Mindoro State University
College of Computer Studies

COCOTAP: DEVELOPMENT OF TUBA (COCONUT WINE) FOR COLLECTION AND FERMENTATION MONITORING SYSTEM

A

Integrative programming & Technologies 1

and Embedded System Project

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by:

Magcuha, Julianne P.

Manobo, Mark Dave A.

Paderes, Jan Mikko

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CHAPTER I

INTRODUCTION

Traditional fermented beverages such as *tuba*—commonly referred to as coconut wine—remain integral to the cultural and economic fabric of many countries in Southeast Asia and the Pacific. Tuba is produced by collecting fresh coconut sap, which ferments naturally over time. Globally, there is a growing movement toward preserving indigenous fermentation practices while integrating modern technology to improve productivity, ensure consistent quality, and support sustainable agricultural livelihoods. The application of real-time monitoring systems and Internet of Things (IoT) technologies has emerged as a transformative approach in various agricultural domains, offering enhanced data accuracy, operational efficiency, and automation.

In the Philippine, particularly in rural and agricultural provinces such as Oriental Mindoro, tuba production continues to serve as a vital source of income for small-scale coconut farmers. Despite its cultural and economic importance, the traditional process of sap collection and fermentation tracking remains largely manual and labor-intensive. This lack of automation presents several challenges, including inaccurate volume estimation, inconsistent fermentation monitoring, and increased risk of sap spoilage. These limitations hinder the optimization of production processes and affect the overall yield, quality, and marketability of the product.

This study aims to address a pressing concern within the local tuba industry. The absence of a real-time, automated monitoring system for coconut wine collection and fermentation. The problem lies in the inability of producers to accurately measure tuba levels and track fermentation stages in a timely and efficient manner. The lack of digital tools and real-time data prevents informed decision-making and results in inefficiencies, economic losses, and missed opportunities for product improvement and scalability.

The study introduces CocoTap, a monitoring system designed to aid coconut farmers and tuba producers in tracking the daily collection and fermentation status of coconut wine (tuba). By utilizing IoT-based technologies and microcontrollers, the system provides accurate, live updates on wine volume and fermentation progress, reducing spoilage and ensuring high-quality production.

This system offers a modernized approach to traditional tuba production by automating the monitoring process and providing accurate, real-time data. As an outcome, the system is expected to enhance operational efficiency, reduce manual workload, and empower local farmers and cooperatives with technology-driven tools to support decision-making and sustainable production. Ultimately, COCOTAP aims to preserve local culture while introducing smart agriculture solutions to improve livelihoods in rural communities.

Objectives

Generally, this study aims to develop COCOTAP: Development of Tuba (Coconut Wine) for Collection and Fermentation monitoring system.

Specifically, it aims to:

1. To design and implement a monitoring system to measure wine volume, temperature and track fermentation conditions, specifically pH level.

2. To integrate a cloud-based storage (Firebase) for collection of the data gathered by sensors.
3. To provide data analytics that monitors and records container, temperature and fermentation status.
4. To support users in monitoring the collection and fermentation of Tuba (Coconut Wine) remotely via mobile/web application.

Scope and Limitation

This study focuses on the development of COCOTAP, a real-time monitoring system for small-scale coconut wine (tuba) production. The system uses ESP32-based sensors to measure liquid volume, pH level, and temperature, with data displayed on a mobile and web dashboard built using Vue.js and Firebase. Each tapping site is equipped with a set of sensors: a pH sensor for monitoring acidity, an ultrasonic sensor for measuring liquid level, and a temperature sensor. The ESP32 micro-controller collects these readings and transmits them to a web server. Data are timestamped and stored in a Firebase database, enabling historical tracking of the fermentation process.

The dashboard provides real-time sensor data, historical charts, and Google account authentication through Firebase. It also includes a control interface allowing authorized users to remotely open or close a solenoid valve, enabling fluid drainage or allow airflow. Power is supplied by a 12,800 mAh battery pack, which, combined with ESP32 deep-sleep functionality, supports operation for up to three days. During sleep mode, the ESP32 draws minimal current and only wakes periodically to take and transmit measurements, thereby conserving power.

However, the system has several limitations. Sensor performance depends on regular calibration and maintenance. Particularly, pH sensors, tend to drift over time and are sensitive to temperature changes, which can affect readings. Ultrasonic sensors may give inconsistent results when used with non-standard or thin container walls. All sensors have limited lifespans and may degrade due to exposure to the fermenting liquid. Additionally, system functionality depends on battery life and stable internet connectivity. Once the battery is depleted or Wi-Fi is unavailable, data collection stops. The system is also designed for small-scale use, with one sensor set per tapping site. Scaling up to multiple trees would require duplicating the hardware, increasing complexity and data load.

Chapter II

REVIEW OF RELATED LITERATURE

Related Literature

Gregorio (2024) highlights the cultural, economic, and historical significance of tuba, a traditional alcoholic beverage in the Philippines derived from coconut sap. In her chapter, Philippine Traditional Alcoholic Beverages: A Germinal Study, she describes how tuba and similar drinks have existed since before Spanish colonization. Despite their deep cultural roots and continued relevance in rural communities, these beverages suffer from limited scientific documentation and inconsistent production quality. Gregorio emphasizes the urgent need for empirical studies and technological interventions to modernize production practices, citing challenges such as spoilage, lack of standardization, and unregulated fermentation.

Ruiz-Garcia, L., Lunadei, L., Barreiro, P., & Robla, J. I. (2009). A review of wireless sensor technologies and applications in agriculture and food industry: state of the art and current trends. *Sensors, 9*(6), 4728–4750. This review paper provides an overview of the applications of wireless sensor networks (WSNs) in agriculture and the food industry, including real-time monitoring, traceability, and environmental control. The authors highlight how sensor-based systems improve operational efficiency and decision-making.

Suganob et al. (2022) examined problems in traditional coconut sap collection practices in the Philippines through field-based studies and interviews with local farmers. They identified spoilage due to poor preservation, inefficiencies in sap collection, and a declining workforce of skilled tappers as critical and growing concerns in the tuba industry. The study proposed incorporating technology such as refrigeration units, automated chillers, and IoT-based tools to reduce manual labor and improve production efficiency.

Adeleke et al. (2023) conducted a bibliometric analysis of recent trends in IoT applications for food fermentation and identified several functional domains, including predictive modeling, remote monitoring, and real-time sensing. The study found that fermentation parameters such as pH, CO_2 emissions, sugar content, and temperature are critical indicators of product safety, taste, and shelf life. IoT-based solutions allow these parameters to be monitored continuously, enabling better decision-making, reduced human error, and increased yield consistency. The integration of these technologies allows local tuba producers to compete with modern food production systems while maintaining their traditional identity.

Oluwole et al. (2023) reviewed microbial and nutritional aspects of palm wine fermentation across various regions, including Africa and Southeast Asia. They concluded that while palm wines offer valuable nutrients and cultural significance, spontaneous fermentation introduces variability in safety, alcohol content, and taste profile. The review emphasized that real-time monitoring and standardization could reduce these inconsistencies and enhance consumer trust in traditional beverages. By integrating reliable fermentation monitoring, the system addresses the scientific concerns raised in international research and promotes a more market-ready product that can be scaled beyond local borders.

Aparnna et al. (2024) explored the global production and consumption of palm-based beverages like tuba, neera, and toddy across tropical countries. Their literature review discussed recurring issues such as rapid spoilage due to microbial instability, inconsistent processing methods, and lack of commercialization due to poor technological adoption. The study recommended innovations including fermentation controls, refrigeration, and digital monitoring to enhance production efficiency and product longevity.

Related Studies

Cañete et al. (2018) developed a smart monitoring system for Spanish wine casks using embedded wireless sensors integrated with digital dashboards. The system tracked ullage (airspace), structural integrity of barrels, and surrounding environmental conditions such as temperature and humidity in real time. This technological model demonstrates the value of non-intrusive monitoring in traditional beverage fermentation, particularly in improving product consistency and preventing spoilage.The system sought to enhance operational efficiency and quality through data-driven decision-making, aligning with modern trends in the food and beverage industry.

Surya et al. (2024) created an Arduino-based fermentation controller aimed at small-scale producers in rural communities. It automatically managed internal temperature using Peltier modules and sent notifications when fermentation deviated from target ranges, thereby reducing human labor and error. The system showcased how affordable microcontrollers and sensors can streamline fermentation and enhance process reliability, even in low-resource settings.Their results affirm that DIY technology and low-cost components can deliver significant benefits when applied strategically to traditional food systems.

Tomtsis et al. (2016) proposed an IoT architecture for monitoring the fermentation of Debina variety semi-sparkling wine using sensor modules connected to wireless transmitters. These modules transmitted temperature, carbon dioxide, and fermentation progress data to a centralized cloud server for real-time analysis and record-keeping. The study illustrates how wireless sensor networks and cloud computing can enhance transparency and traceability in traditional winemaking.

Sainz, B., Antolín, J., López-Coronado, M., & Castro, C. D. (2013).This study proposed a low-cost temperature monitoring solution for wine fermentation, showing how affordable sensors can achieve precise monitoring in wine production environments.

Angelkov, D., & Martinovska-Bande, C. (2018). This research developed a modular sensor system that measures key fermentation parameters such as temperature, pressure, and pH. The system was built using microcontrollers and transmitted data wirelessly, demonstrating a practical application of embedded systems in fermentation monitoring.

Chapter III

METHODOLOGY

This chapter presents the methodologies used in developing the system. This includes development method, requirement specification ,system architercture, computer aided design, database schema, and budget requirements.

Development Method

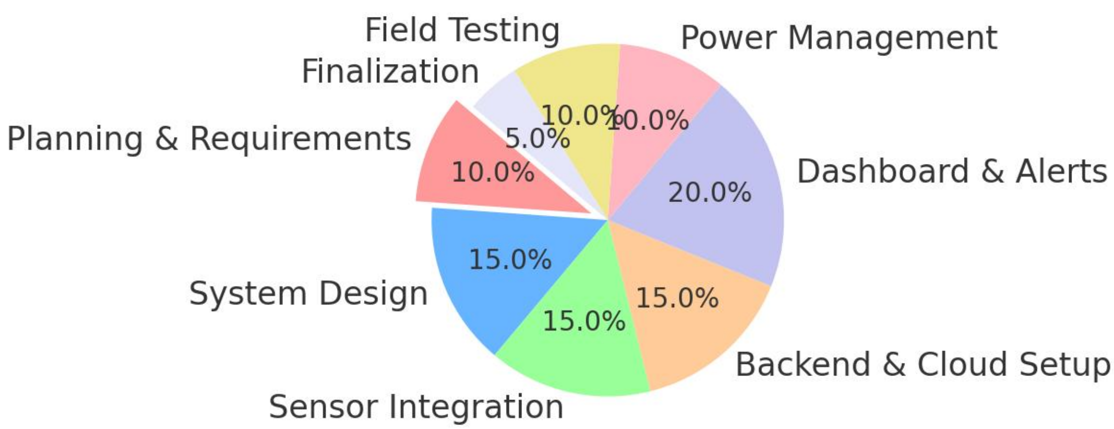

Figure 1. Incremental Development Model

Figure 1 shows the system follows the Incremental Development Model to ensure iterative prototyping and testing. Each module—sensor calibration, data transmission, dashboard development, and alert system—is developed in stages. Continuous feedback and adjustments are implemented during each cycle to improve reliability. This approach facilitates early detection of design flaws and allows for feature expansion based on actual field performance. It also helps developers maintain focus on functional system modules and integrate enhancements progressively.

Gantt Chart

ACTIVITIES	APRIL 2025 - MAY 2025							
	April				**May**			
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Planning & Requirements Analysis								
System Design & Component Selection								
Sensor Setup & Datalogging								
Cloud database Integration (Firebase)								
Dashboard and Alerts								
Power System Integration								
Field Testing & Optimization								

Finalization and Documentation								

Table 1. Gantt Chart

Table 1 outlines the project timeline from April to May 2025, detailing the sequence and duration of each development activity. It includes phases such as requirement analysis, hardware and sensor selection, data transmission coding, cloud database setup, UI development, integration, testing, and debugging. The color yellow indicates as an active development period. This chart visually represents the scheduling and overlapping of tasks, ensuring efficient time management and clear progress tracking throughout the development life-cycle.

Requirement Specification

Hardware	Specification
Laptop	Acer Aspire 3
Microcontroller	ESP32
Relay Module	SRD-05VDC
Ultrasonic Sensor	HC-SR04

Ph Sensor with Module	PH-4502C
Temperature Sensor	ds18B20
Solenoid Valve	12V DC
Power Supply	Li-ion 12800 mAH Battery
Level Hose	1/4 inch, 4 meters length

Table 2. Hardware Specification

Table 2 illustrates the hardware components selected for this system are designed to support real-time monitoring and control in a field setting. The ESP32 development board serves as the microcontroller, responsible for gathering data from various sensors and connecting to Wi-Fi. Sensors such as the pH sensor, ultrasonic sensor, and temperature sensor provide critical fermentation metrics. Actuators like the solenoid valve enable limited automation, while the power system—comprising a motorcycle battery and voltage regulator—ensures stable operation in remote areas.

Software	Specification
Arduino	Arduino IDE
Programming Languages	C++ , JavaScript
Code Editor	Visual Studio Code
Cloud Storage	Firebase
Hosting Platform	Vercel
JavaScript Framework	Vue.js
Interface	Mobile/Web App Dashboard

Table 3. Software Specification

Table 3 shows the system utilizes a combination of development tools, programming languages, and cloud platforms to facilitate efficient monitoring. Arduino IDE is used for firmware development on the ESP32 using C++. Firebase enables cloud-based real-time data storage and synchronization, allowing seamless access across devices. JavaScript is employed for frontend development using the Vue.js framework, while Visual Studio Code serves as the primary development environment. The dashboard is hosted via Vercel, ensuring easy deployment and access on both mobile and web platforms. Together, these software tools create a cohesive and scalable environment for data collection, and visualization.

System Architecture

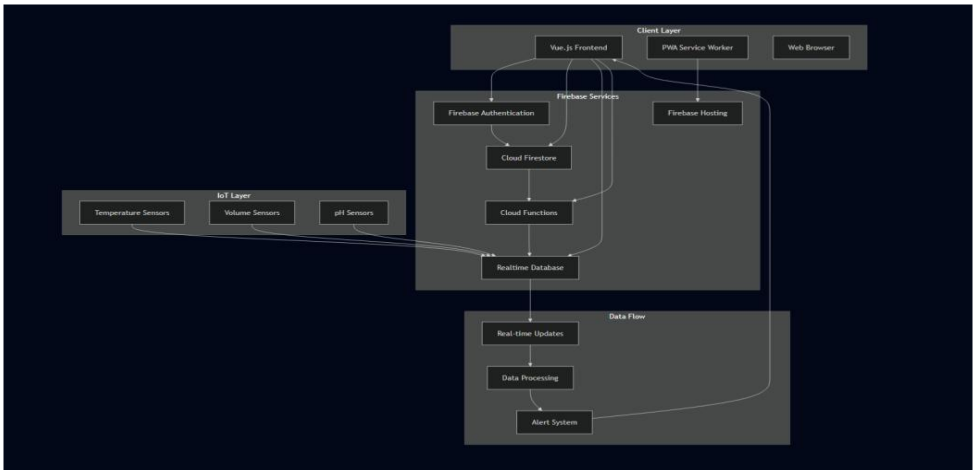

Figure 2. System Architecture

The system architecture is composed of four main layers: IoT, Firebase Services, Data Flow, and Client Layer. The IoT Layer includes temperature, volume, and pH sensors that collect real-time data. This data is sent to the Firebase Services, which handles authentication, cloud storage, backend processing, and hosting. The Data Flow layer processes sensor data, and provides real-time updates when necessary. Lastly, the Client Layer features a web-based dashboard built with Vue.js, allowing users to monitor data and receive alerts through a browser or mobile device.

Computer-Aided Design (CAD)

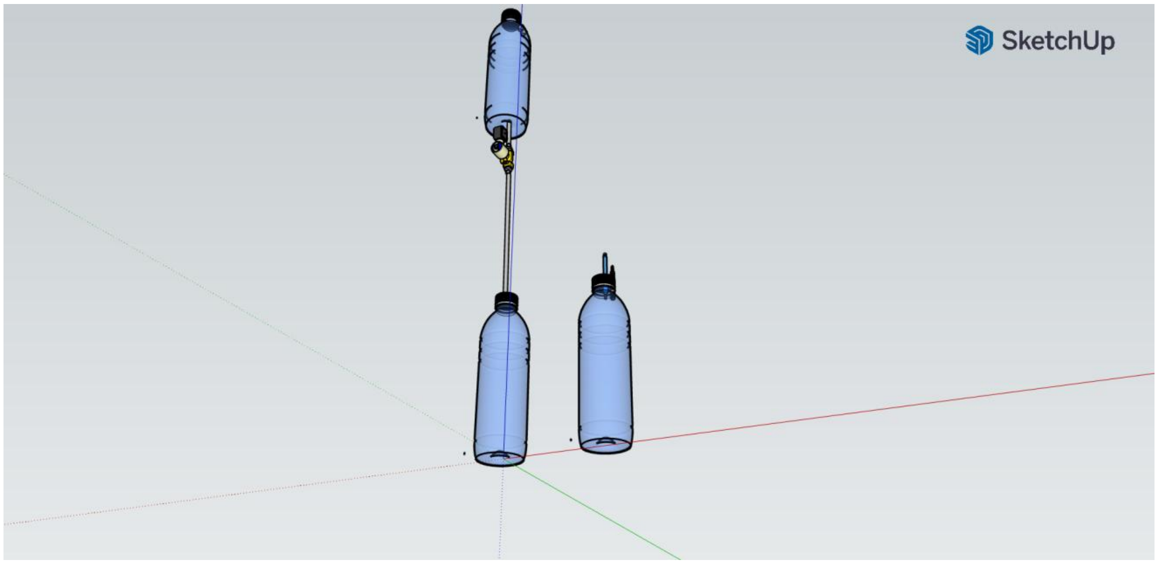

Figure 3. The Front View of the Project

Figure 3 show the overall design of Cocotap. It Illustrates the basic physical structure used for the automated collection and fermentation tracking of coconut wine (tuba). It features a vertical alignment of containers connected by a level hose and a solenoid valve. The upper container serves as the source, allowing liquid to flow through the hose into the lower containers. The solenoid valve regulates this flow based on sensor readings. This setup simulates how the system manages the transfer of liquid during the fermentation process while allowing for accurate volume, pH, and temperature monitoring.

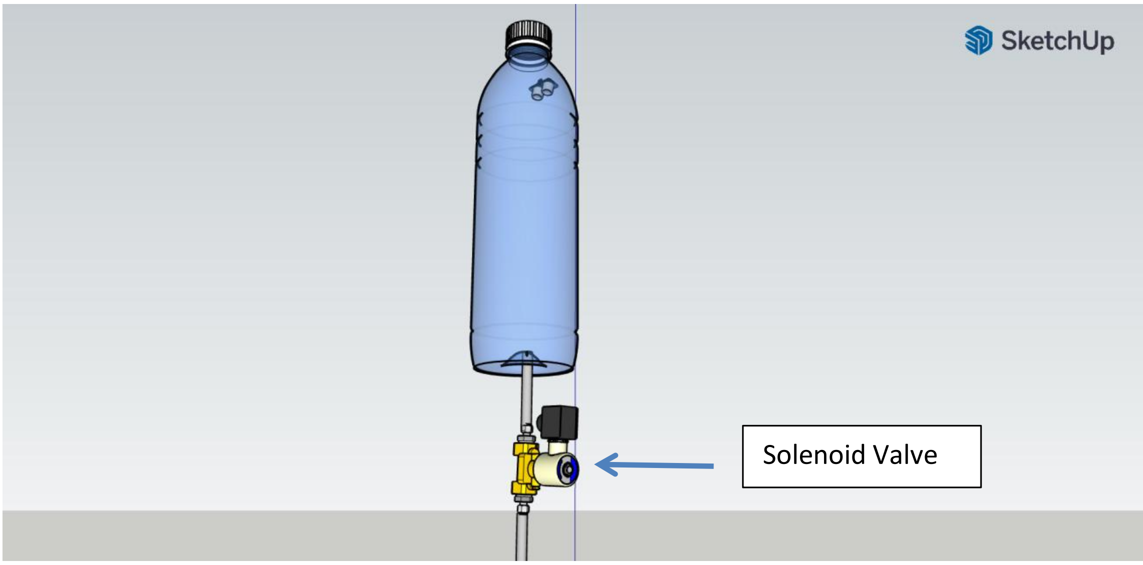

Figure 4 Closed-up View of Solenoid valve

Figure 4 shows the design of the solenoid valve used in this device. It illustrates the upper part of the system structure, featuring a plastic container mounted vertically to serve as the primary vessel for liquid collection or storage. Attached at the bottom of the container is a network of components, including a solenoid valve, piping, and a sensor mechanism, which appears to monitor or regulate liquid output. This design represents the initial stage of a fluid management system, ensuring controlled release and real-time data collection.

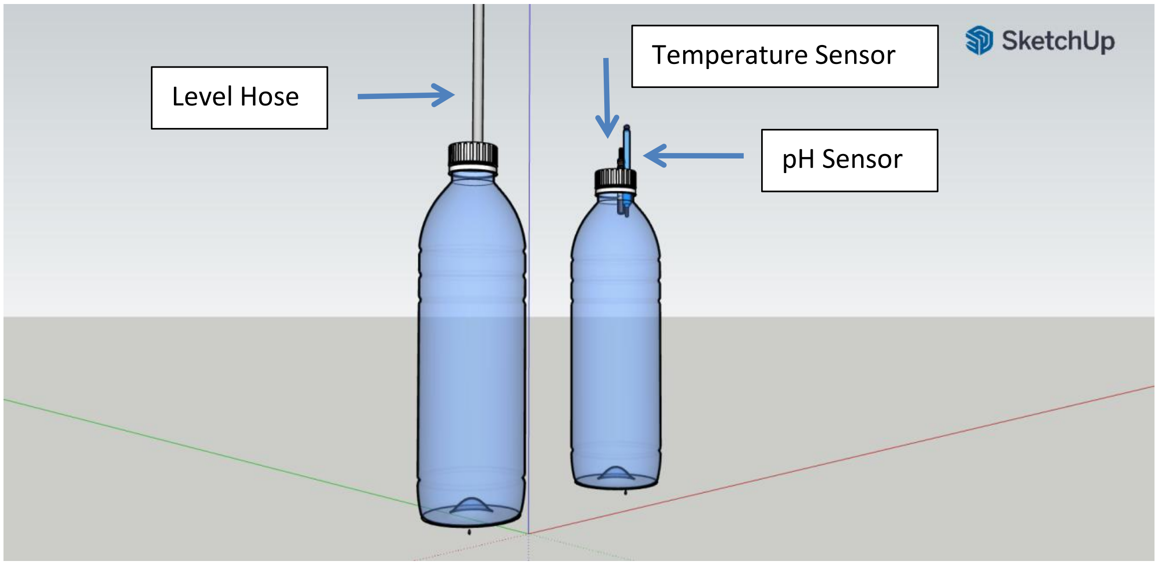

Figure 5 Closed up View of Temperature Sensor and pH Sensor

Figure 5 shows the design of the temperature sensor and oh sensor used in this project. The lower part structure of the system illustrates the tuba collection station. It features two vertically positioned plastic containers, which act as primary collection vessels for the coconut wine. One container is connected to a pipe, suggesting an inlet for tuba flow from the upper system, while the other has a pH sensor and temperature sensor for fermentation monitoring. These containers are strategically designed to ensure efficient and sanitary collection of tuba directly from the source.

Database Schema

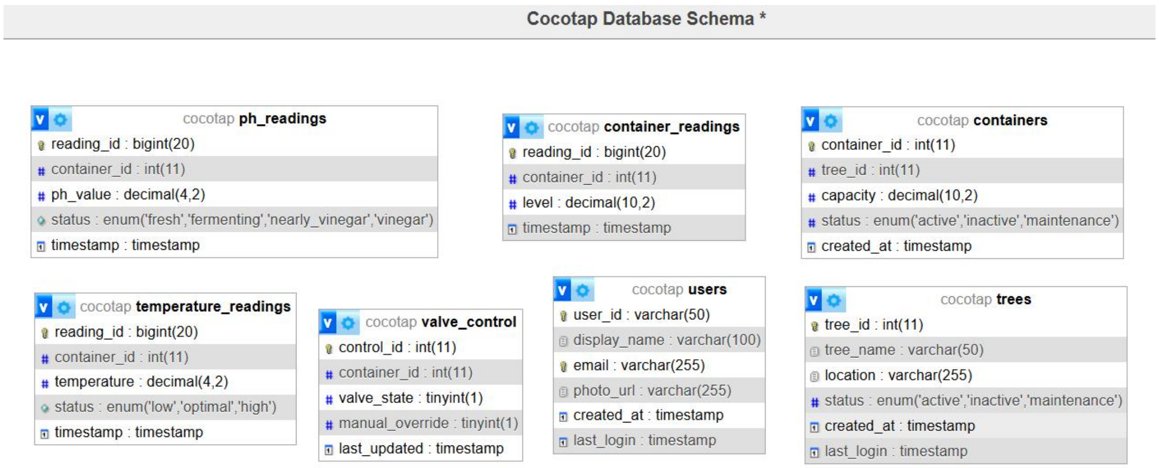

Figure 6. Database Schema

The database schema is designed to support the real-time monitoring of coconut wine (tuba) production by organizing essential data related to trees, sensor readings, , valve control, and user management. The trees table stores details about individual coconut trees, including their name, location, container capacity, and status. The sensor_readings table captures real-time data such as liquid volume, pH level, and temperature to monitor the fermentation process. Complementing this, the temperature_readings table records specific temperature values along with sensor location data. The users table manages user profiles, including email addresses, display names, and login timestamps, while the user_sessions table logs user activity, capturing session times, IP addresses, and browser details. The settings table contains configuration data, such as key-value pairs and descriptions for system parameters.

Budget Requirement

Item	**Quantity**	**Unit Cost(₱)**	**Total (₱)**
Laptop	1	₱36,000	₱36,000
ESP32	2	₱349	₱698
Solenoid Valve	1	₱188	₱188
Ph sensor	1	₱529	₱529
Level Hose	1	₱23	₱23
Ultrasonic sensor	1	₱39	₱39
Temperature sensor	1	₱99	₱99
Dayway Motorcycle Battery YTX4L-BS	1	₱329	₱329
USB DC DC 6-24V to 5V 3A	1	₱20	₱20
Miscellenous fees	1	₱500	₱500
Total			**₱38,425**

Table 4. Budget Requirement

The budget requirement outlines the estimated costs necessary for developing the COCOTAP prototype. It includes the essential hardware components and miscellaneous expenses. The ESP32 serves as the system’s microcontroller, while the solenoid valve, pH sensor, ultrasonic sensor, and temperature sensor are responsible for monitoring and regulating fermentation parameters. Additional components such as the level hose and a USB DC-DC converter ensure system functionality and connectivity. A Dayway motorcycle battery powers the unit for field deployment. Miscellaneous fees account for wires, connectors, mounting materials, and unexpected minor expenses. The total estimated cost for the complete system setup is **₱38,425**, making it a cost-effective solution for small-scale coconut wine producers.

CHAPTER IV

PRESENTATION OF SYSTEM OUTPUT

Client Side

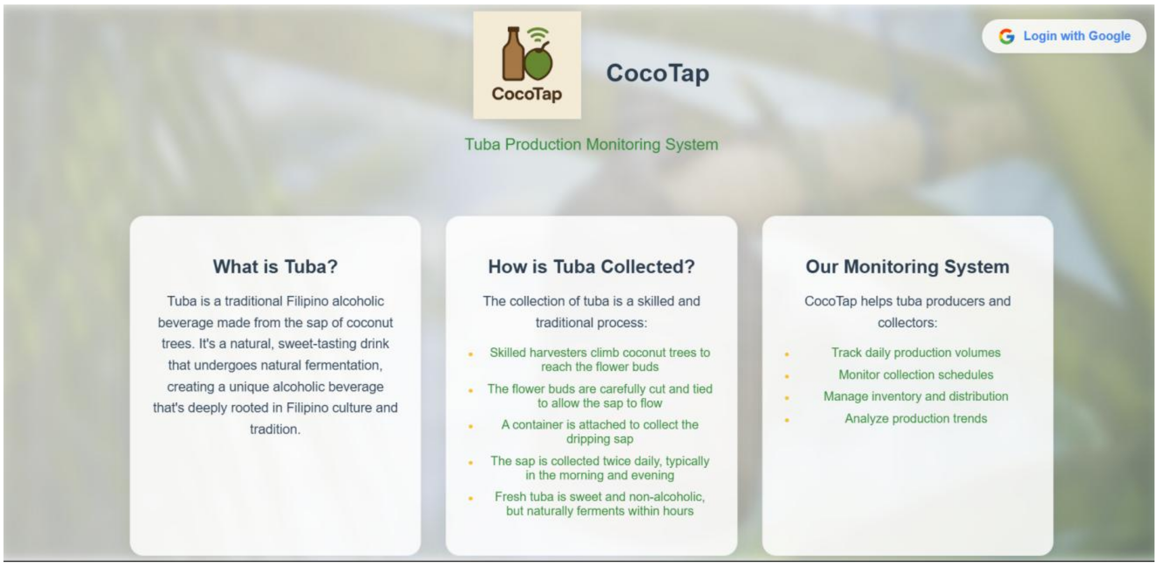

Figure 7. Landing Page

The landing page of the CocoTap system introduces users to the platform and its purpose. It highlights what tuba is—a traditional Filipino drink made from coconut sap—explains the traditional method of collecting it, and presents how CocoTap helps producers and collectors. The system offers features such as tracking production volumes, monitoring collection schedules, managing inventory, and analyzing trends.

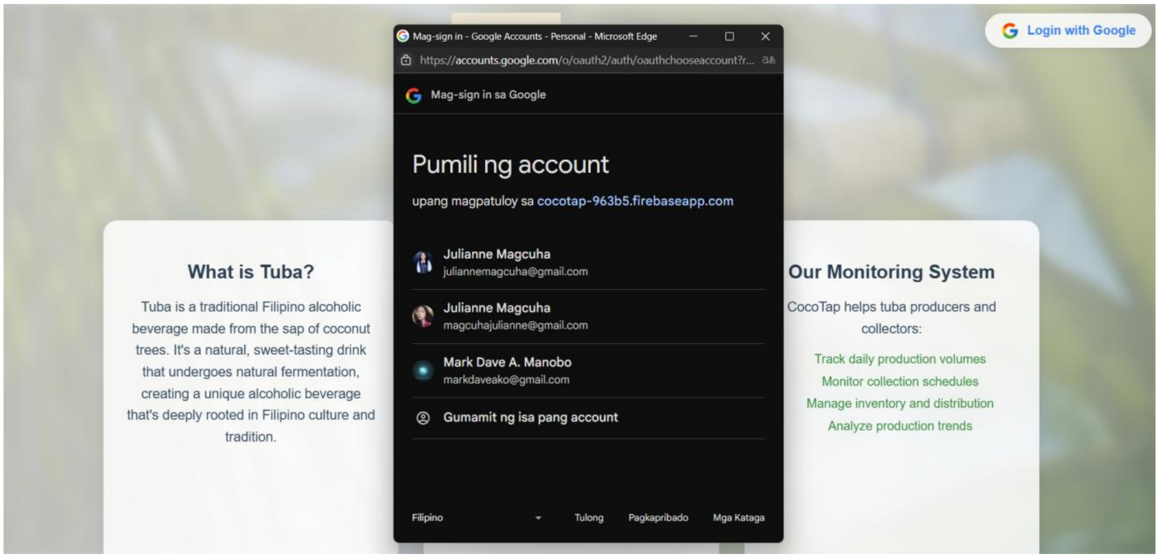

Figure 8. Google Authentication

The Google Authentication for login in the CocoTap system allows users to securely sign in using their Google accounts. This feature simplifies the login process by enabling users to select their account from a list and gain access without creating a separate username and password. It ensures secure and quick authentication, enhancing user experience while protecting sensitive data related to tuba production monitoring.

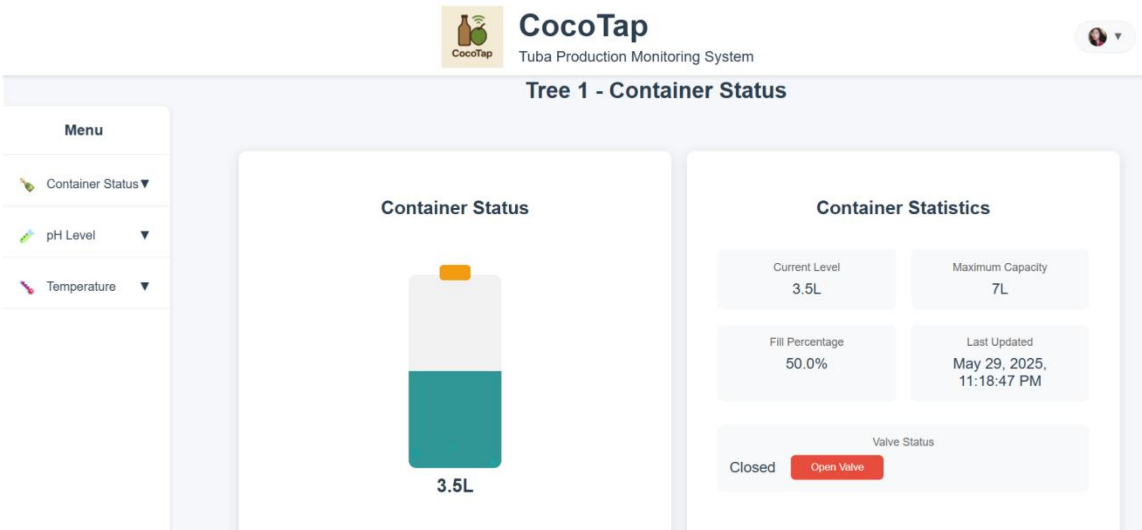

Figure 9. Dashboard

The Cocotap Dashboard provides a real-time overview of the Tuba container status for a specific tree. It features a visual representation of the current liquid level (e.g., 3.5L), alongside detailed statistics such as maximum capacity (7L), fill percentage, last updated timestamp, and valve status. The side menu allows users to navigate between data views including Container Status, pH Level, and Temperature, offering an organized and user-friendly interface for monitoring the fermentation process.

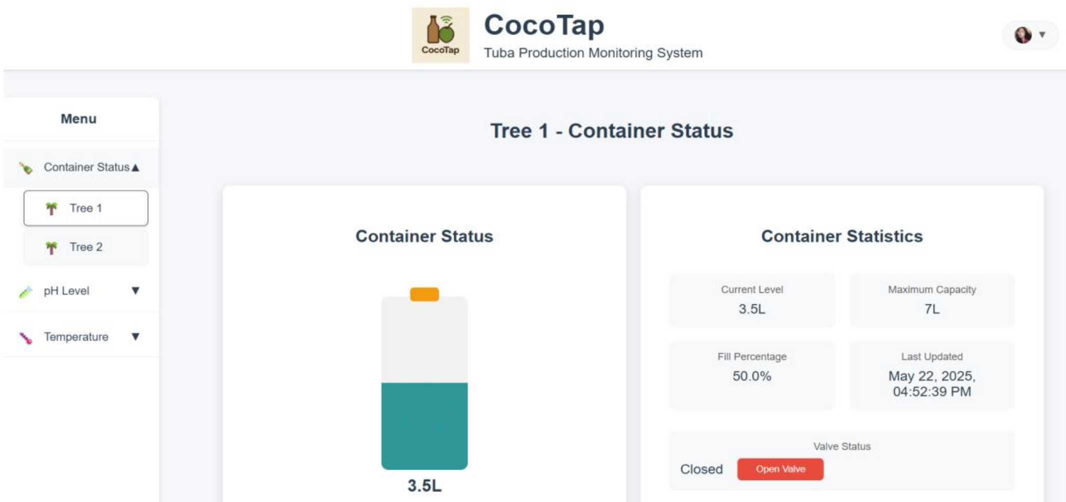

Figure 10. Container Satus

The Container Status section displays the real-time volume of collected tuba (coconut wine) in the container. It includes a visual fill indicator showing the current liquid level (e.g., 3.5L) relative to the maximum capacity (7L). Additional statistics such as the fill percentage, timestamp of the latest update, and valve status (open/closed) are provided to help users monitor and manage the tuba collection process efficiently.

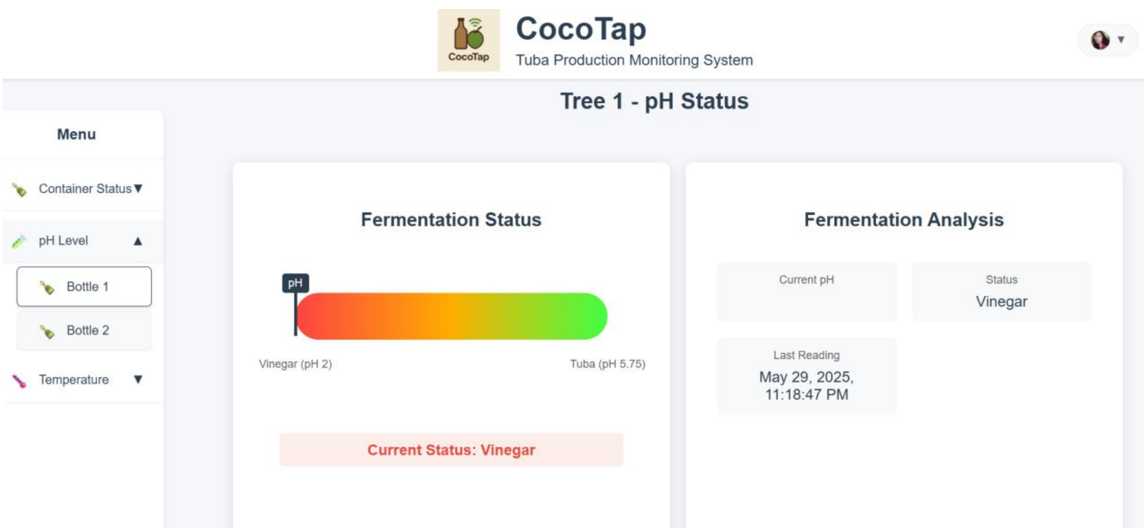

Figure 11. Fermentation Status

The Fermentation monitors the key environmental factors affecting the quality of tuba, such as pH level and temperature. These parameters are tracked in real-time to help ensure the optimal conditions for the natural fermentation process. By observing trends and fluctuations, users can better manage the transformation of coconut sap into tuba, improving both safety and product quality.

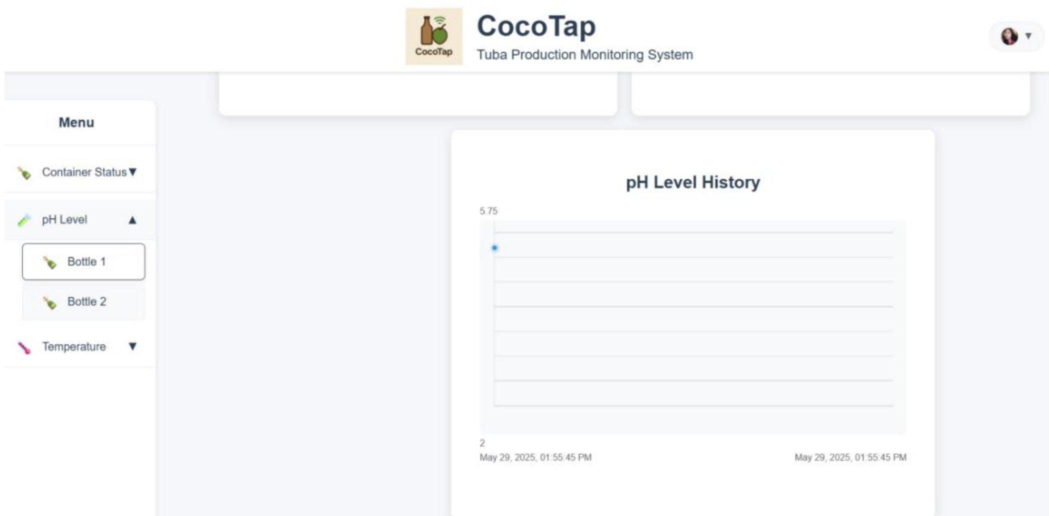

Figure 12. pH level History

The pH Level History displays a visual record of the acidity levels of the tuba in real time. This feature helps users monitor fermentation progress by showing pH changes over time for each container, such as Bottle 1 and Bottle 2. Tracking pH is essential in determining the quality and stage of the tuba, ensuring it is safe and suitable for consumption. The data is automatically updated and presented in a simple graph for easy interpretation by producers and collectors.

Figure 13. Temperature Status

This section provides real-time monitoring of the current temperature of each tuba fermentation container. It also includes a status indicator, such as "Optimal," to help users easily assess whether the conditions are favorable for fermentation. This feature supports proper environmental control, helping to ensure the quality and consistency of the tuba during production.

Figure 14. Temperature History

The Temperature History displays a visual timeline of the temperature readings recorded for each tuba fermentation container. This feature charts temperature values over specific time intervals, allowing users to monitor changes and identify any fluctuations that may affect the fermentation process. The graph provides a clear and organized view of historical temperature data, helping tuba producers ensure that the environment remains within the ideal range for optimal fermentation.

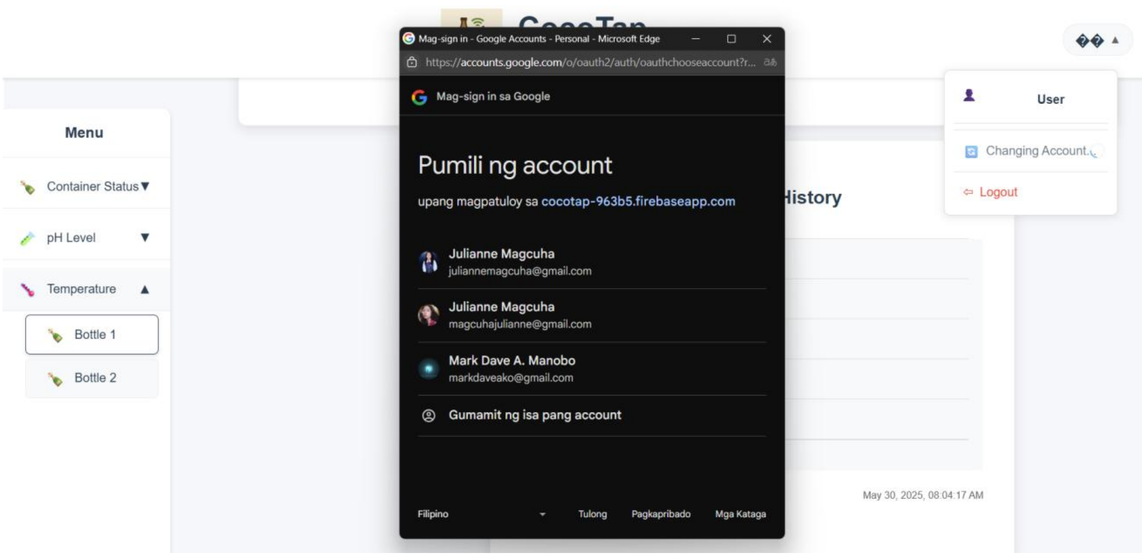

Figure 15. Changing Account

The system provides a way for users to switch Google accounts. From the user dropdown menu, selecting "Changing Account" prompts the Google sign-in window where users can choose a different account. This is useful for shared devices or multiple users, allowing seamless account management and system access.

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APPENDICES

PICTURE DURING DEVELOPMENT