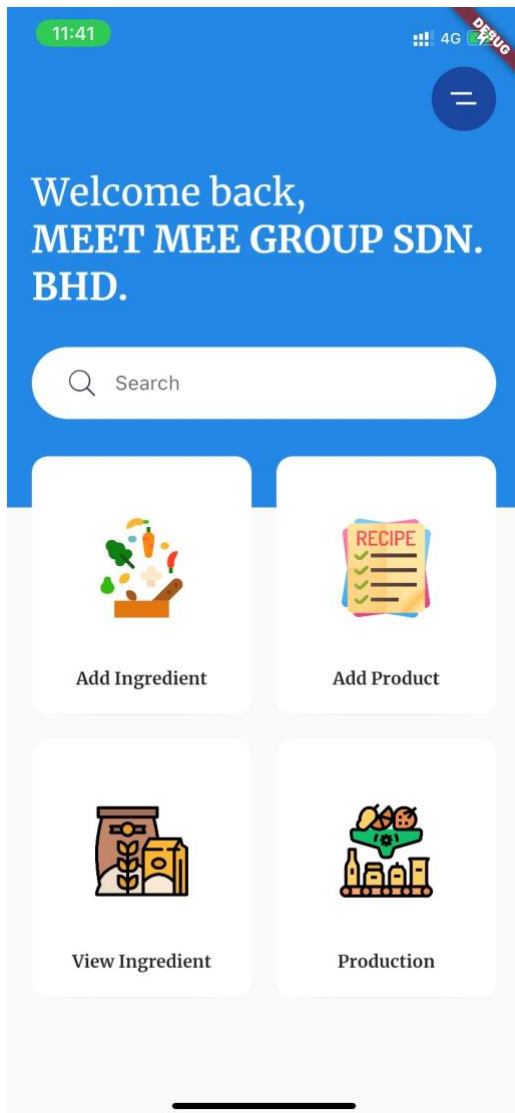
Figure 5.13 Home page of the proposed system
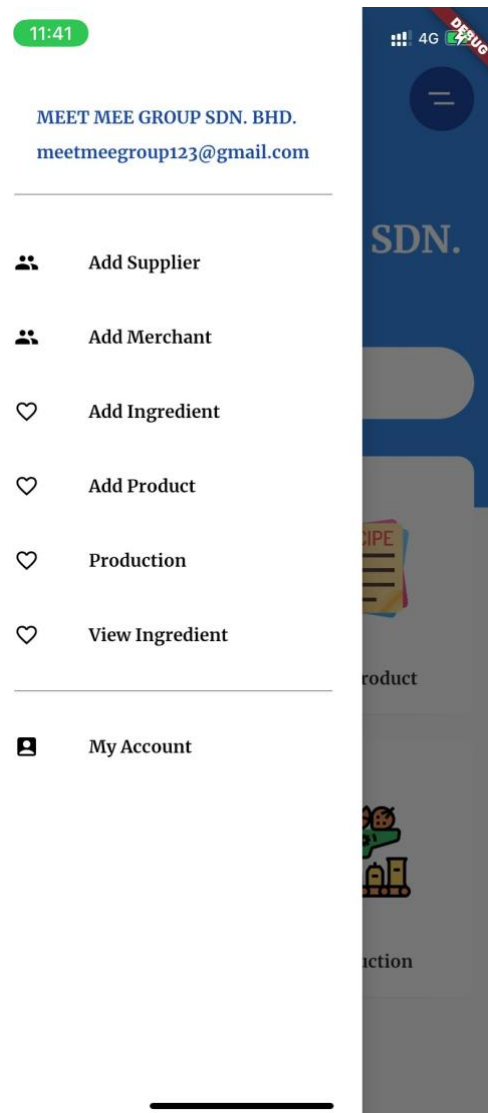
Figure 5.14 Navigation drawer of the proposed system

Figure 5.13 shows the home page of the proposed system that allows the user to navigate to the specific page to store the information required in the ingredient collection, processing, and distribution phase. The user can also click on the menu button located on the top right of the screen to open the navigation drawer, as shown in figure 5.14.

Figure 5.15 Add supplier information form

Figure 5.16 Dialogue message (add supplier)

The user can click on the "Add Supplier" button displayed in figure 5.14 to navigate to the add supplier form, as shown in figure 5.15. The user can click on the "Add Supplier" button to store the supplier information in the blockchain and the dialogue message displayed in figure 5.16 will be shown if the supplier information is added successfully.

Figure 5.17 Add merchant information form



Figure 5.18 Dialogue message (add merchant)

This step is similar to the step to add supplier information. The user can click on the "Add Merchant" button displayed in figure 5.14 to navigate to the add merchant form, as shown in figure 5.17. The user can click on the "Add Merchant" button to store the merchant information in the blockchain and the dialogue message displayed in figure 5.18 will be shown if the merchant information is added successfully.

Figure 5.19 Add ingredient information form
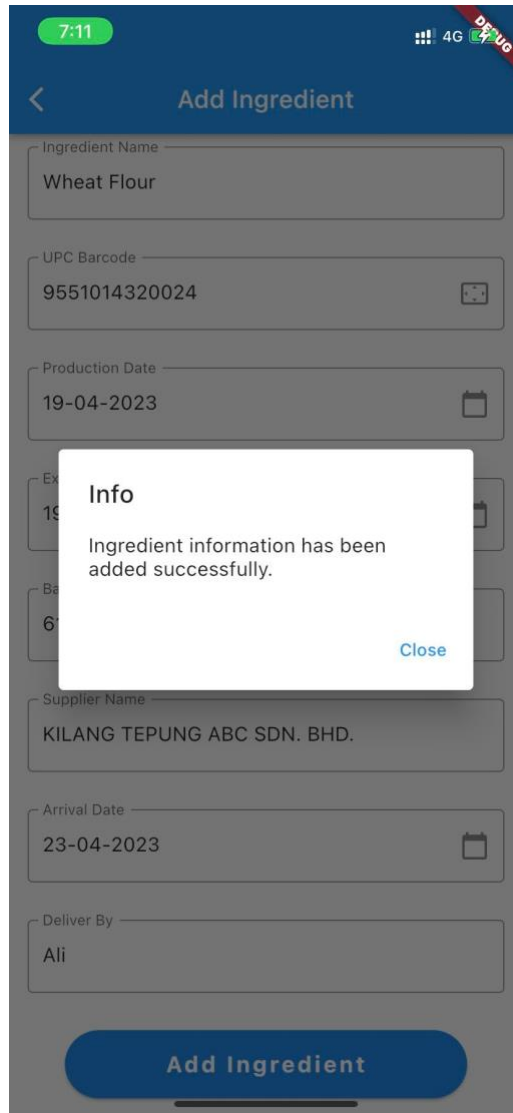


Figure 5.20 Dialogue message (add ingredient)



Figure 5.21 Open camera to scan barcode

This step is similar to the step mentioned above. However, the add ingredient form will open the phone camera when the user clicks on the icon button located at the UPC barcode text field, as shown in figure 5.21. Then, the user is required to fill in all the fields in the add ingredient form shown in figure 5.19 in order to store the ingredient information in the blockchain for tracing purposes. When the ingredient information is successfully added to the blockchain, it will be prompted with the dialogue message shown in figure 5.20.
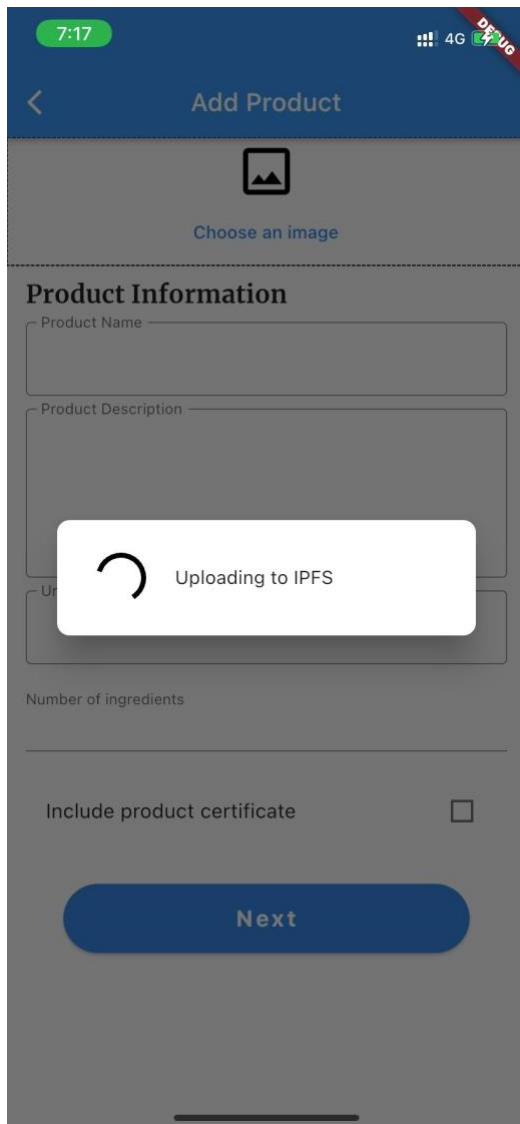


Figure 5.22 Upload product image to IPFS
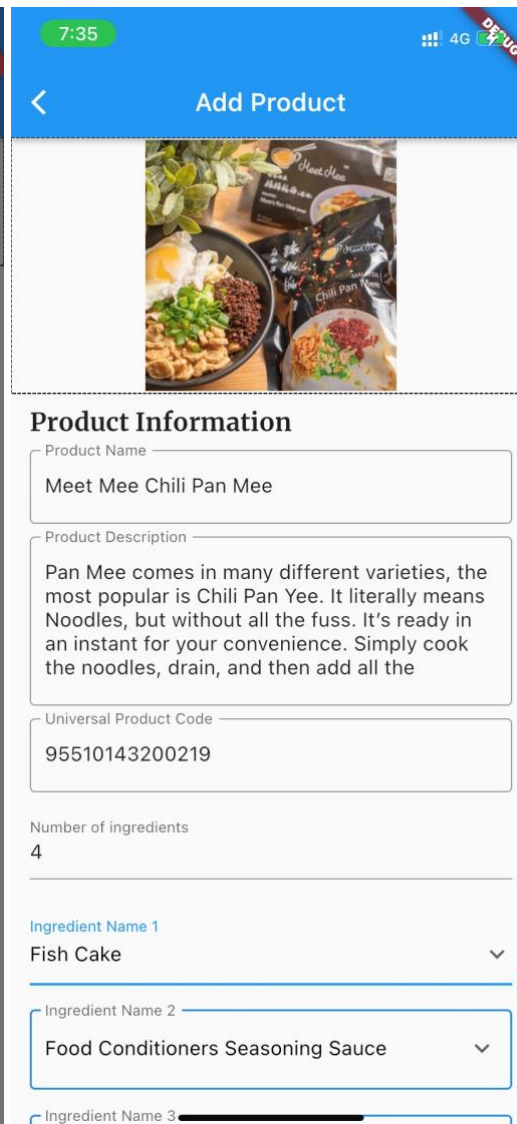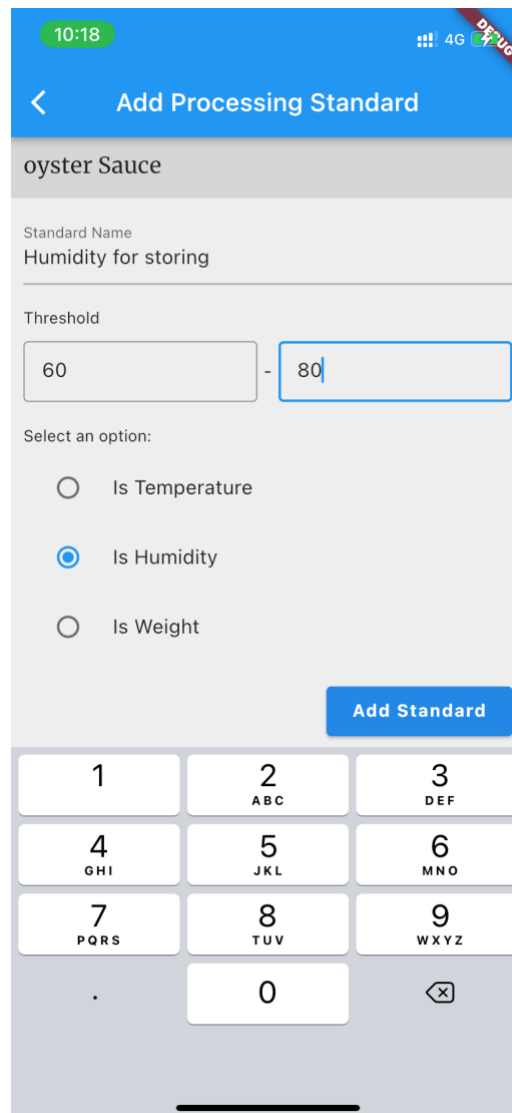


Figure 5.23 Display product image

Figure 5.24 Add product information form

Figure 5.25 Dialogue message (add product)

Figure 5.22 illustrates the user can upload the product image to the IPFS by selecting an image from the phone gallery. Then, the system will display the product image in the user interface (as shown in figure 5.23) after the IPFS return the hash value of the image to the system. The same procedure applied to upload the certificate file. In the add product information form displayed in figures 5.24, the user can enter the product details as well as enter the total number of ingredients used in that product. The number of drop-down menus on the interface depends on the number of ingredients enter by the user. Then, the user can select the ingredient from the items in the drop-down menu. When the product information is successfully added to the blockchain, it will be prompted with the dialogue message shown in

figure 5.25. The user is required to click on the "Add Processing Standard" button to navigate to the add standard page.



Figure 5.26 Add processing standard page

Figure 5.26 shows the add processing standard page that allows the user to add the minimum and maximum threshold for each ingredient in a product. The user can add more than one processing standard for one ingredient by clicking the "Add Standard" button.
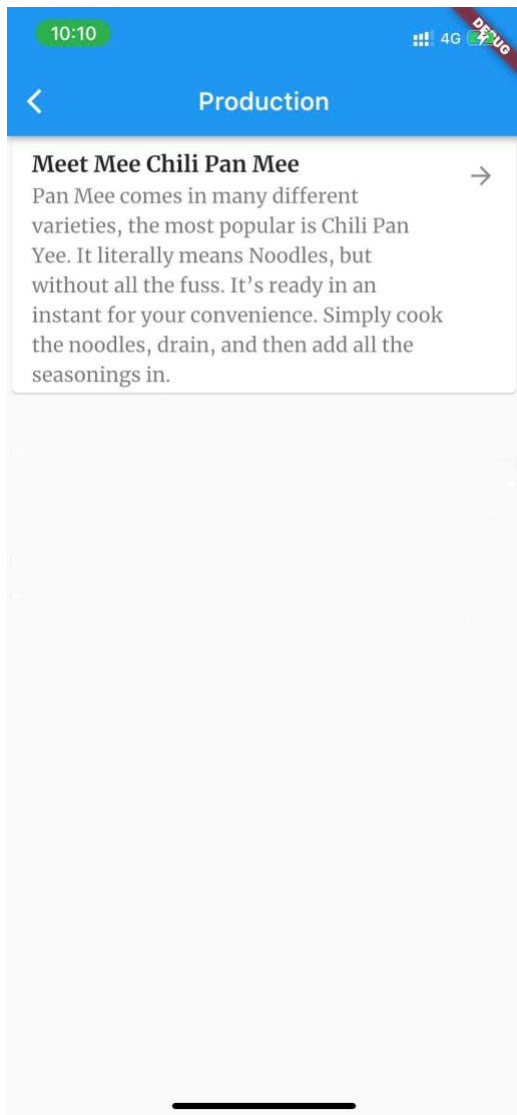
Figure 5.27 Product list
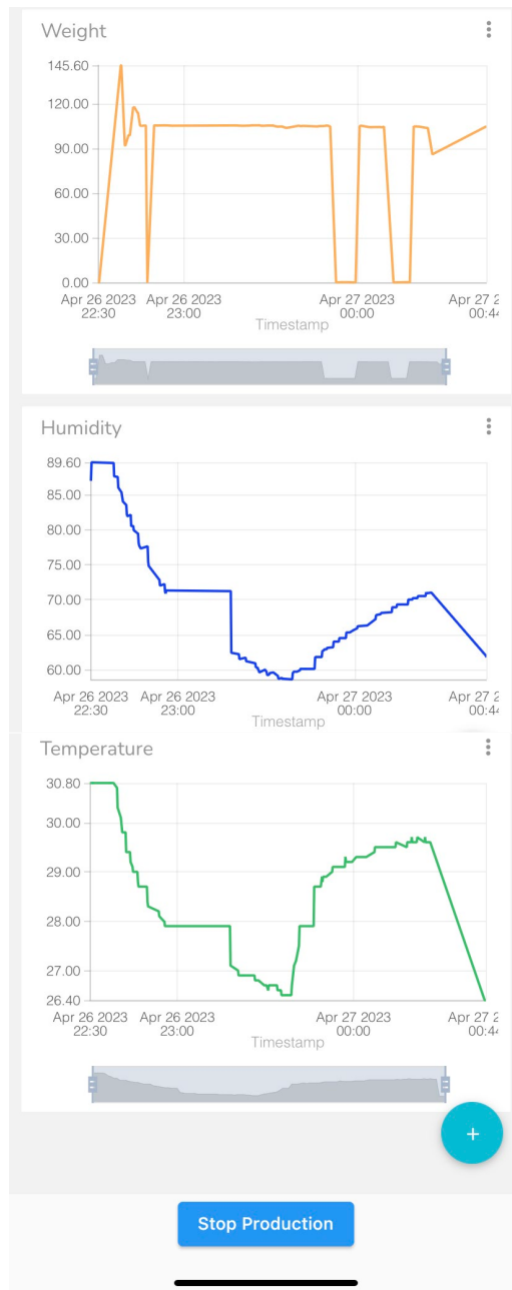


Figure 5.28 Dashboard

The user can click on the "Production" button on the home page to view the list of products added by the manufacturer. Figure 5.27 shows the name and description of a product in the list view and allows the user to click on the arrow icon in order to start the production and view the real-time data while stop the production by clicking the "Stop production" button, as shown in figure 5.28.
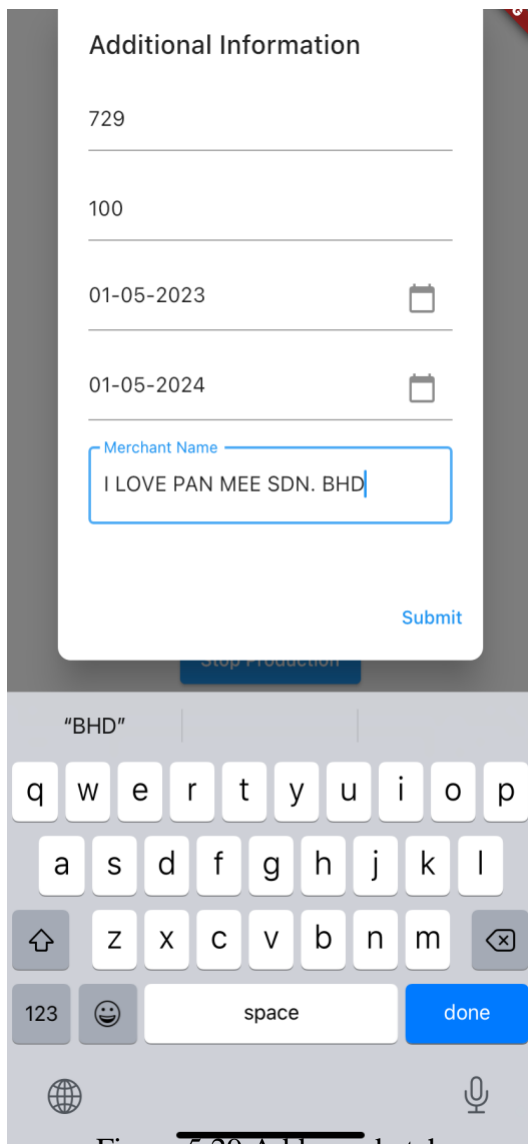
Figure 5.29 Add new batch
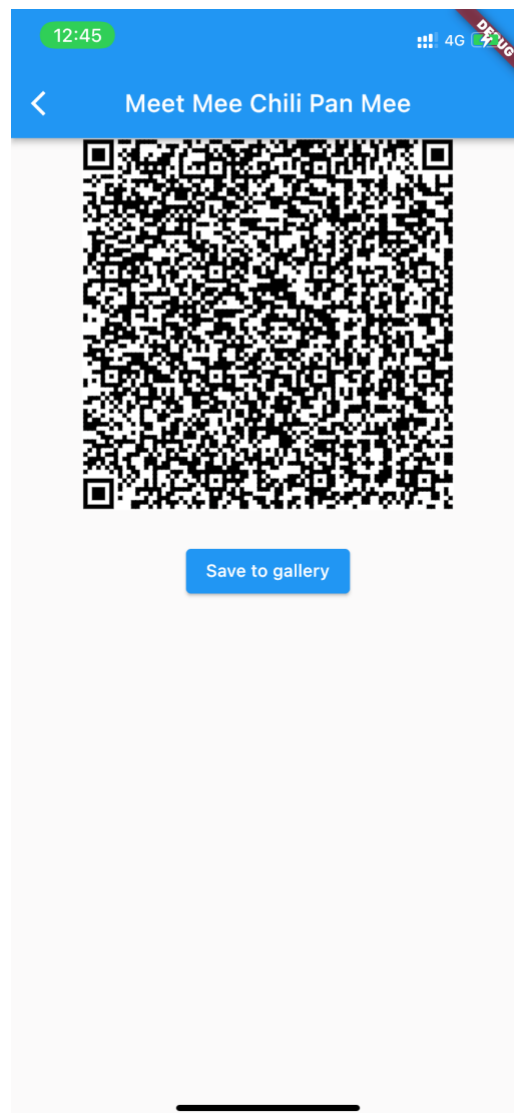


Figure 5.30 Generated QR code

After the user stops the production, the user can click on the "Submit" button to add new batch details, as shown in figure 5.29, in order to create a new batch record and generate a QR code so that the generated QR code can be attached to the packaging of the physical item and let the consumer scan. As shown in figure 5.30, the system shows the QR code for this specific product batch and the user can save the generated QR code to the gallery for future reference.

Figure 5.31 Dashboard (violate        Figure 5.32 Alert message
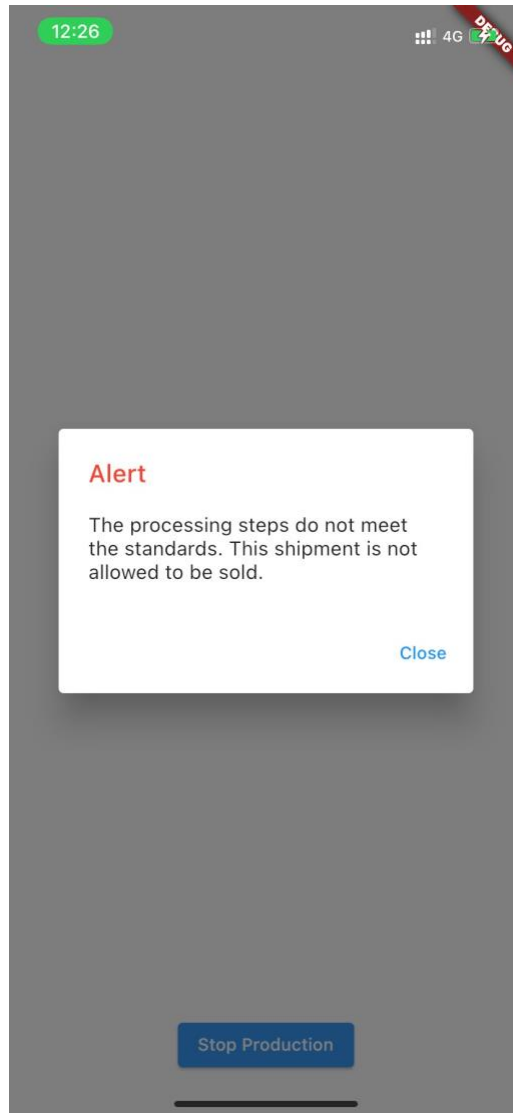
processing standard)

However, if any of the values retrieve from the sensor are not within the acceptable range of its processing standard or the ingredient used is contaminated, the user is not allowed to add a new batch to prevent the user from distributing the low-quality product to the market. Hence, the alert message shown in figure 5.32 will be prompted. Figure 5.31 shows that the temperature is not within its threshold.
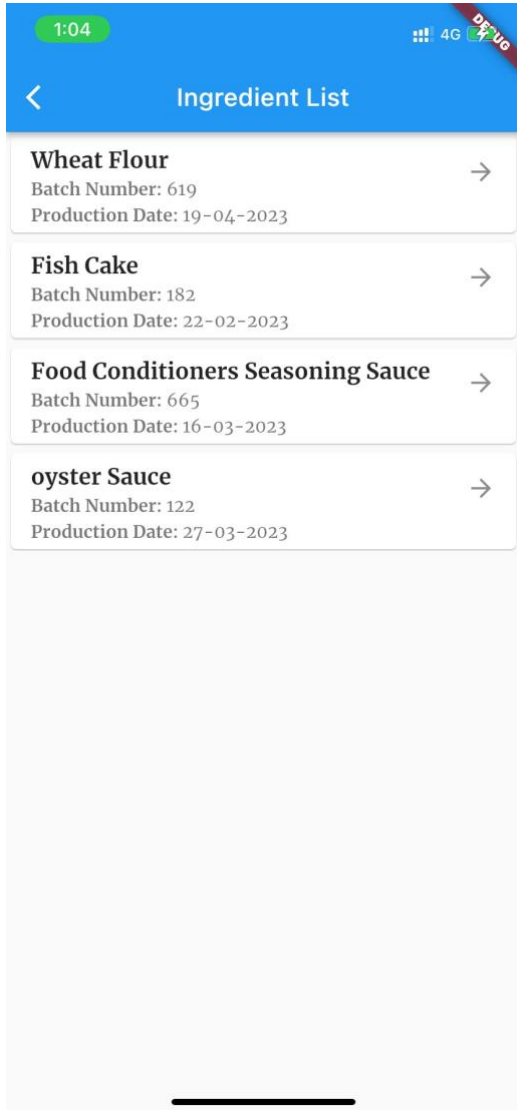
Figure 5.33 View the list of ingredients
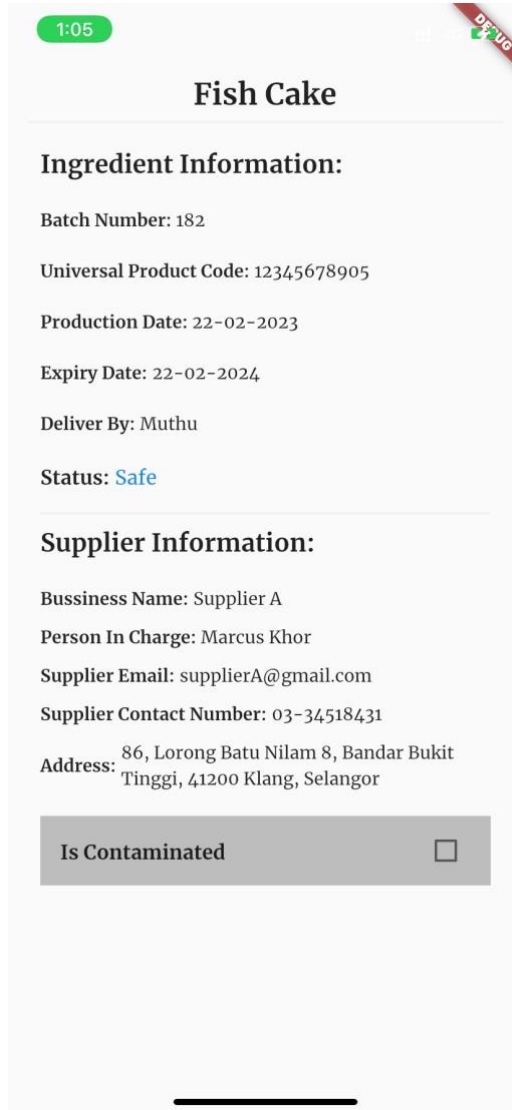


Figure 5.34 View the details of a specific ingredient
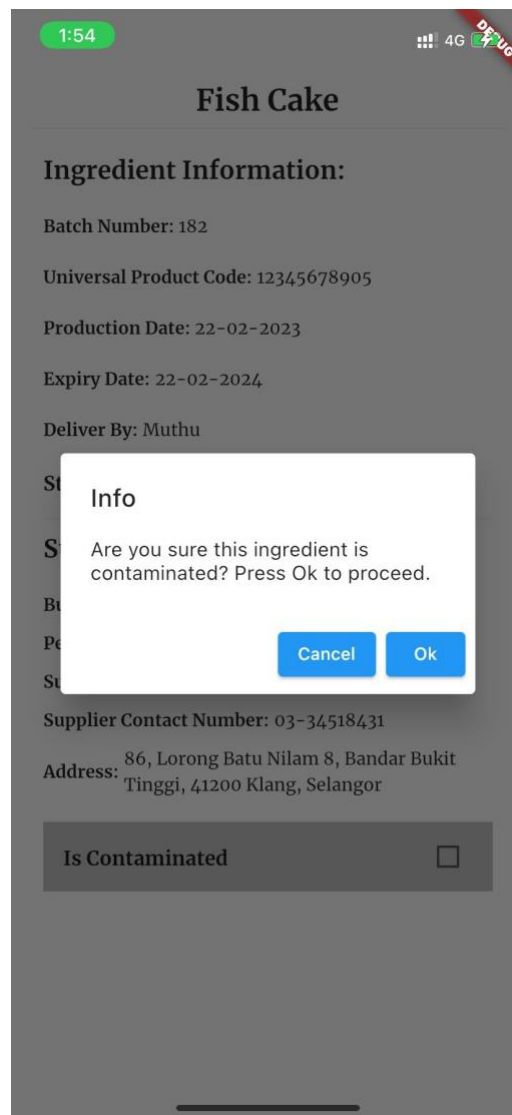
Figure 5.35 Confirmation message

The user can click on the "View Ingredient" button on the home page to view the list of ingredients added by the manufacturer. The ingredient list shown in figure 5.33 displays the ingredient name, batch number, and production date of all ingredients. If the user wants to get more details about a specific ingredient, the user can click on the arrow icon located at the end of the list and view the detailed information about the ingredient (figure 5.34). Moreover, the user can update the status of the ingredient by checking the check box. A confirmation message shown in figure 5.35 will be prompted to confirm with the user whether to mark that specific ingredient as contaminated.
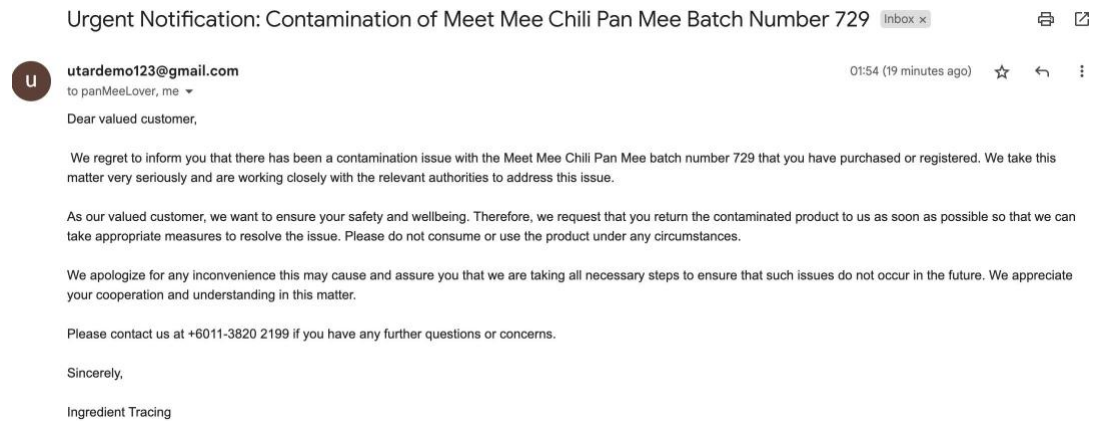
Figure 5.36 Alert email message to the consumer and merchant
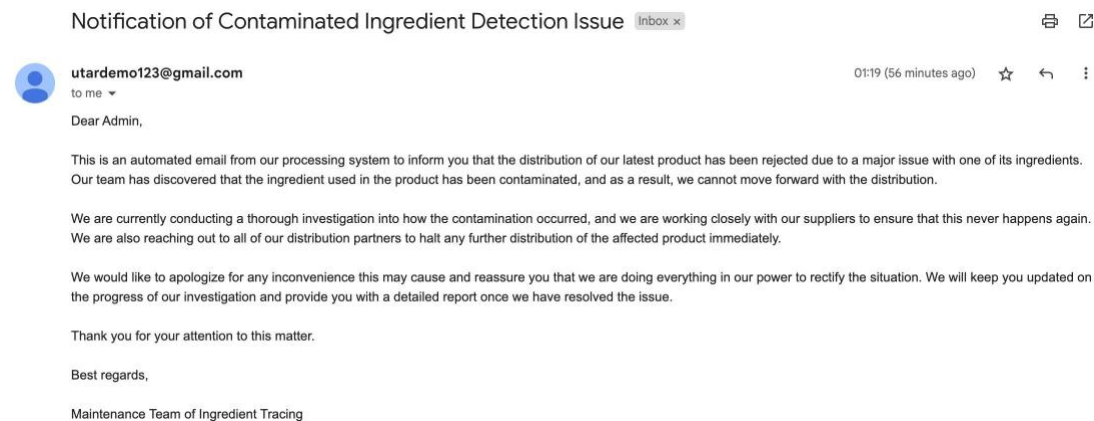


Figure 5.37 Alert email message to the manufacturer (1)
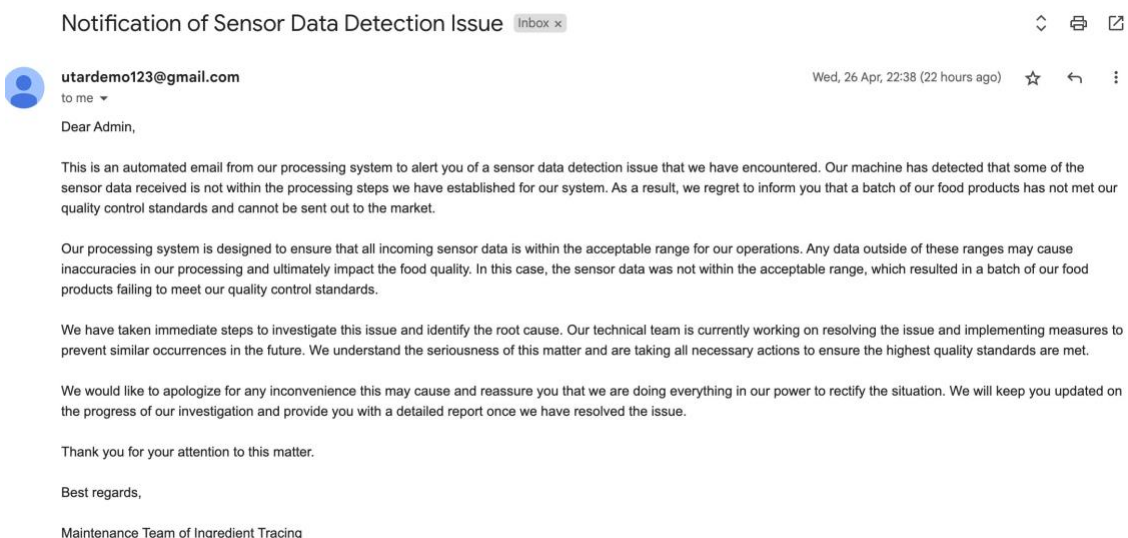


Figure 5.38 Alert email message to the manufacturer (2)

Figure 5.36 shows the alert email that will be received by the consumer and merchant who has purchased the product when any of their registered product is marked as contaminated. This can occur when there is a contamination issue happen in one of the ingredients used in this specific product. Then, the manufacturer will receive the alert message shown in figure 5.37 when any of the ingredients used in the product is contaminated or receive the alert message shown in figure 5.38 when any of the values retrieved from the sensor is not within its threshold.

## 5.3.2   Consumer View
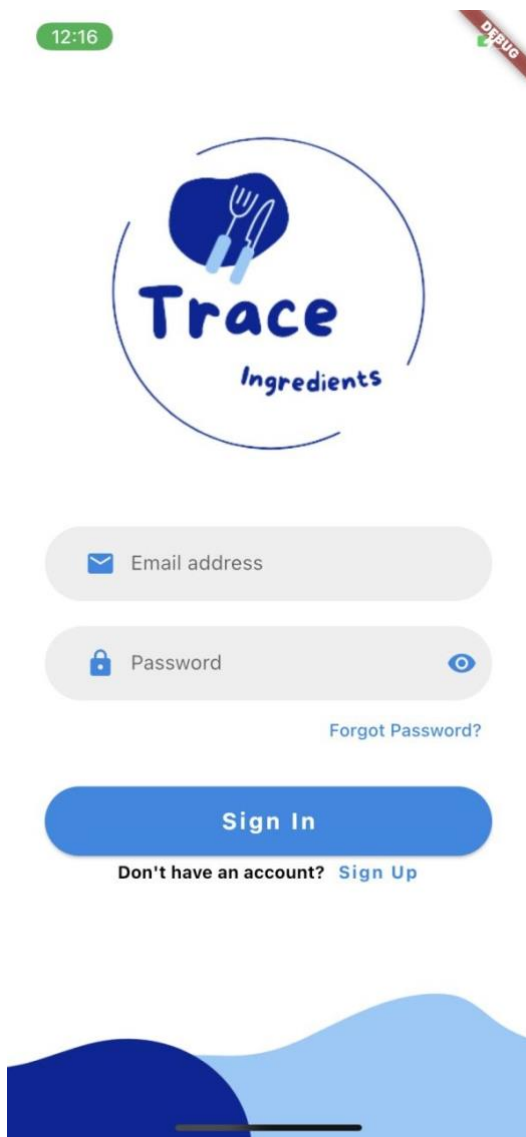


Figure 5.39 Log in page of consumer          Figure 5.40 Scan QR code
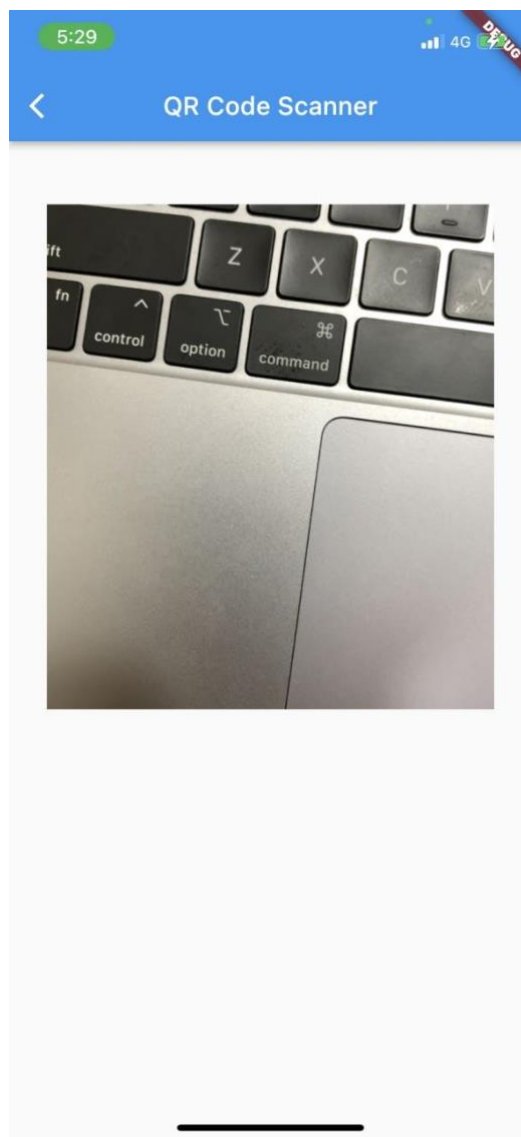
The user will be navigated to the login page of the consumer if the user selects "Consumer Login" on the main page of the proposed system. Figure 5.39 is the login page of the consumer that requires the user to log in using their email address and password. The user can also sign up for a user account by clicking on the "Sign Up" button.

Once the user has successfully logged in to the proposed system, the system will open the mobile camera of the user and allow the user to scan the QR code attached to the product packaging, as shown in figure 5.40.
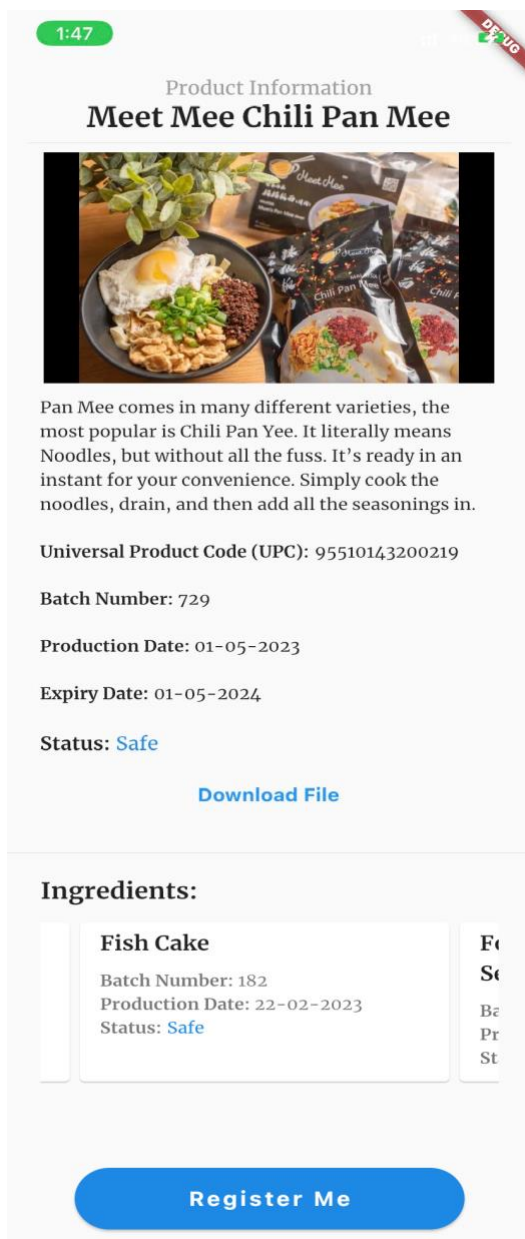


Figure 5.41 View product details (Safe)    Figure 5.42 View product details (Alert)
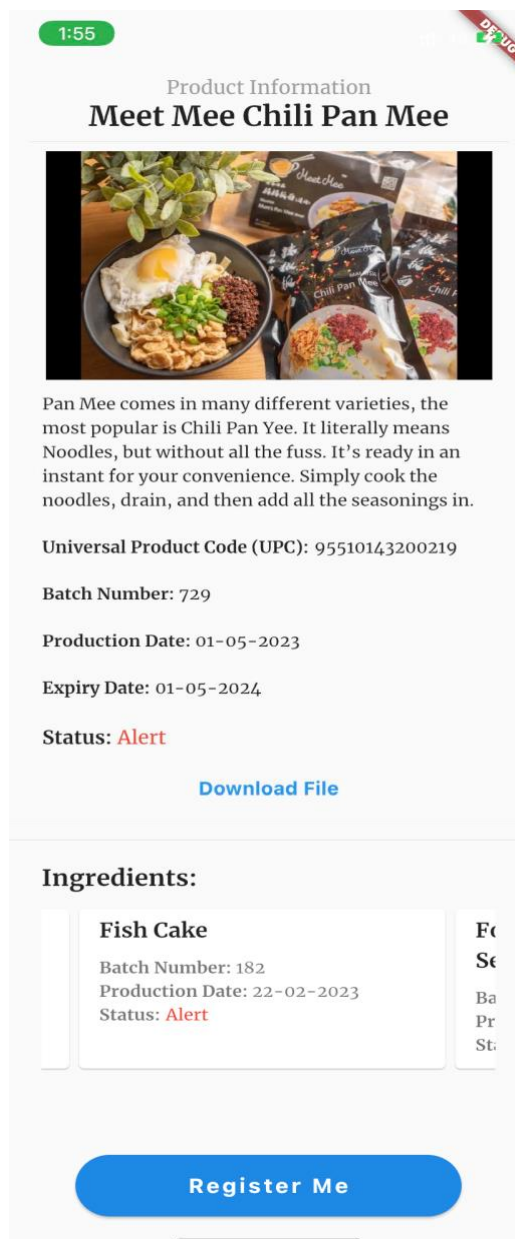
If the scanned QR code is valid, the proposed system will display the product information and part of the ingredient information to the user. The product status and ingredient status are marked as "Safe" if all the ingredients used are not contaminated and all processing steps have met the processing standard (figure 5.41). The product status shown in figure 5.42 is marked as "Alert" because one of the ingredients used in this specific product is contaminated.

## 5.4      Implementation Issues and Challenges

One of the challenges encountered throughout the development of the proposed system was the lack of clarity with the development of blockchain technology in decentralized applications. The information from online resources is limited as the development of decentralized applications is still new. Therefore, it is a challenge to integrate the proposed system with blockchain technology and ensure that the blockchain does not disrupt the proposed system and can integrate seamlessly with it.

In addition, deploying the smart contract in the local environment is troublesome. This is because Ganache is an Ethereum development tool that allows developers to develop and test their smart contracts locally. However, there is a need to recompile and redeploy the smart contract every time the computer's internet protocol (IP) address has changed. Therefore, this issue takes up some time in the implementation phase because after the smart contract is deployed, all the data needs to be entered again. Moreover, the information to be entered into the proposed system is large because there are several phases in the food supply chain, which include ingredient collection, production, and distribution. Hence, more time is required to enter the information about the food supply chain into the blockchain.

# CHAPTER 6
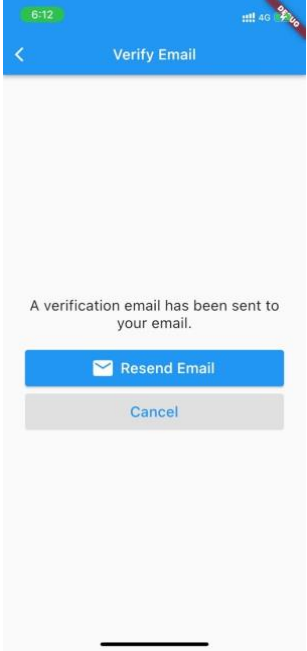
# System Evaluation and Discussion
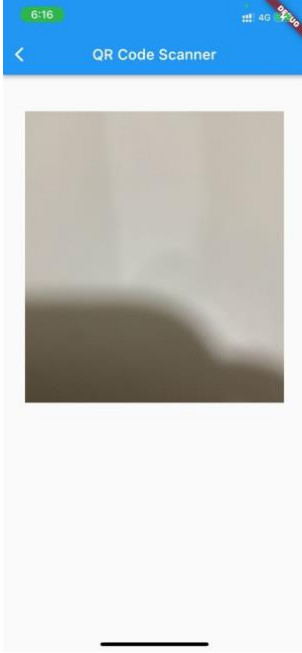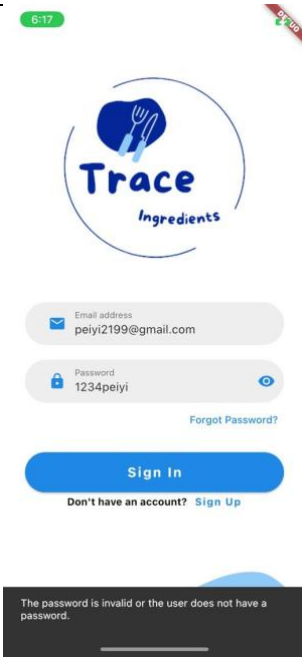
This chapter focused on the test cases to check whether the objectives of this project are achieved. Besides, this chapter also mentions why blockchain is important in this project and what would happen if blockchain is not applied to this project.

## 6.1 System Testing and Performance Metrics
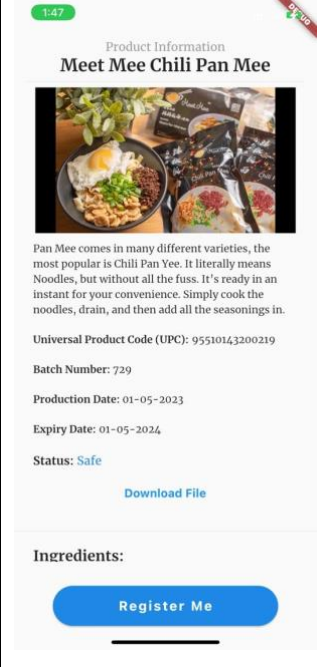
### 6.1.1 Authentication Module

| Test Case | Test Case Description | Test Data | Expected Result | Actual Result | Pass / Fail |
|---|---|---|---|---|---|
| 1 | Check if the consumer can sign-up with an incorrect format of credentials | Email: peiyi (invalid format) Password: peiyi1234 | The system should not allow the consumer to sign-up for the user account and display the error message. |  | Pass |

| 2 | Check if the consumer can sign-up with the correct format of credentials | Email: peiyi2199@gmail.com Password: peiyi1234 | The system should allow the consumer to sign-up for the user account and send the verification link to the consumer. |  | Pass |
|---|---|---|---|---|---|
| 3 | Check if the consumer can sign-in without verified the email address | Email: peiyi2199@gmail.com Password: peiyi1234 | The system should ask the consumer to verified the email or click the "Resend email" button to get a new verification link. |  | Pass |

| 4 | Check if the consumer can sign-in with the verified email address | Action: Click the verification link in the Email inbox.<br><br>Email: peiyi2199@gmail.com<br>Password: peiyi1234 | The system will be navigated to the consumer's home page |  | Pass |
|---|---|---|---|---|---|
| 5 | Check if the consumer can sign-in with invalid sign-in credentials | Email: peiyi2199@gmail.com<br>Password: 1234peiyi (wrong password) | The system should not allow the consumer to sign in and display the error message. |  | Pass |
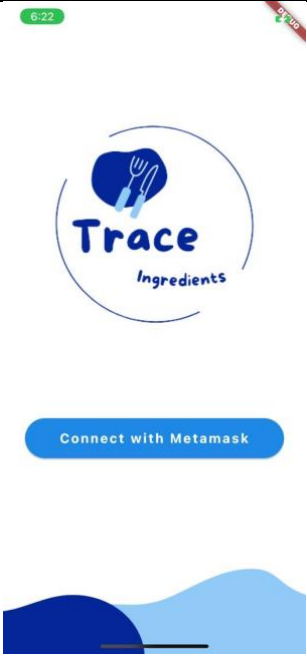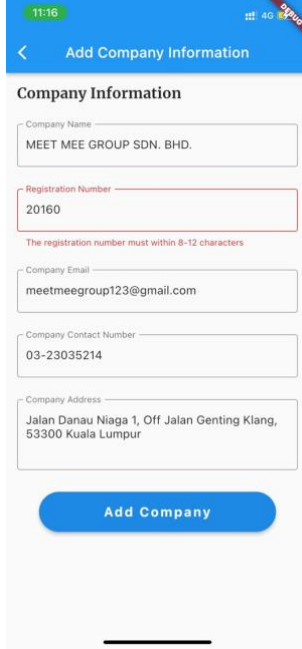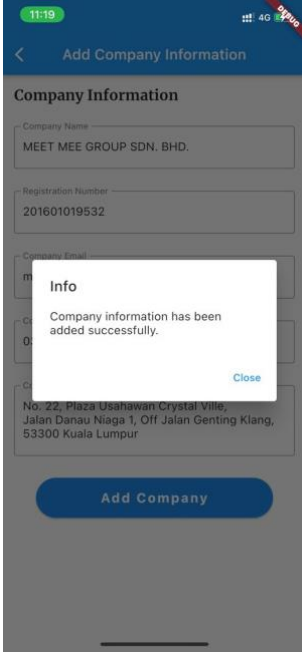
## 6.1.2   Consumer Module

| Test Case | Test Case Description | Test Data | Expected Result | Actual Result | Pass/ Fail |
|---|---|---|---|---|---|
| 1 | Check if the consumer can scan the QR code to view the correct product and ingredient information | Action: Scan with a valid QR code | The system should display the product and ingredient information, including its status |  | Pass |
| 2 | Check if the system sends an email message to registered consumers in the event of contamination in their registered product | Action: Consumer click the "Register me" button and Manufacturer mark any one of the ingredients as contaminated | The system should send an alert email to all registered consumers regarding contamination issue |  | Pass |
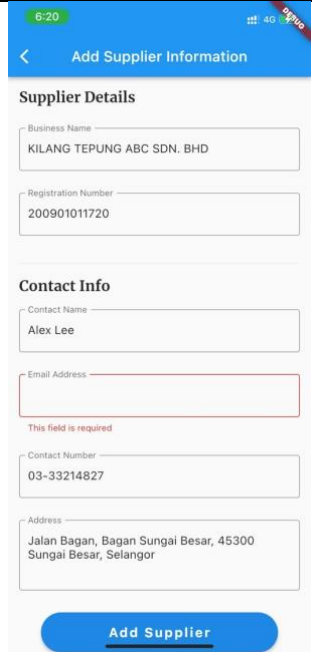
## 6.1.3 Manufacturer Module
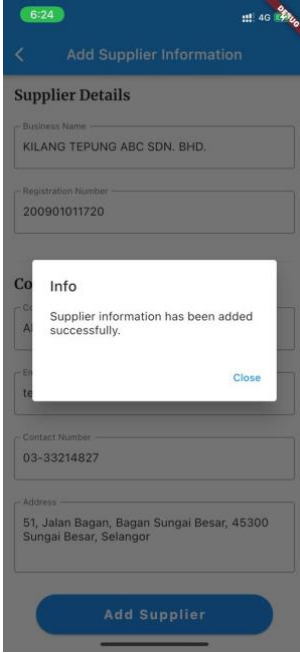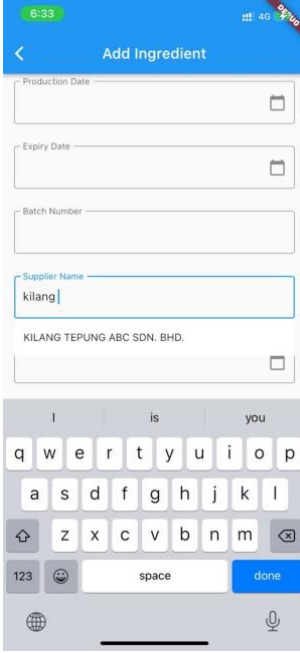
| Test Case | Test Case Description | Test Data | Expected Result | Actual Result | Pass / Fail |
|---|---|---|---|---|---|
| 1 | Check if the manufacturer is not connected to the blockchain | Action: Press the "Cancel" button in Metamask | The system should not allow the manufacturer to log in. |  | Pass |
| 2 | Check if the manufacturer is connected to the blockchain | Action: Press the "Connect" button in Metamask | The system should allow the manufacturer to log in and display the public address of the Metamask account. |  | Pass |

| 3 | Check if the manufacturer can add company details with invalid input fields | Company Name: MEET MEE GROUP SDN. BHD. Registration Number: 20160 (less than 8 characters) Email Address: meetmeegroup123@gmail.com Contact Number: 03-23035214 Address: No. 22, Plaza Usahawan Crystal Ville, Jalan Danau Niaga 1, Off Jalan Genting Klang, 53300 Kuala Lumpur | The system should not allow the manufacturer to add company details and display the error message. |  | Pass |

| 4 | Check if the manufacturer can add company details with valid input fields | Company Name: MEET MEE GROUP SDN. BHD. Registration Number: 201601019532 Email Address: meetmeegroup123@gmail.com Contact Number: 03-23035214 Address: No. 22, Plaza Usahawan Crystal Ville, Jalan Danau Niaga 1, Off Jalan Genting Klang, 53300 Kuala Lumpur | The system should allow the manufacturer to add company details and display successful message. | | Pass |
|---|---|---|---|---|---|
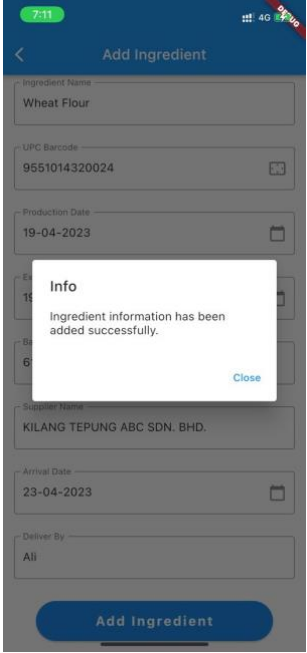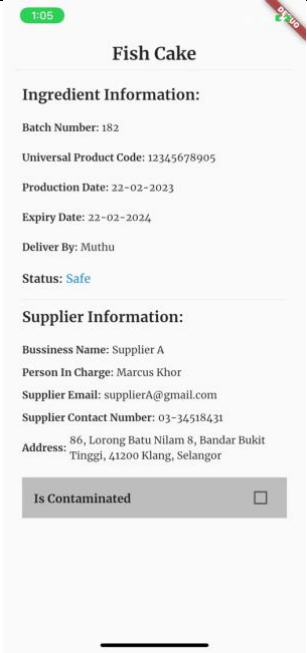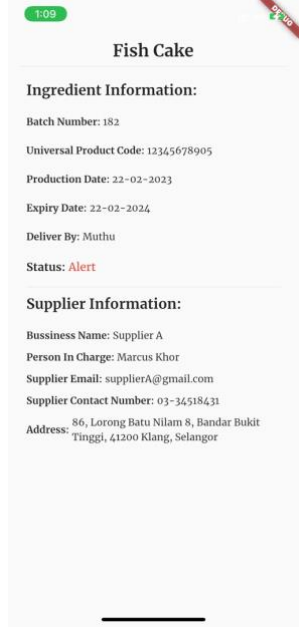
## 6.1.4  Ingredient Collection Module

| Test Case | Test Case Description | Test Data | Expected Result | Actual Result | Pass / Fail |
|---|---|---|---|---|---|
| 1 | Check if the manufacturer can add new supplier information with invalid input fields | Business Name: KILANG TEPUNG ABC SDN. BHD. Registration Number: 200901011720 Contact Name: Alex Lee Email Address: (Blank) Contact Number: 03-33214827 Address: 51, Jalan Bagan, Bagan Sungai Besar, 45300 Sungai Besar, Selangor | The system should not allow the manufacturer to add supplier details and display the error message. |  | Pass |

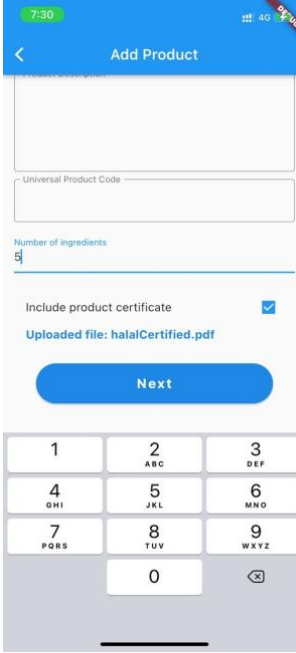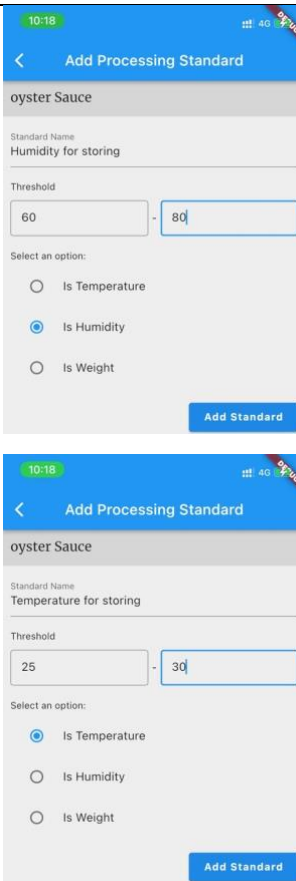| 2 | Check if the manufacturer can add new supplier information with valid input fields | Business Name: KILANG TEPUNG ABC SDN. BHD. Registration Number: 200901011720 Contact Name: Alex Lee Email Address: tepungABC@gmail.com Contact Number: 03-33214827 Address: 51, Jalan Bagan, Bagan Sungai Besar, 45300 Sungai Besar, Selangor | The system should allow the manufacturer to add supplier details and display successful message. |  | Pass |
|---|---|---|---|---|---|
| 3 | Check if the manufacturer can select a supplier from the supplier list that added previously through filtering | Supplier: kilang | The system show all the supplier business name that contain the words "kilang" |  | Pass |

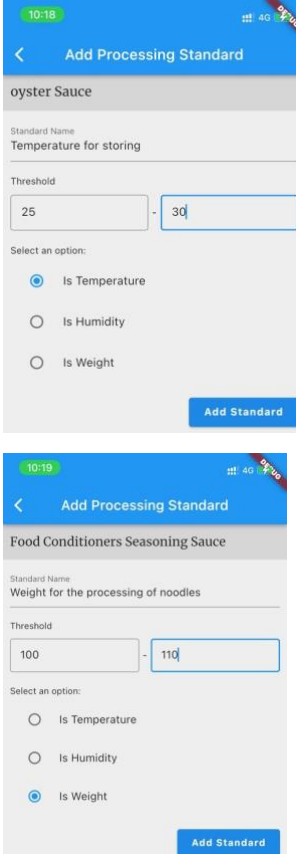| 4 | Check if the system able to read barcode from the scanner | Action: Press the scanner icon located at the UPC Barcode text field. | The system should show the barcode number of the scanned item |  | Pass |
|---|---|---|---|---|---|
| 5 | Check if the manufacturer add a new ingredient to the system with invalid input fields | Ingredient Name: Wheat Flour UPC Barcode: (From Scanner) Production Date: 19-04-2023 Expiry Date: 19-04-2024 Batch Number: 619 Supplier Name: KILANG TEPUNG ABC SDN. BHD. Arrival Date: 23-04-2023 | The system should not allow the manufacturer to add ingredient details and display the error message. |  | Pass |

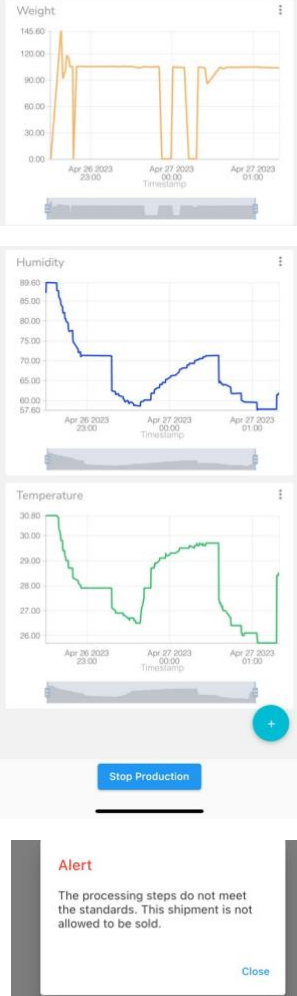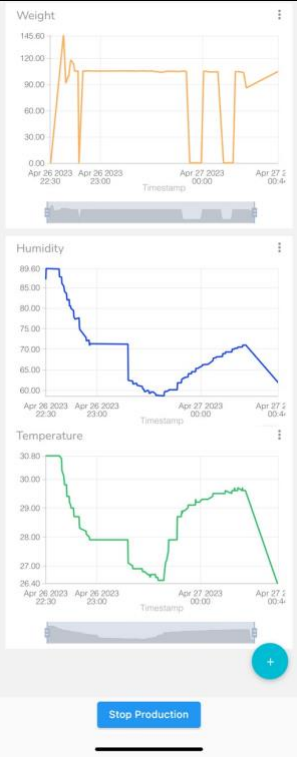| | | Deliver By: (Blank) | | | |
|---|---|---|---|---|---|
| 6 | Check if the manufacturer add a new ingredient to the system with valid input fields | Ingredient Name: Wheat Flour UPC Barcode: (From Scanner) Production Date: 19-04-2023 Expiry Date: 19-04-2024 Batch Number: 619 Supplier Name: KILANG TEPUNG ABC SDN. BHD. Arrival Date: 23-04-2023 Deliver By: Ali | The system should allow the manufacturer to add ingredient details and display successful message. |  | Pass |
| 7 | Check if the manufacturer can view the ingredient details | Action: Select the ingredient with the name "Fish Cake" | The system should display the ingredient details of the "Fish Cake" |  | Pass |

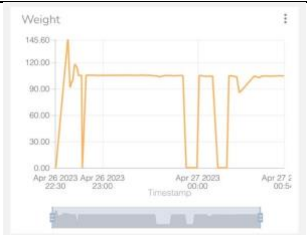| 8 | Check if the manufacturer can mark the ingredient as contaminated | Action: Tick "Is contaminated" | The system should show the ingredient status as Alert |  | Pass |
|---|---|---|---|---|---|
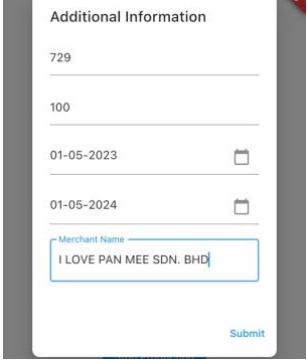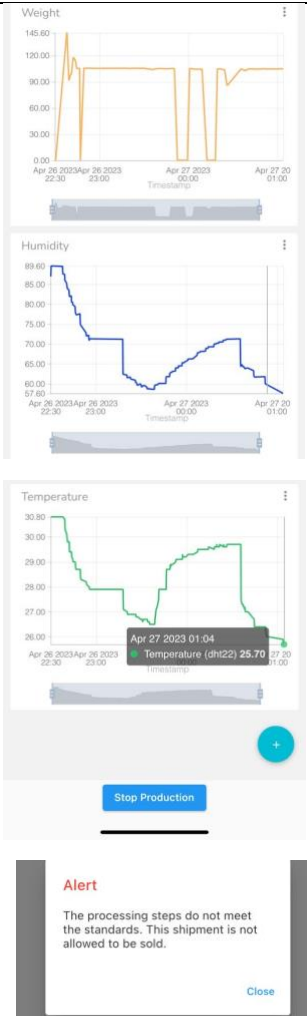
### 6.1.5 Production Module
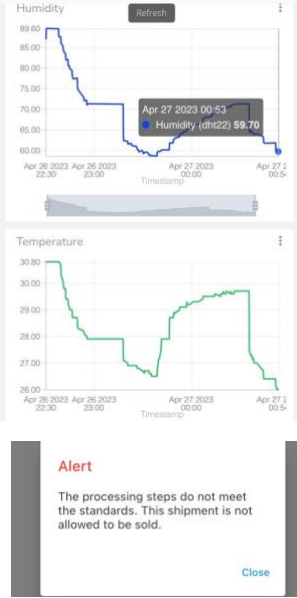
| Test Case | Test Case Description | Test Data | Expected Result | Actual Result | Pass / Fail |
|---|---|---|---|---|---|
| 1. | Check if the manufacturer can upload product image and certificate to IPFS | Action: Select the product image and certificate from the mobile | The system should display the product image and the certificate file name |  | Pass |

| 2 | Check if the manufacturer can add the ingredients more than the number of ingredients that have been added previously | Number of ingredients: 5 | The system should not display the ingredient choices |  | Pass |
|---|---|---|---|---|---|
| 3 | Check if the manufacturer can add more than one processing standard for one ingredient | Ingredient: Oyster Sauce Standard Name: Humidity for storing Threshold: 60 – 80 Option: Is Humidity  Ingredient: Oyster Sauce Standard Name: Temperature for storing Threshold: 25 – 30 Option: Is Temperature | The system should allow the manufacturer add more than one processing standard for each ingredient |  | Pass |

| 4 | Check if the manufacturer can add more than one processing standard for one product | Ingredient: Oyster Sauce Standard Name: Temperature for storing Threshold: 25 – 30 Option: Is Temperature<br><br>Ingredient: Food Condition Seasoning Sauce Standard Name: Temperature for storing Threshold: 100 – 110 Option: Is Weight | The system should allow the manufacturer add more than one processing standard for each product |  | Pass |
| 5 | Check if the manufacturer can view the real-time dashboard | Action: Select product with the name "Meet Mee Chili Pan Mee" | The system should show the Ubidot Dashboard |  | Pass |

| 6 | Check if the manufacturer can add a new batch of products with contaminated ingredient | Action: Mark one of the ingredient as contaminated | The system should allow the manufacturer to add batch |  | Pass |
| 7 | Check if the manufacturer can add a new batch of products that meet all the processing standards | Action: Press "Stop production" button | The system should allow the manufacturer to add batch |  | Pass |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| 8 | Check if the manufacturer can add a new batch of products when temperature is not within its threshold | Action: Press "Stop production" button | The system should not allow the manufacturer to add batch and display an error message | | Pass |
| 9 | Check if the manufacturer can add a new batch of products when humidity is | Action: Press "Stop production" button | The system should not allow the manufacturer to add batch and display an error message | | Pass |

| | | | | |
|---|---|---|---|---|
| | not within its threshold | | |  | |
| 10 | Check if the manufacturer can add a new batch of products when weight is not within its threshold | Action: Press "Stop production" button | The system should not allow the manufacturer to add batch and display an error message |  | Pass |
| 11 | Check if the manufacturer can receive email message about sensor | One of the sensor data value is not within its threshold | The system should send an alert email to the manufacturer regarding sensor detection issue |  | Pass |

| | | | | | |
|---|---|---|---|---|---|
| | detection issue | | | | |
| 12 | Check if the manufacturer can receive email message about ingredient contamination issue | Action: Mark one of the ingredient as contaminated | The system should send an alert email to the manufacturer regarding ingredient contamination issue |  | Pass |
| 13 | Check if the system can generate QR code | Action: Press "Submit" button in add batch form | The system should display the QR code for the particular batch of product |  | Pass |

| 14 | Check if the manufacturer can save the QR code | Action: Press "Save to gallery" button | The system should save the QR code to the mobile device and display successful message |  | Pass |
|----|---|---|---|---|---|

## 6.2    Objective Evaluation

1. To develop a blockchain-based ingredient tracing system for rapid recall of food hazards.

   - All the information is stored in the blockchain and linked up as a chain.
   - The consumer who has registered the product and the merchant who has purchased the product is able to receive an alert email message when the contamination issue occurs. Thus, the process of product recall is faster.

2. To visualize the blockchain data for consumers to view the supply chain information.

   - The consumer is able to view the product and ingredient information by scanning the QR code.

3. To develop the smart contract on the blockchain-based system to ensure that the proposed system has zero tolerance for outliers.

   - The smart contract is able to reject the distribution of the batch of products if any values retrieved from the sensor are not within its threshold.

4. To integrate the IoT device and dashboard to enable automation of readings entry and real-time monitoring.

- The system is able to retrieve sensor data from the IoT Devices and send it to the smart contract for quality detection and storage purpose.
- The system is able to display the dashboard in the production page.

# CHAPTER 7

# Conclusion and Recommendation

## 7.1    Conclusion

To summarize, the proposed system has achieved its objectives by providing a blockchain-based ingredient tracing system that allows manufacturers to record information about the product and the ingredients used. With this, the information will be stored in the blockchain and linked to a chain so that the journey of the product is traceable. The IoT devices are used in this project to avoid human error due to carelessness while the dashboard is being integrated into the system to allow the manufacturer to monitor the status of the production line. In addition, the use of smart contracts to automatically reject batches of products whenever processing steps do not meet standards has the potential to significantly prevent manufacturers from distributing low-quality products to the market, thereby improving food safety and reducing the likelihood of product recalls.

Furthermore, the project's main motivation is to empower consumers by allowing them to scan the QR code on product packaging with their mobile phones to obtain detailed information and the status of the product and to ensure that they purchase safe and uncontaminated products. With the help of the smart contract, consumers can consume food with confidence as the system has zero tolerance for outliers.

In conclusion, the proposed project has enhanced the existing system's weaknesses while retaining the existing system's strengths to provide a user-friendly system to the user and solve their problem in this domain. The proposed system provides a transparent system capable of tracing the movement of the product which then eased the product recall process and increased consumer confidence.

## 7.2    Recommendation

For future work, the proposed system can be further expanded in its capabilities by adding more IoT devices to further monitor the environment and other relevant factors, including water quality. Thus, the proposed system could improve the effectiveness of the ingredient tracing process by incorporating more IoT devices to collect a more complete set of data. In addition, it is recommended that the proposed system include the feature of allowing the manufacturers to add the storage information for batches of products to the blockchain so that the location of the product can be traced as the quality of the food might be affected by external conditions, such as temperature and humidity. Storing this information can further help determine the root cause of any problems and test all batches located in the same storage area before distribution to the market. Currently, the proposed system does not include this feature due to limited resources.

In addition, the integration of artificial intelligence (AI) with the proposed system may further improve the speed and accuracy of the tracing. This is because AI technology can be used for fraud detection to spot data anomalies that may point to fraudulent activity such as the use of counterfeit ingredients in the supply chain. Hence, the likelihood of foodborne illness can be minimized.

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# FINAL YEAR PROJECT WEEKLY REPORT
*(Project II)*

| Trimester, Year: 3, 3 | Study week no.: 2 |
|---|---|
| **Student Name & ID: LEOW PEI YI & 19ACB03957** | |
| **Supervisor: Dr Aun Yichiet** | |
| **Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall** | |

**1. WORK DONE**
[Please write the details of the work done in the last fortnight.]

Go through the FYP2 guideline.
Finished the review of the IoT devices and hardware necessary for this project.

**2. WORK TO BE DONE**

Bought the necessary IoT devices, hardwares from the internet.

**3. PROBLEMS ENCOUNTERED**

None.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
Supervisor's signature

_____
Student's signature

# FINAL YEAR PROJECT WEEKLY REPORT
*(Project II)*

| Trimester, Year: 3, 3 | Study week no.: 4 |
|---|---|
| Student Name & ID: LEOW PEI YI & 19ACB03957 | |
| Supervisor: Dr Aun Yichiet | |
| Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall | |

**1. WORK DONE**
[Please write the details of the work done in the last fortnight.]
Get the Raspberry Pi 4B from the lab and all the hardwares are arrived.

**2. WORK TO BE DONE**

Connect the IoT device to the Raspberry Pi and write the Python script to print the result

**3. PROBLEMS ENCOUNTERED**

One of the sensors spoiled, have to buy a new sensor.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
Supervisor's signature

_____
Student's signature

# FINAL YEAR PROJECT WEEKLY REPORT
*(Project II)*

| | |
|---|---|
| **Trimester, Year: 3, 3** | **Study week no.: 6** |
| **Student Name & ID: LEOW PEI YI & 19ACB03957** | |
| **Supervisor: Dr Aun Yichiet** | |
| **Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall** | |

**1. WORK DONE**
[Please write the details of the work done in the last fortnight.]
Finished the connection of IoT devices to the Raspberry Pi and was able to retrieve data from sensor to Raspberry Pi.

**2. WORK TO BE DONE**

Send the data to Flutter and save it in the blockchain. Besides, send to the Ubidot as well to allow real-time monitoring.

**3. PROBLEMS ENCOUNTERED**

None.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
**Supervisor's signature**

_____
**Student's signature**

# FINAL YEAR PROJECT WEEKLY REPORT

*(Project II)*

| Trimester, Year: 3, 3 | Study week no.: 8 |
|---|---|
| Student Name & ID: LEOW PEI YI & 19ACB03957 | |
| Supervisor: Dr Aun Yichiet | |
| Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall | |

**1. WORK DONE**

[Please write the details of the work done in the last fortnight.]

Able to save the sensor data to the blockchain and display the dashboard in Flutter.

**2. WORK TO BE DONE**

Allow the manufacturer to upload product image and certificate. Then, able to store them in the distributed file system.

**3. PROBLEMS ENCOUNTERED**

None.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
Supervisor's signature

_____
Student's signature

# FINAL YEAR PROJECT WEEKLY REPORT
*(Project II)*

| Trimester, Year: 3, 3 | Study week no.: 10 |
|---|---|
| Student Name & ID: LEOW PEI YI & 19ACB03957 | |
| Supervisor: Dr Aun Yichiet | |
| Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall | |

**1. WORK DONE**
[Please write the details of the work done in the last fortnight.]
Able to save the file to the distributed file system and display the uploaded file in the user interface.

**2. WORK TO BE DONE**

Include the alert feature that send the alert email message to the consumer, merchant, and manufacturer in the event of contamination.

**3. PROBLEMS ENCOUNTERED**

None.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
Supervisor's signature

_____
Student's signature

# FINAL YEAR PROJECT WEEKLY REPORT
*(Project II)*

| Trimester, Year: 3, 3 | Study week no.: 12 |
|---|---|
| **Student Name & ID: LEOW PEI YI & 19ACB03957** | |
| **Supervisor: Dr Aun Yichiet** | |
| **Project Title: Ingredients Tracing Using Blockchain For Rapid Product Recall** | |

**1. WORK DONE**
[Please write the details of the work done in the last fortnight.]
Able to send alert email to consumer, merchant, and manufacturer.

**2. WORK TO BE DONE**

Write and finalise the report.

**3. PROBLEMS ENCOUNTERED**

None.

**4. SELF EVALUATION OF THE PROGRESS**

Satisfy.

_____
Supervisor's signature

_____
Student's signature

# POSTER

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**FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY**

| **Full Name(s) of Candidate(s)** | LEOW PEI YI |
|---|---|
| **ID Number(s)** | 19ACB03957 |
| **Programme / Course** | BACHELOR OF COMPUTER SCIENCE (HONOURS) |
| **Title of Final Year Project** | INGREDIENTS TRACING USING BLOCKCHAIN FOR RAPID PRODUCT RECALL |

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***Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.***

Signature of Supervisor

Name: __Aun Yichiet__

Date: __28/4/2023__

Signature of Co-Supervisor

Name: _____

Date: _____

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# UNIVERSITI TUNKU ABDUL RAHMAN

## FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY
## (KAMPAR CAMPUS)
### CHECKLIST FOR FYP2 THESIS SUBMISSION

| Student Id | 19ACB03957 |
|---|---|
| Student Name | LEOW PEI YI |
| Supervisor Name | DR. Aun Yichiet |

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