Developed Model of Iot Based Smart Load Cell for Milk Collection System A Case of in Yambo Flesh Dairy Ltd (Nyanza District)

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Abstract: This research explores the development of an IoT-based smart system to enhance milk collection and quality assessment, with a case study at INYAMBO Flesh Dairy Ltd, Rwanda. The study focuses on improving the accuracy, efficiency, quality control, and transparency of the milk collection process. The system integrates technologies such as a Total Dissolved Solids (TDS) sensor for quality testing, RFID for farmer identification, and a centralized database for data management. The process includes assessing milk quality through TDS measurements, followed by weighing the milk and associating it with the farmer's RFID card for data storage. Real-time SMS updates are sent to farmers about their milk's quality, weight, and payments. The study addresses traditional challenges like quality control issues, manual errors, and inefficient record-keeping. Results show that the IoT-based system enhances the milk collection process by ensuring consistent quality, reducing errors, and automating notifications. This leads to better decision-making, improved quality control, and increased transparency, benefiting all stakeholders in the milk production chain. The study demonstrates the potential of IoT technologies to improve dairy management practices.

Keywords: *Iot-Based Smart Load Cell System, RFID Technology, Centralized Database, SMS Gateway API*

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I. INTRODUCTION

Technological advancements are transforming numerous industries, with agriculture and dairy production being no exception. This study focuses on the development and implementation of an Internet of Things (IoT)-based smart load cell system at INYAMBO Flesh Dairy Ltd, designed to optimize the milk collection and quality assessment process. The research highlights the importance of integrating modern technologies, such as Total Dissolved Solids (TDS) sensors, RFID for farmer identification, and a centralized database, to improve the accuracy, efficiency, and transparency of milk collection. By addressing challenges in traditional systems, such as manual errors and quality control issues, this system aims to ensure consistent quality standards, streamline operations, and provide real-time data access. The study explores the system's potential to enhance dairy management practices, foster better communication between farmers and the dairy, and promote overall industry improvements. The following sections present the background, problem statement, research objectives, and key questions guiding this investigation into the impact of IoT technology on dairy operations.

II. PROBLEM STATEMENT

INYAMBO Flesh Dairy Ltd. currently employs a traditional method for milk collection, which involves manual weighing and record-keeping. This approach, however, presents several challenges, such as discrepancies in recorded milk weights and delays in data processing. Farmers frequently report inconsistencies between the recorded and actual milk quantities, leading to disputes and diminished trust. These inaccuracies undermine the reliability of the system, resulting in financial losses for both farmers and the dairy. Furthermore, the manual system is time-consuming, making it difficult to efficiently track milk supply trends and plan operations.

To address these challenges, this research proposes the implementation of an Internet of Things (IoT)-based smart load cell system. This system will automate the milk weighing process, use RFID technology to identify farmers,

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and store data in a centralized database for quick, accurate access. The introduction of this technology aims to reduce errors, save time, and enhance communication between the dairy and farmers. By overcoming the limitations of the current manual system, the solution seeks to improve the reliability and transparency of the milk collection process for all stakeholders.

III. LITERATURE REVIEW

➢ *Things Online (IoT)*

The Internet of Things (IoT) refers to a network of physical objects, such as cars, appliances, and other devices, embedded with electronics, software, sensors, and connectivity, enabling them to collect and exchange data. In this study, IoT is employed to integrate various electronic components, including RFID technology, microcontrollers, and load cells, to develop a smart system that automates the milk collection process.

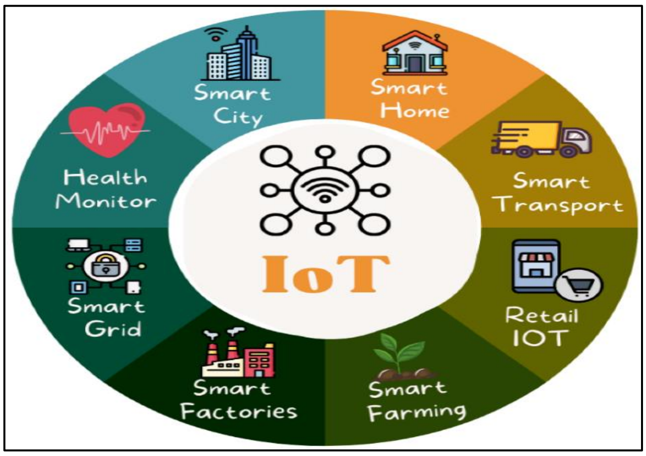

Fig 1 RFID

➢ *RFID Module*

RFID (Radio Frequency Identification) is a technology that uses electromagnetic fields to automatically identify and track objects with attached tags. This technology is ideal for applications requiring quick and accurate data collection, as the tags store information that can be read remotely without physical contact. In the milk collection system, RFID is utilized to assign a unique identity to each farmer, linking their RFID tag with their database profile.

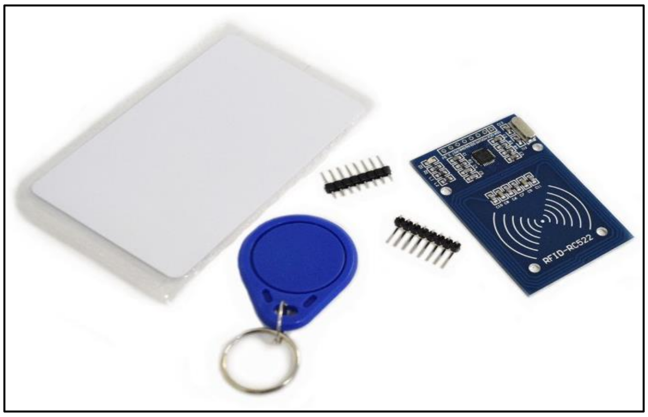

Fig 2 RFID Reader and Tag

The system links the collected milk's weight to the farmer's database profile by reading their RFID tag, ensuring accurate identification. This automation minimizes human error in record-keeping, improving data accuracy. By giving farmers confidence that their milk is accurately tracked, RFID enhances transparency and enables timely, fair payments.

➢ *Current Milk Collection at Inyambo Flesh Dairy*

The existing milk collection system at Inyambo relies on manual processes without real-time data integration. Mechanical scales measure milk, and data is manually recorded. This model faces several issues:

- *Inefficiency*:

  Manual procedures lead to delays and inaccuracies in data collection.

- *Limited Data Accessibility:*

  Farmers struggle to manage operations effectively due to lack of real-time production data.

- *Quality Control Issues:*

  Without automated monitoring, ensuring quality standards and preventing spoilage becomes difficult.

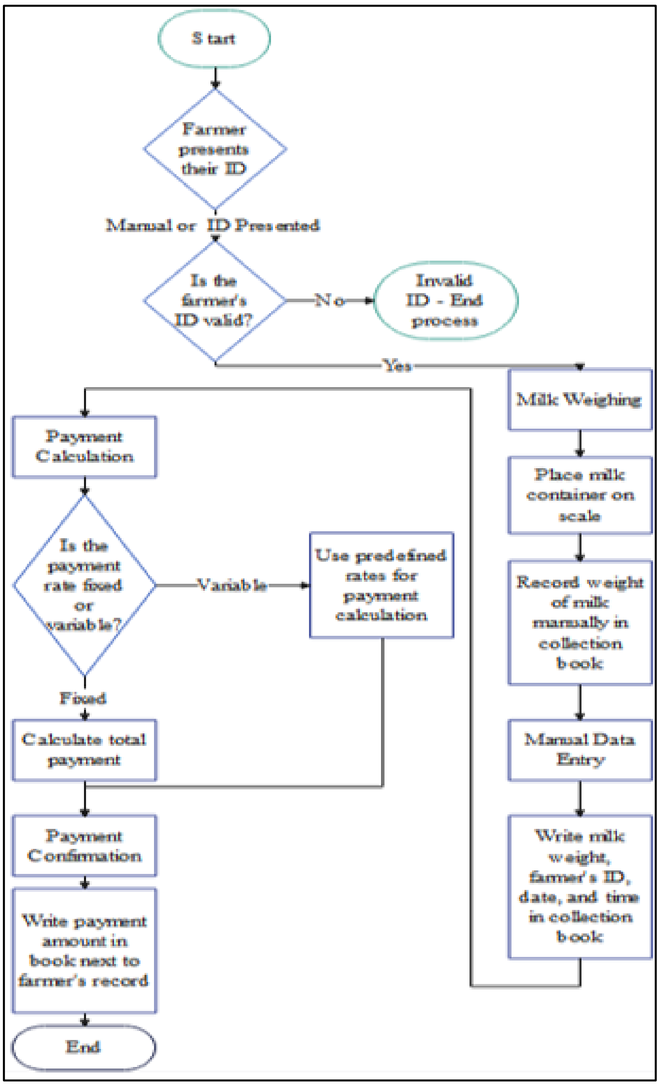

Fig 3 Existing Model Flowchart

➢ *Milk Collection Process at INYAMBO Flesh Dairy Ltd.*

The milk collection process begins when farmers present their ID (manual or RFID) at the collection point. They then place their milk container on the scale, and the weight is recorded in a book if the ID is valid. Payment is determined based on the recorded weight using either a variable or fixed rate. If payment is made, the status is marked as "Paid" in the book, otherwise, it's marked as "Pending." A receipt is given to the farmer, and the process is ready for the next farmer. This system is largely based on manual record-keeping.

IV. RESEARCH AND METHODOLOGY

➢ *Research Design*

This study adopts a descriptive and exploratory design. The descriptive part aims to analyze the current milk collection system at INYAMBO Flesh Dairy Ltd., highlighting inefficiencies and challenges. The exploratory component evaluates how an IoT-based smart load cell system can improve the process. Both qualitative and quantitative methods were used: qualitative data explores user experiences and challenges, while quantitative data assesses system performance, such as weighing accuracy and automated notification efficiency.

➢ *Study Population*

The study involves all stakeholders in the milk collection process: employees (cleaners, milk checkers), managers, and farmers. This approach provides a comprehensive view of the system's impact from different perspectives.

➢ *Sampling*

Sampling follows the formula n=N1+N(e)2n = \frac{N}{1 + N(e)^2} n=1+N(e)2N, with a margin of error (e) of 0.05. For a population of 1006, the sample size is calculated to be 286. This sample includes employees and farmers, ensuring representation from all categories.

➢ *Data Collection Methods*

Data will be gathered through surveys, interviews, and observations. Surveys will be distributed to managers, employees, and farmers to measure system effectiveness and user satisfaction. Interviews will be conducted with select individuals to gain deeper insights into their experiences. Additionally, observations will be made to assess the system's usability and real-world implementation.

➢ *Data Processing*

Data will first be entered digitally, followed by cleaning to correct any errors. Quantitative and qualitative data will be integrated to provide a comprehensive view of the system's performance and user feedback.

➢ *Data Analysis*

Both qualitative and quantitative analyses will be employed. Descriptive statistics will summarize key metrics, while inferential statistics will identify significant patterns. Thematic and content analysis will be used for qualitative data, with thematic analysis focusing on identifying patterns in interviews and observations.

➢ *Limitations and Ethical Considerations*

Ethical standards are crucial in this research. Participants will be fully informed about the study's purpose and their role, and informed consent will be obtained. All data will be kept confidential, and participants will have the freedom to withdraw at any time. The research will respect participants' rights and ensure their dignity throughout the process.

V. CONCEPTUAL FRAMEWORK

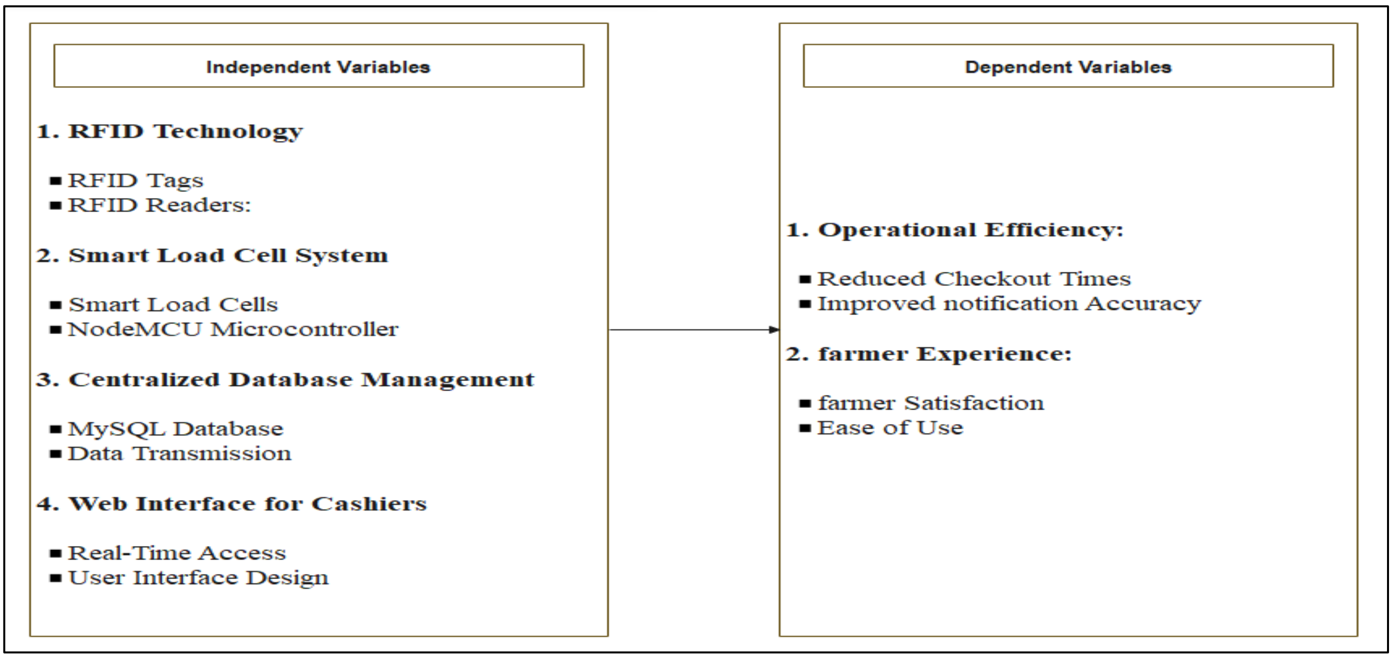

Fig 4 Concept Framework Image

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VI. PRESENTATION AND ANALYSIS OF RESEARCH FINDINGS

his chapter details the design, analysis, and implementation of the Smart Milk Data Management System, including components, specifications, cost estimates, and the implementation process.

➢ *Mathematical Models:*

Various system variables are connected using mathematical calculations. The primary model for the Smart Milk Load Cell System focuses on calculating the milk's weight, with the load cell generating an analog signal proportional to the milk's weight. This signal is then converted to digital data by the NodeMCU and processed using load cell-specific calibration factors to determine the precise weight.

➢ *RFID Reader Calculation:*

The RFID reader scans farmer tags, with the time required to scan a tag dependent on the reader's range and the tag's distance. For a 10 cm range and a 5 cm distance, the scanning time is 1 second.

➢ *Load Cell Calculation:*

The load cell measures the milk's weight by calculating the force applied. For a 2 kg mass of milk, the force is 19.6 N, which results in a weight of 19.6 kg when processed through the load cell's calibration factor.

➢ *Nodemcu / Microcontroller Calculation:*

The NodeMCU processes the data from both the load cell and the RFID reader and sends it to the database. With a data size of 2 kB and Wi-Fi bandwidth of 1 Mbps, the transmission time is 0.016 seconds, ensuring quick data processing.

➢ *Wi-Fi Router Calculation:*

The Wi-Fi router's performance is impacted by the distance between the NodeMCU and the router, as well as interference from other devices. With a 10-meter distance and 2 devices causing interference, the bandwidth is halved to 0.5 Mbps, resulting in a transmission time of 0.032 seconds.

➢ *Mysql Database:*

Data collected by the system is stored in a MySQL database. The query execution time for data retrieval and storage depends on the data size and optimization techniques. With a 50% improvement in query efficiency due to optimization, the database operations become faster.

The proposed Model / Smart load cell based on IOT with RFID Technology.

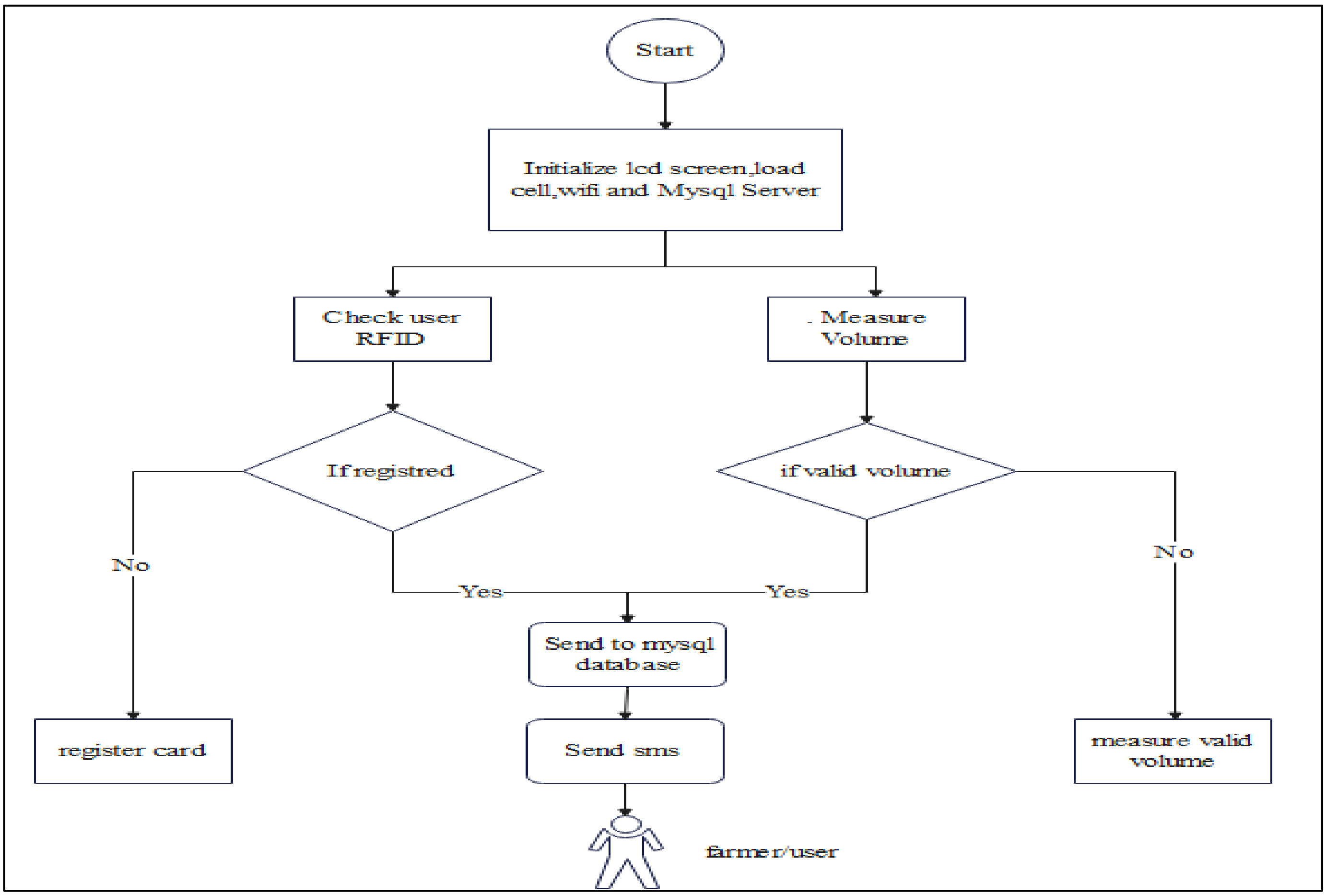

Fig 5 Proposed Model Flowchart

➢ *Flowchart Diagram*

The algorithm or flowchart outlines the step-by-step process for the operation of the IoT Based Smart Milk Data Management System. The flowchart includes the following steps.

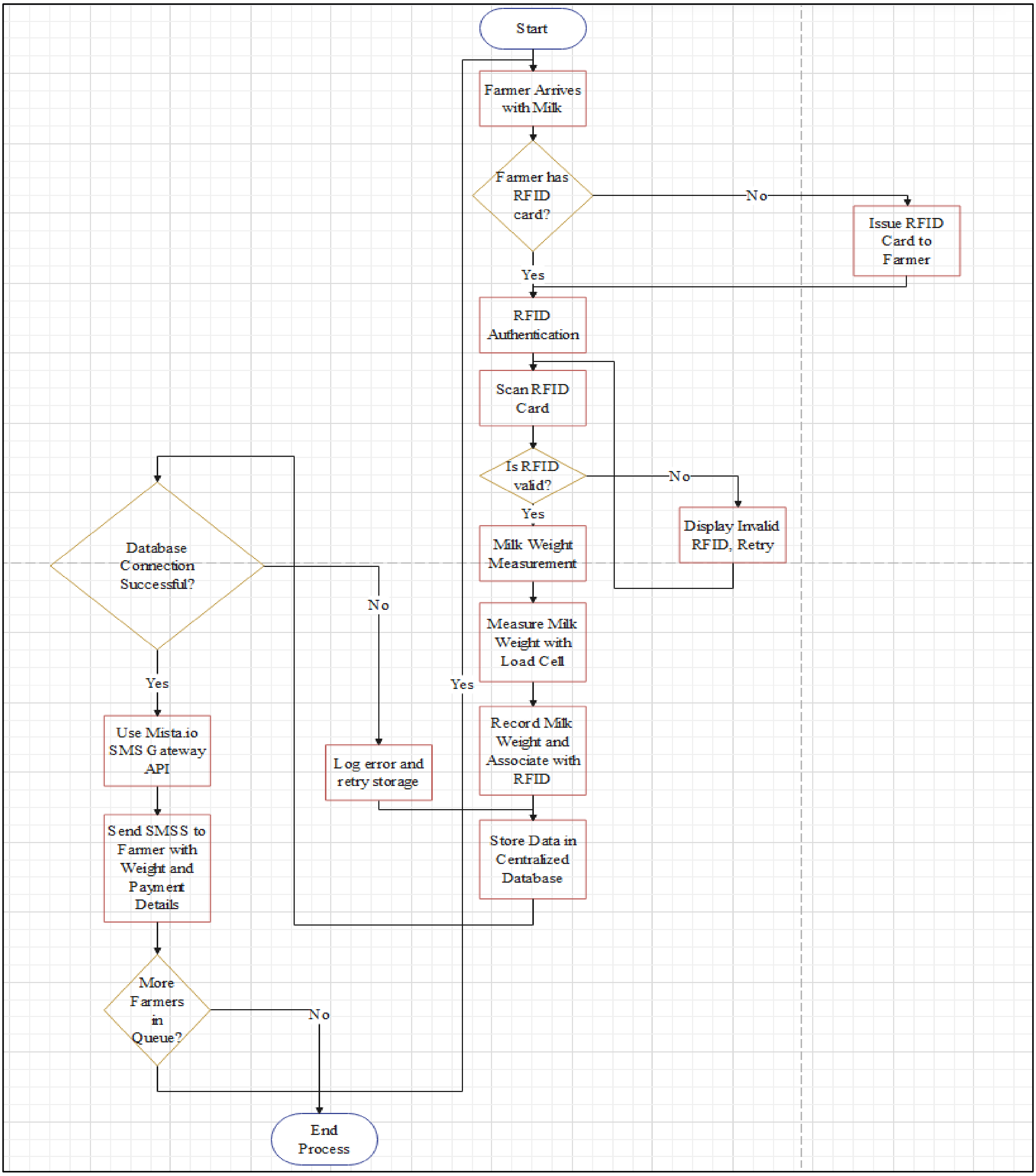

Fig 6 Image Shows Flow Chart of System

➢ *System Block Diagram*

The system block diagram provides an overview of the main components of the IoT Based Smart Milk Data Management System and how they interact with each other.

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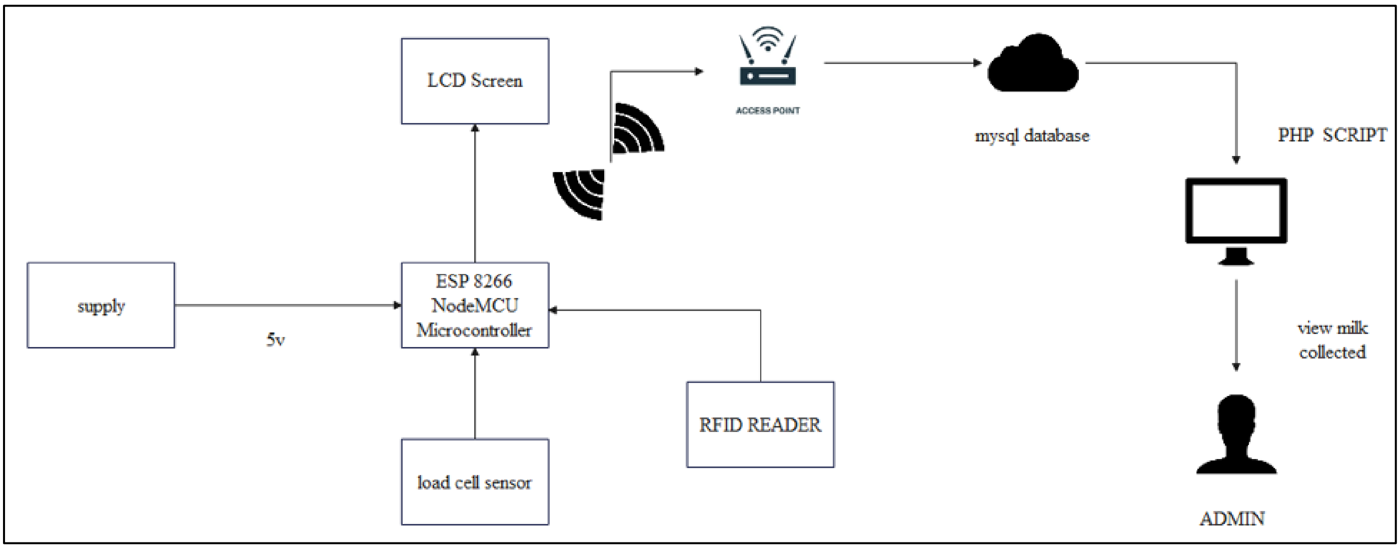

Fig 7 Block Diagram of System

➢ *Circuit Diagram*

This diagram illustrates the physical connections between key components of the system, including the RFID reader, load cell, LCD display, and NodeMCU. It shows how these components are powered and connected to ensure proper communication between them, serving as a guide for the correct assembly of the hardware.

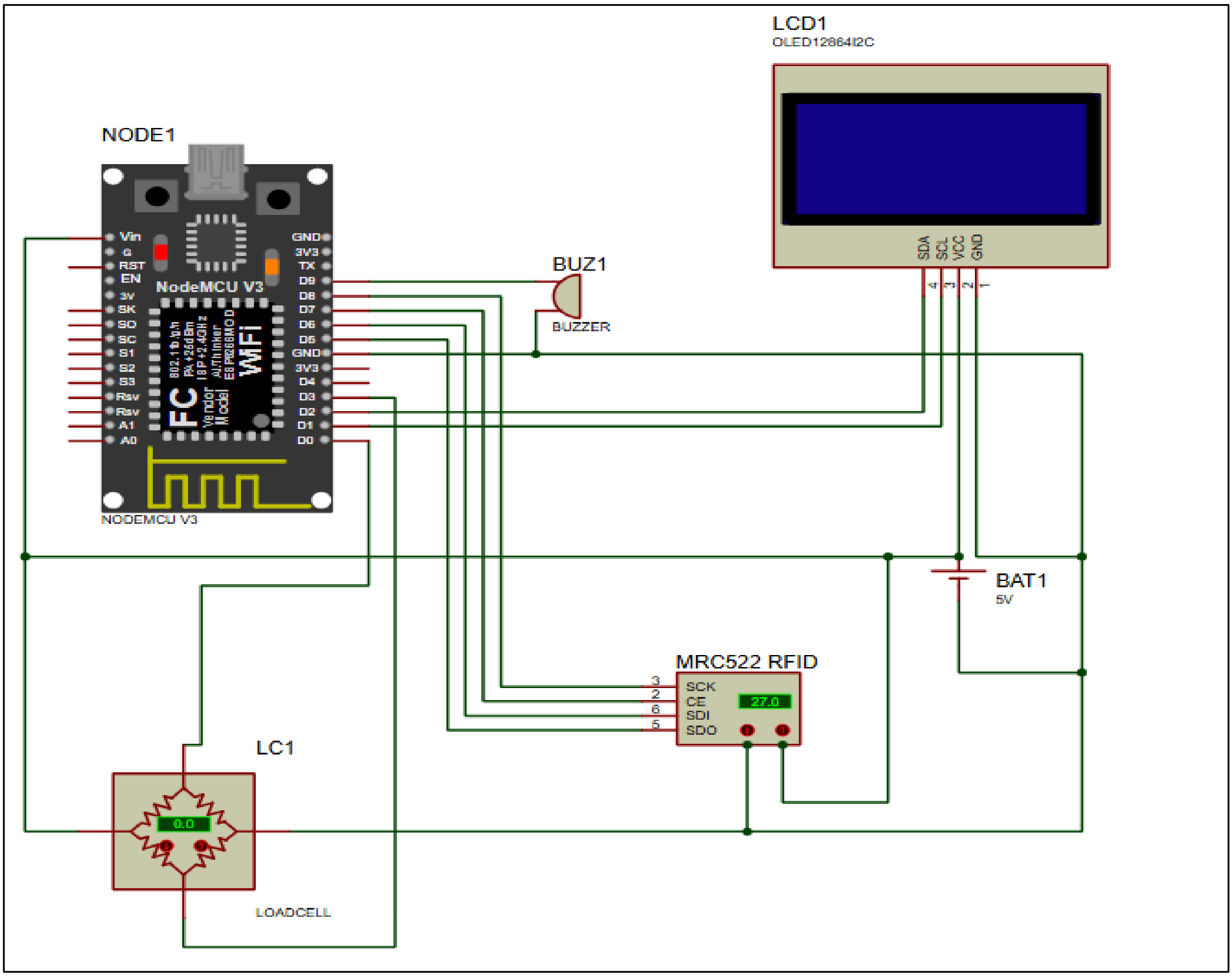

Fig 8Circuit Diagram of system

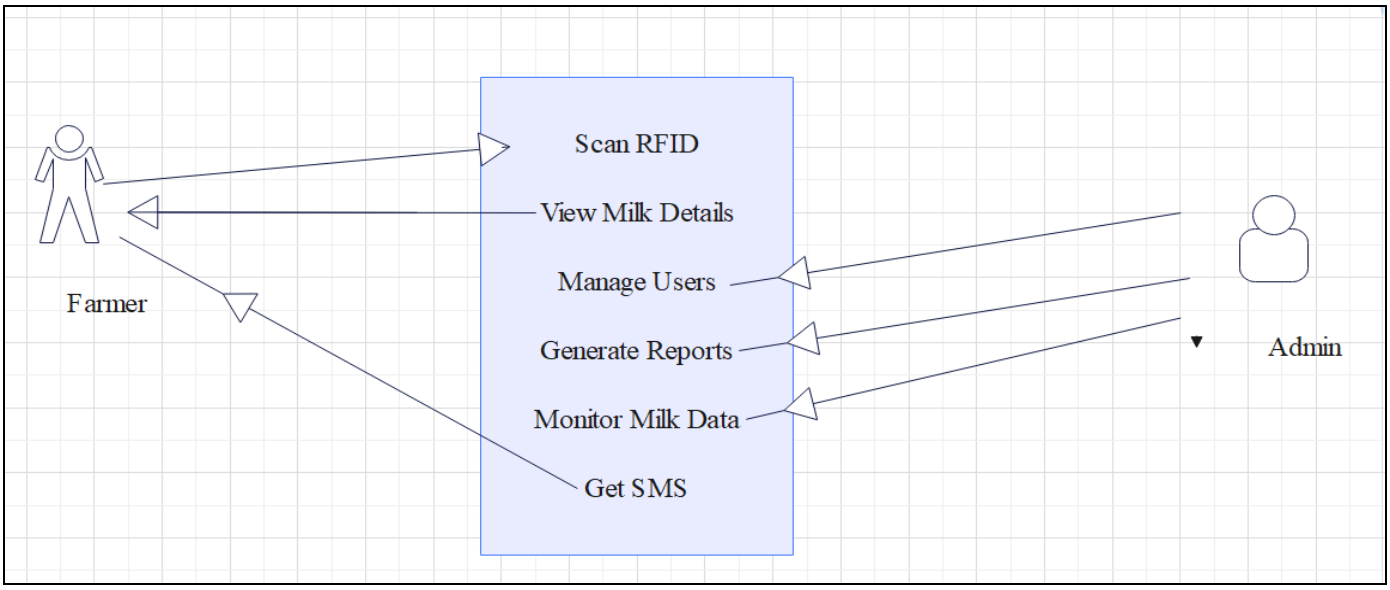

Fig 9 User Case Diagram of System

➢ User case diagram

The image illustrates the interaction between two key users—Admins and Farmers—in the IoT-based milk collection system. Farmers can perform three main tasks: scan RFID tags, view milk details, and receive SMS notifications. Admins, on the other hand, have broader control, enabling them to manage users, generate reports, and oversee milk data. The system leverages RFID technology for communication with data management and reporting systems, ensuring farmers are updated on their milk deliveries, while admins can efficiently manage the entire process.

IMPLEMENTATION OF SYSTEM

➢ *System Setup*

I started by Assembling the load cell with its amplifier and connect it to the NodeMCU. After I Install the RFID reader and connect it to the NodeMCU also.

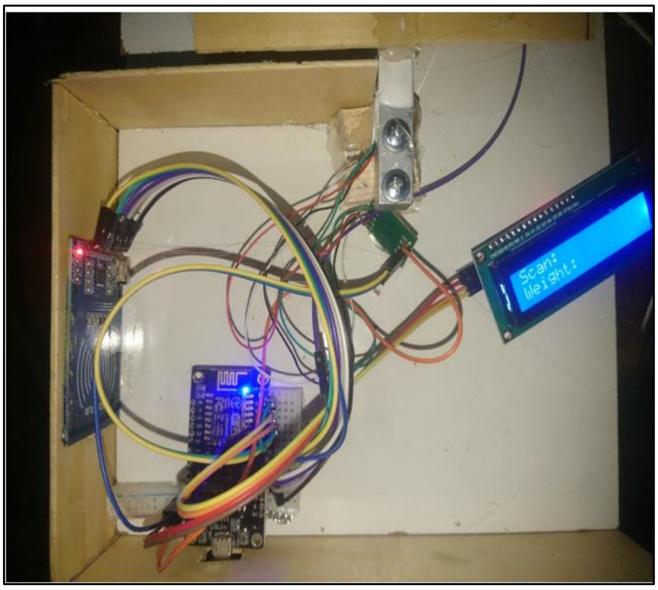

Fig 10 Connecting Devices to Microcontroller

The image in Fig_Chapter4.7 illustrates the connection of electronic components, including the NodeMCU, RFID reader, LCD screen, and load cell module, which are integrated to perform the required tasks in the system.

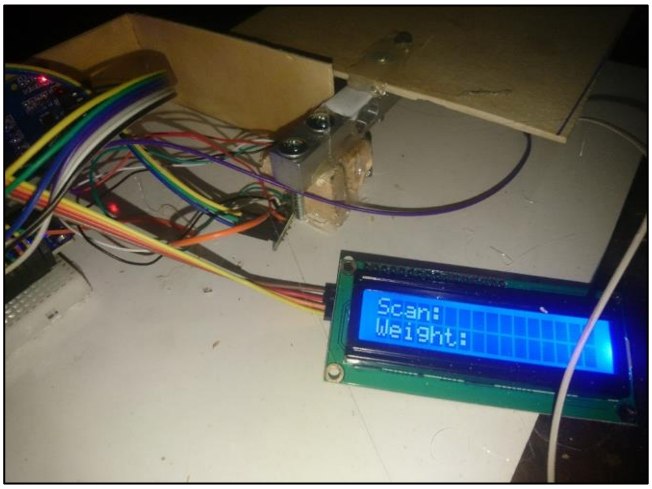

Fig 11 Checking lcd screen

The image shown in Fig_ Fig_Chapter4.8 based on lcd display which help both milk checker and farmer to view all milk corrected milk details

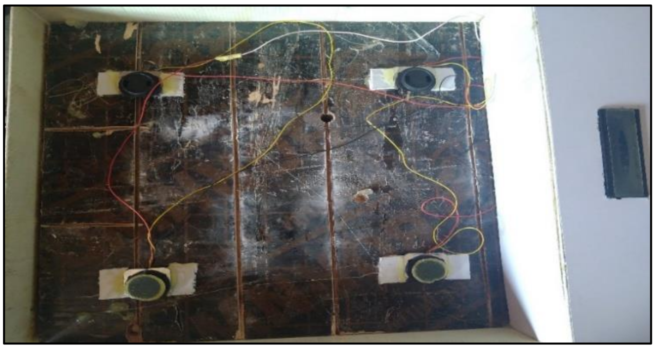

Fig 12 Load Cell Image

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The system combines several hardware components to establish a complete milk collection station. It uses an RFID reader for farmer identification, a load cell with HX711 amplifier for weight measurement, a TDS sensor for quality testing, and an LCD display for user feedback. Additionally, it connects to Wi-Fi for server communication and SMS notifications. Upon startup, the system initializes all components with correct pin configurations and calibrations.

Fig 13 Starting for Ready to Measure

Fig 14 Place Card

The process begins when a farmer scans their RFID card. Once detected, the system reads and displays the unique ID. It then checks for milk on the scale, ensuring the weight is above a minimum threshold and stable before proceeding.

Fig 15 Card Detected

The stability check is essential to prevent inaccurate readings caused by movement or disturbances. Before measuring the weight, the system first conducts a quality check using the TDS sensor, which assesses the dissolved solids content in the milk.

Fig 16 Checking Quality of Milk

After obtaining a valid measurement, the system sends the data, along with the farmer's RFID details, to a server. The server processes this information and returns the farmer's name, contact number, total collected weight, and the corresponding payment. This data is then shown on the LCD screen for the farmer to view.

Fig 17 Detected

The quality assessment process is particularly important as it helps prevent the collection of substandard milk. The TDS sensor takes multiple readings and averages them to ensure accuracy. The system considers milk acceptable if its TDS value falls between 800 and 12500 ppm (parts per million).

Fig 18 Quality Is Good

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If the milk does not meet the quality standards, the system will display an error message and halt the weight measurement process. This ensures that only milk meeting the required quality is accepted into the collection system. If the milk passes the quality test, the system continues to measure its volume in liters by taking multiple readings from the load cell and calculating the average for precise measurement.

Fig 19 Place Card Again

Fig 20 Checking Quality Again

Fig 21 Bad Quality


Fig 22 Invalid Quality Cause Invalid Measure

Finally, the system sends an automated SMS notification to the farmer's phone number, confirming the transaction. The message includes details about the quantity of milk collected and the payment amount in Rwandan Francs. This provides immediate confirmation and record-keeping for the farmer. Throughout the entire process, the LCD display provides real-time feedback, showing each step's status and any error messages if something goes wrong. The system then resets itself, taring the scale and preparing for the next farmer's milk collection.

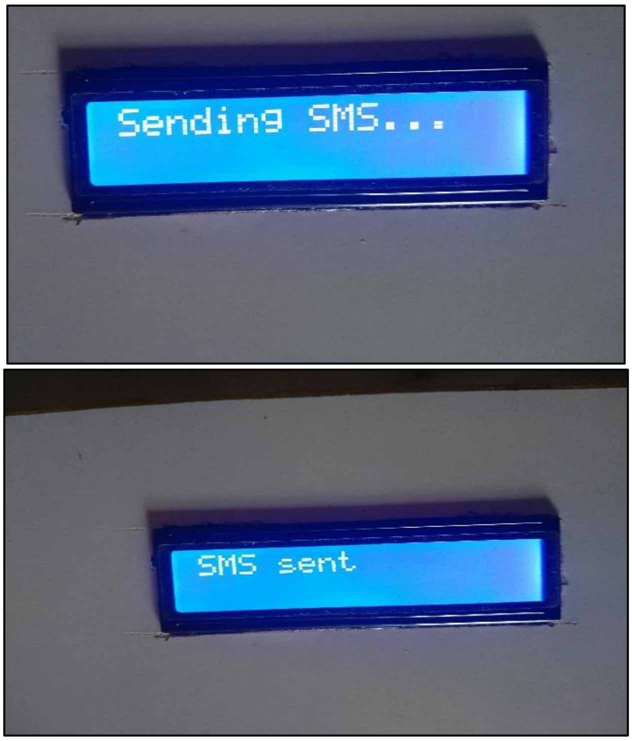

Fig 23 Sending SMS

- Software Setup

I write and upload the code to the NodeMCU to handle data collection from the load cell and RFID reader. Ensure the code interfaces with the MySQL database to store collected data.

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FULL_CODE_MILK_CORRECTION | Arduino 1.8.18

File Edit Sketch Tools Help

FULL_CODE_MILK_CORRECTION §

```
#include <HX711.h>
#include <SPI.h>
#include <MFRC522.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClientSecure.h>
#define RST_PIN D0
#define SS_PIN  D8
const char* WIFI_SSID = "shyaka";
const char* WIFI_PASSWORD = "1234567890";
const char* SERVER_URL = "http://172.20.10.6/milk/manage_weight.php";
const char* serverName = "https://api.mista.io/sms";
const char* apiToken = "573|q3fyofhnmy7ux39FFrfbseOqufq0nGbQSg2pBxo2";
const char* senderID = "E-Notifier";
const int LCD_ADDRESS = 0x27;
const int LCD_COLS = 16;
const int LCD_ROWS = 2;
const int LOADCELL_DOUT_PIN = D4; // Data pin
const int LOADCELL_SCK_PIN = D3;   // Clock pin
HX711 scale;
const float CALIBRATION_FACTOR =-100.615; // Adjusted calibration factor
MFRC522 rfid(SS_PIN, RST_PIN);
LiquidCrystal_I2C lcd(LCD_ADDRESS, LCD_COLS, LCD_ROWS);
WiFiClient wifiClient;
```

Fig 24 Compiling Code, Arduino IDE Software

After uploading the code to the microcontroller, I created the required database tables and configured the server to receive data from the NodeMCU. This setup ensures efficient data logging and retrieval. The image below displays the table structure in the MySQL server.

Containing the word:

	Table	Action							Rows	Type	Collation	Size	Overhead
☐	admin	☆	Browse	Structure	Search	Insert	Empty	Drop	2	InnoDB	latin1_swedish_ci	32.0 KiB	-
☐	historic	☆	Browse	Structure	Search	Insert	Empty	Drop	0	InnoDB	latin1_swedish_ci	32.0 KiB	-
☐	price	☆	Browse	Structure	Search	Insert	Empty	Drop	1	InnoDB	latin1_swedish_ci	32.0 KiB	-
☐	users	☆	Browse	Structure	Search	Insert	Empty	Drop	4	InnoDB	latin1_swedish_ci	16.0 KiB	-
	4 tables	Sum							7	InnoDB	utf8mb4_general_ci	112.0 KiB	0 B

☐ Check all With selected:

Fig 25 Table in Database of Milk

After creating tables, I created registration form that will help administrator to log in in website

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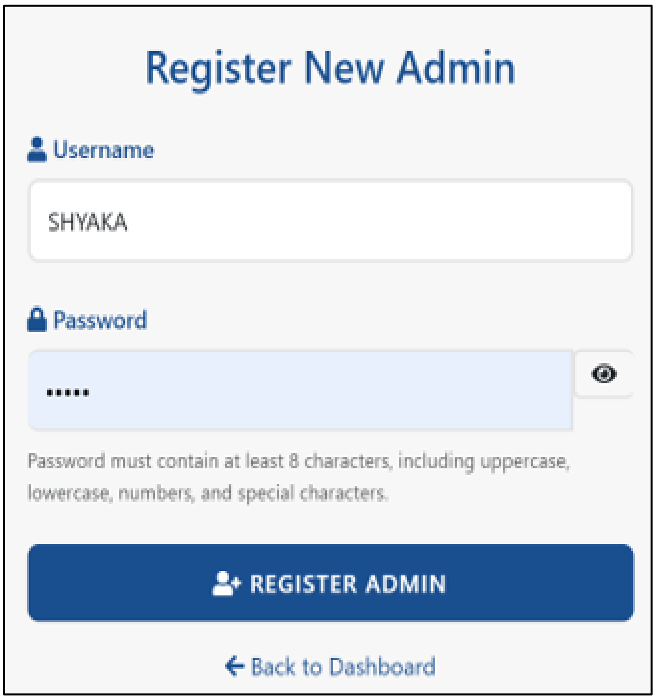

Fig 26 Create Account Screenshot

After creating form of registration and I created form of login where to reach to home page require credentials

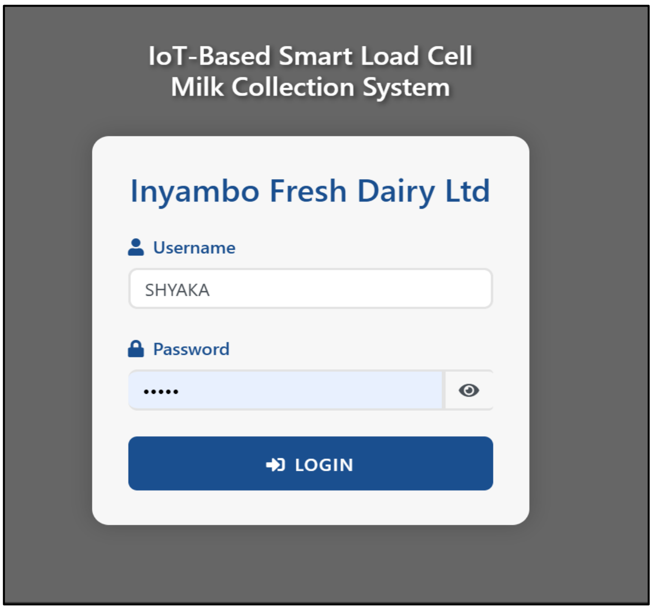

Fig 27 Login Form Screenshot

Fig 28 Home Page of Website

The home page serves as the administrator's dashboard for the Smart Milk Load Cell System, offering various milk data management features. The administrator can perform tasks such as creating new user accounts, viewing historical data on the total liters of milk collected via a graphical interface, and managing users by modifying or deleting accounts. Additionally, the admin can input pricing details for the collected milk and track the total milk collected, all through an intuitive, user-friendly interface. The design includes clearly visible menu buttons for functions like home, registration, total milk liters, user management, and a logout option for security.

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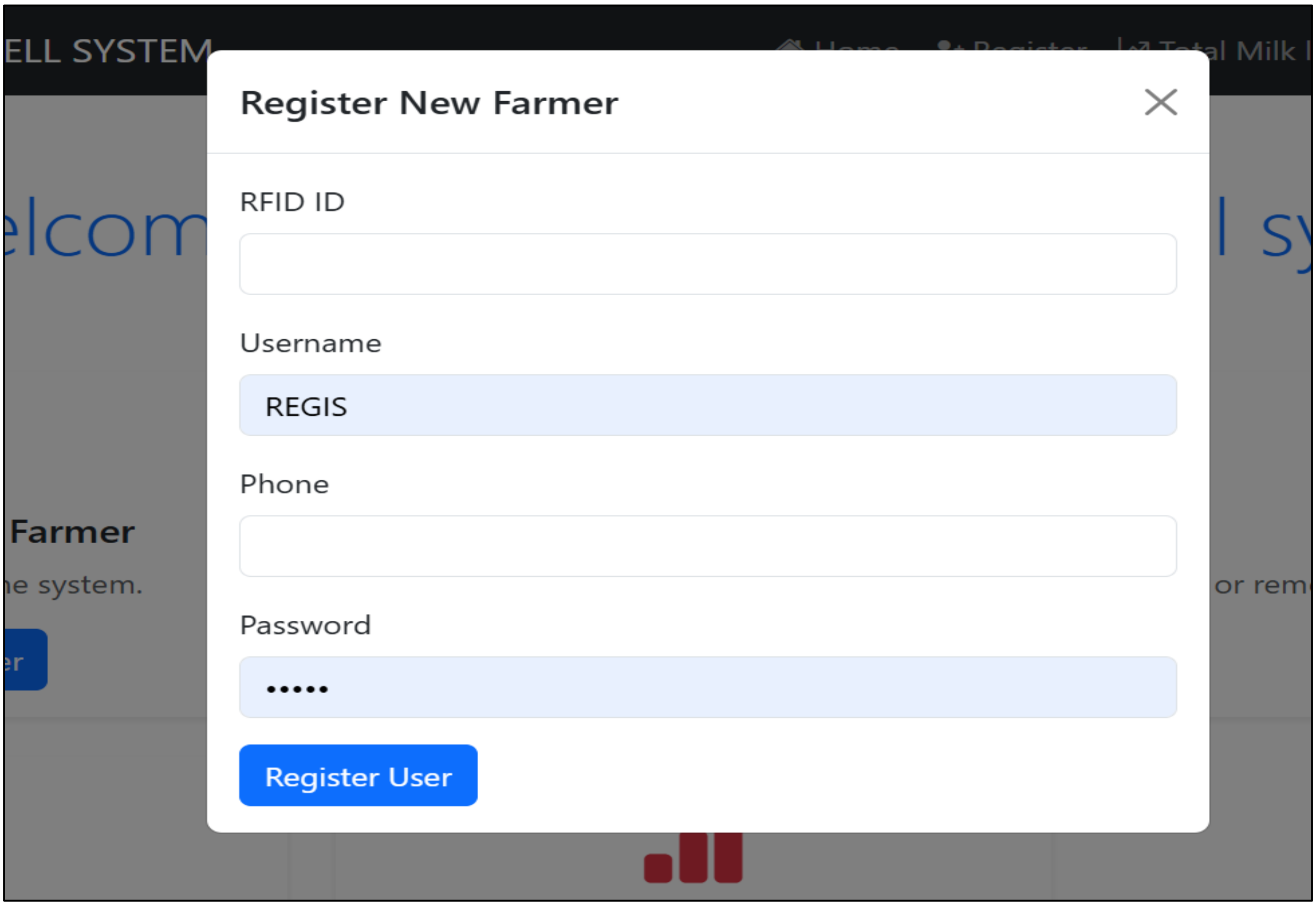

Fig 29 Register Farmer Form

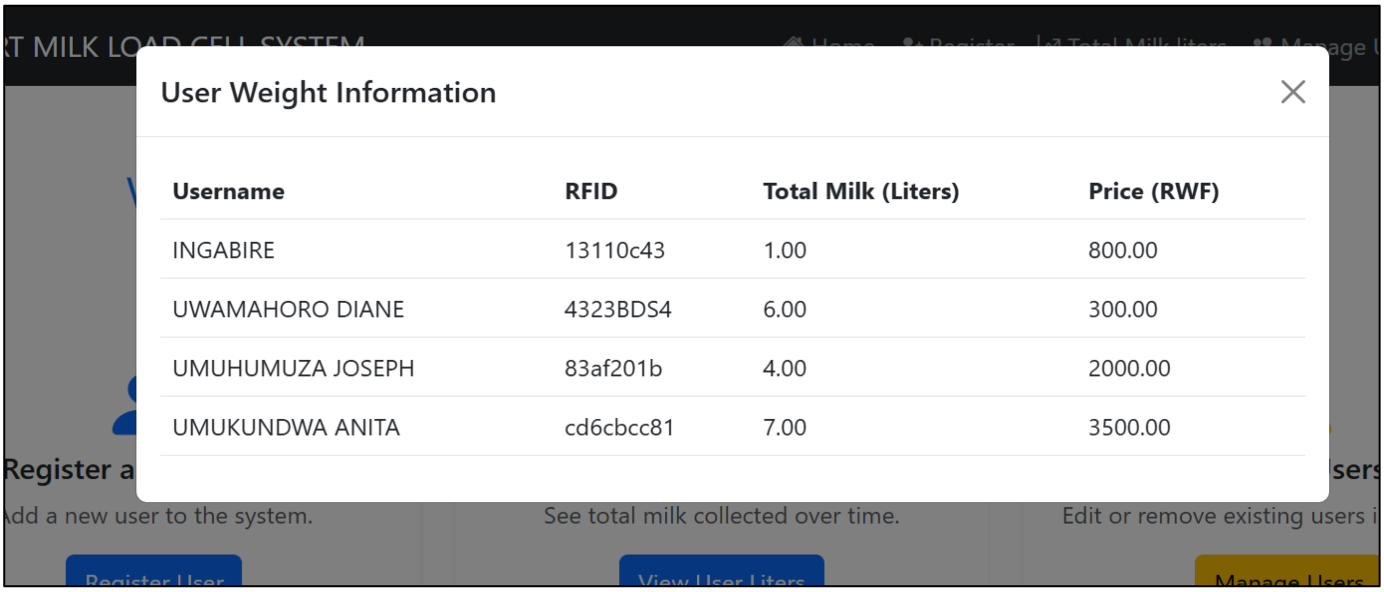

Fig 30 Famer Information's Details

This form shows how admin may view all information related to the famers even total milk collected in storage.

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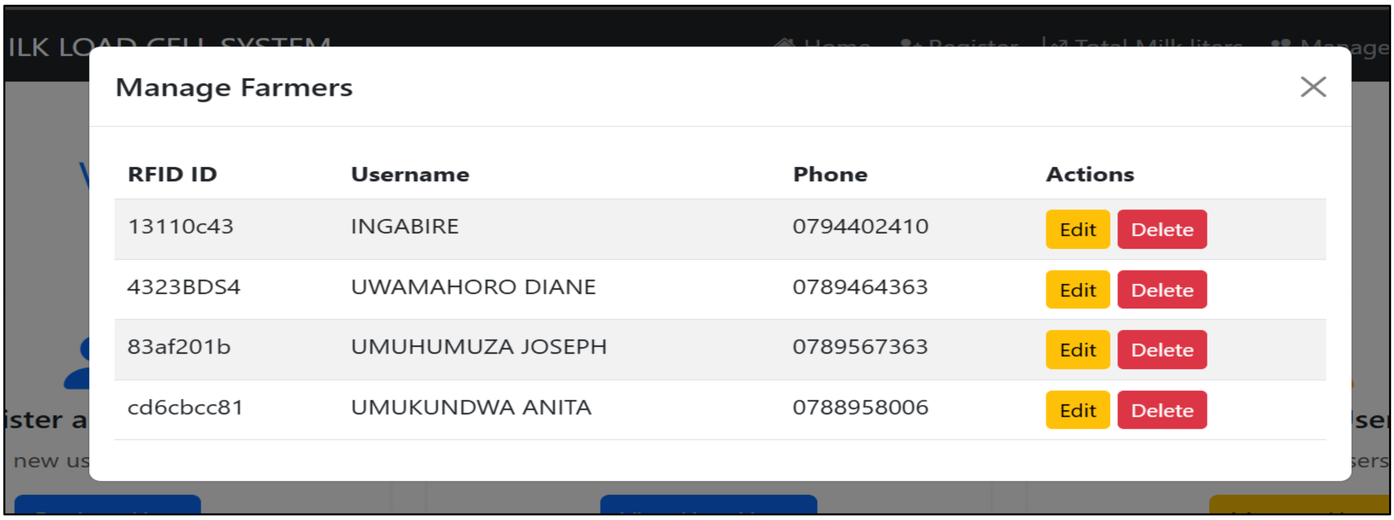

Fig 31 Managing Famers

The image above shows form of famers where they are managed by admin by editing their information or deleting them.

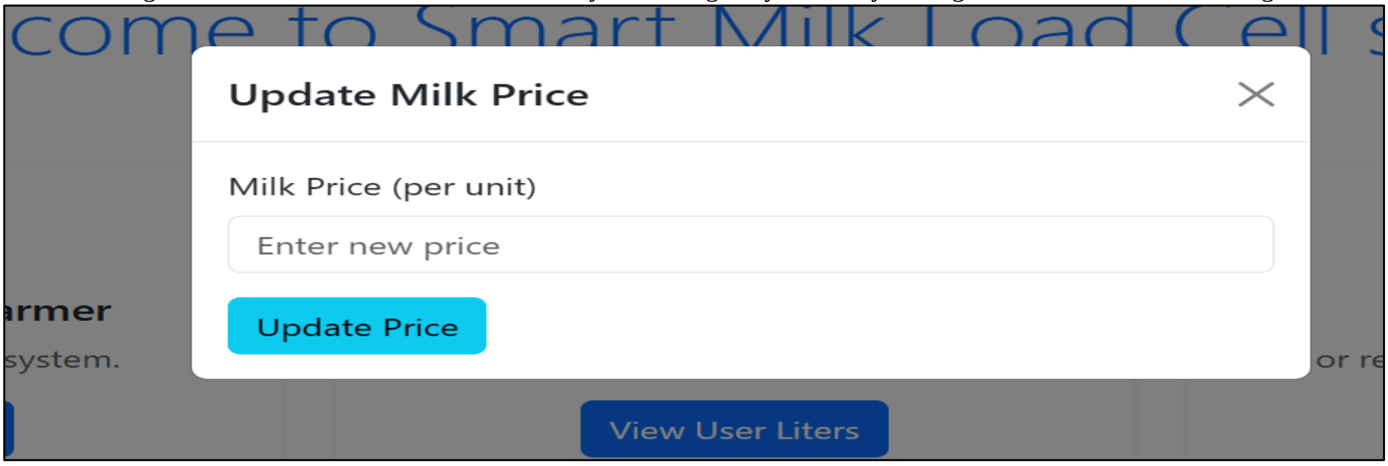

Fig 32 Setting Price Per Milk Litter

This means if admin need to change price this form helps him/her by updating price per litter of milk

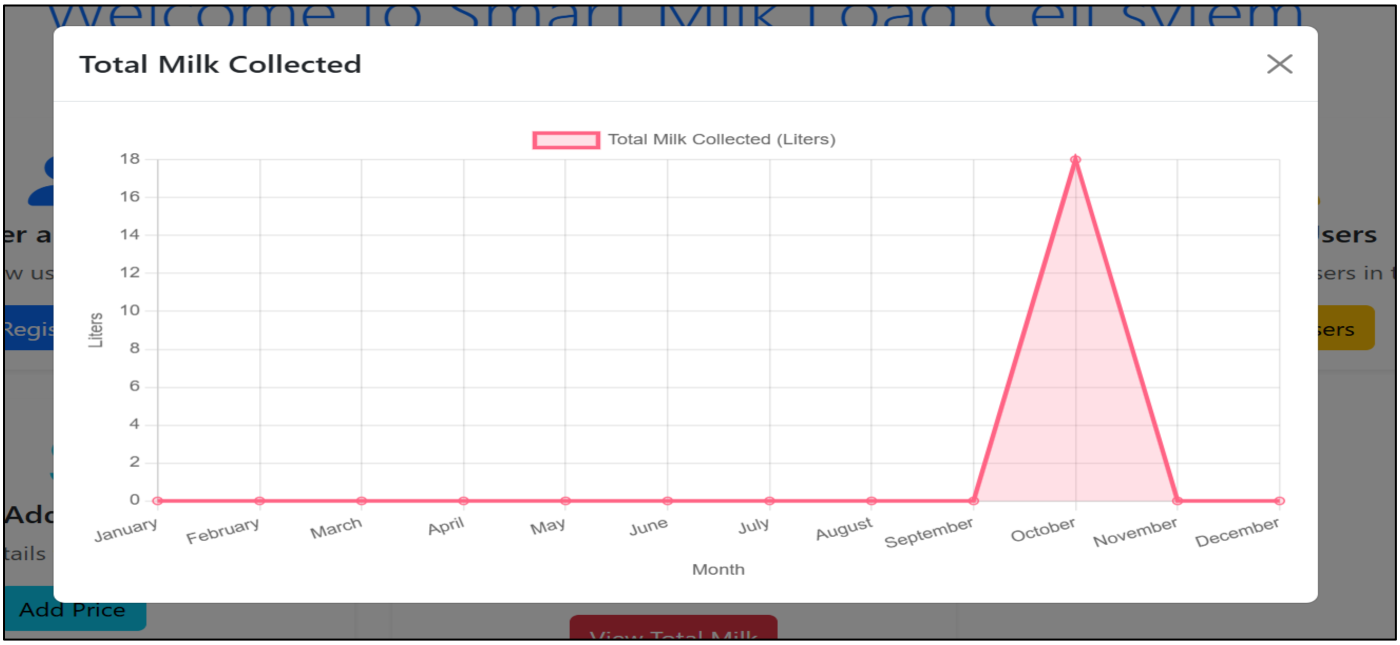

Fig 33 Total Milk Collated Graph

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Graph shows total milk collected and its dynamically not static

- Testing

I test the system with sample milk collections to ensure accurate weight measurement and RFID data capture. After it send SMS to farmer as alert, the images below show them.

Fig 34 Testing and Running Results

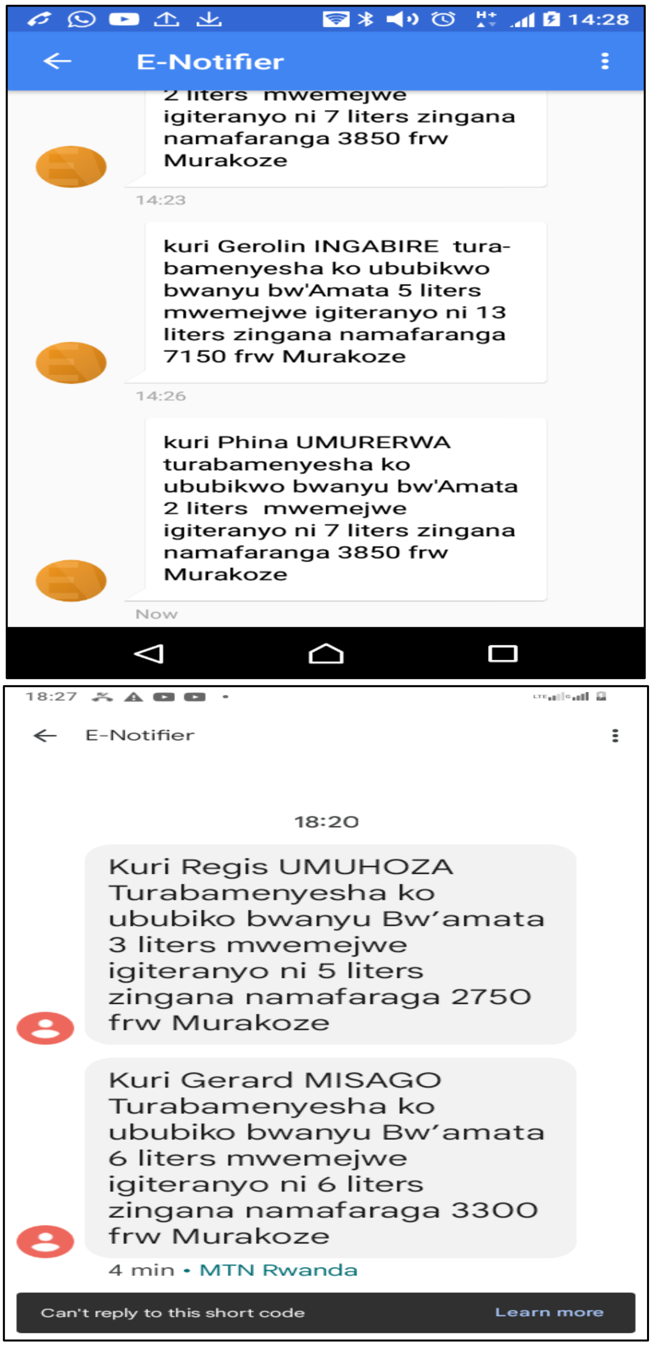

Fig 35 Testing and Running Results with SMS

VII. CONCLUSIONS

The implementation of the Smart Milk Data Management System at Inyambo Flesh Dairy Ltd has significantly enhanced the accuracy and efficiency of milk collection. The integration of RFID technology for automated tracking and load cell technology for precise weight measurement has reduced inconsistencies in milk recording. The research questions were addressed by showing improved measurement accuracy, reduced human error, and more reliable data. Additionally, the system has boosted operational efficiency, increasing milk collection productivity. It has also facilitated timely and accurate payments to farmers, positively impacting their livelihoods.

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RECOMMENDATIONS

Based on these findings, it is recommended that Inyambo Flesh Dairy Ltd, along with other dairy processors, consider upgrading their milk collection systems by adopting similar smart technologies. The integration of RFID, load cells, and IoT solutions will enhance overall efficiency, productivity, and data accuracy. To ensure the effective use of these technologies, staff training programs should be established. Additionally, the system should undergo regular maintenance and updates to maintain reliability and adapt to technological advancements.

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