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Implementation of WSN with LoRa Communication for Monitoring Digital Scales and Sugar Warehouse Environment

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Abstract—**Monitoring sugar stock levels and warehouse environmental conditions is essential to ensure product availability and quality. Pak Adib's Sugar Agent Shop in Wates District, Kediri Regency, requires an efficient system to monitor sugar quantity and storage conditions. This research proposes a monitoring system based on Wireless Sensor Network (WSN) technology integrated with a Telegram ChatBot to improve usability and functionality. The system employs a load cell sensor to measure sugar weight and a DHT22 sensor to monitor temperature and humidity, with data transmission using Long Range (LoRa) communication. Test results show that the system accurately measures sugar weight and warehouse conditions, with average errors of 0.25% for weight, 4.63% for temperature, and 0.26% for humidity. The system achieves high accuracy levels of 99.75% for weight, 95.37% for temperature, and 99.74% for humidity. Integration with Telegram ChatBot enables users to request data and receive real-time notifications when environmental conditions exceed predefined thresholds. Overall, the system improves monitoring efficiency, reduces the risk of stock miscalculations, and provides a practical solution for UMKM-scale businesses in maintaining sugar availability and quality.**

Keywords— WSN, LoRa, Scales Digital, Monitoring, ChatBot.

I. INTRODUCTION

In carrying out economic activities, economic actors interact with each other according to the variety of transactions carried out, so that they become the driving force of economic activities [1]. These interactions occur continuously and form a complex economic cycle involving production, distribution, and consumption activities. Economic actors, which consist of producers, distributors, and consumers, have their respective roles that are interrelated and mutually dependent. Producers are responsible for producing goods or services, distributors ensure the distribution of goods reaches consumers, and consumers utilize goods or services to meet their needs. The smooth interaction between these actors determines the effectiveness and efficiency of economic activities in a region.

As is the case with sugar traders in carrying out buying and selling transactions, there is a need for sugar storage as an integral part of the distribution and supply chain process. Sugar is one of the basic commodities that has a high level of demand in the community and is widely used for household consumption as well as for small and medium-scale food industries. Therefore, maintaining the availability of sugar stock becomes a crucial factor for traders to ensure business continuity and meet market demand consistently. The existence of a warehouse as a storage facility plays a strategic role in supporting the smooth operation of sugar trading activities.

The treatment of sugar storage in the warehouse, such as in maintaining the availability and quality of sugar, is very important. Sugar is hygroscopic in nature, meaning it easily absorbs moisture from the surrounding environment. If storage conditions are not properly controlled, sugar can experience quality degradation, such as clumping, discoloration, and even contamination. Therefore, it is necessary to monitor both the quantity of sugar stock and the environmental conditions of the warehouse carefully and efficiently. Proper monitoring not only ensures that sugar remains in good condition but also helps business actors manage inventory more accurately and systematically.

However, in practice, stock checks and warehouse condition monitoring are often still carried out manually by Micro, Small, and Medium Enterprises (UMKM) scale business actors. This condition is also experienced by the Pak Adib Shop Sugar Agent located in Wates District, Kediri Regency. As an UMKM, Pak Adib's shop operates with limited manpower and relies heavily on manual processes in daily operations. The manual method of monitoring inventory and warehouse conditions is prone to inefficiency and inaccuracies, especially when the volume

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of goods stored is relatively large.

Pak Adib’s shop provides sugar in kilogram packages and is capable of accommodating up to 5 tons of packaged sugar stock every day. This amount reflects a fairly high trading intensity, considering that sugar is distributed almost daily to various shops in the market. In the sugar packaging process, the parties involved are the owner himself, Mr. Adib, and assisted by his wife. With limited human resources, all operational activities such as packaging, recording stock, monitoring warehouse conditions, and serving customers are carried out independently without the support of an automated system.

The marketing target achieved by Pak Adib’s shop mainly includes retail shops in traditional markets. As a result, buying and selling transactions occur almost every day with varying volumes. This condition requires accurate stock data so that supply can always meet demand. If stock data is inaccurate, it can lead to shortages or overstocking, both of which can cause losses. For example, a shortage of sugar stock can result in lost sales opportunities, while excess stock can increase storage costs and the risk of quality degradation.

One of the main problems that arise in this business is the manual process of checking sugar stock in the warehouse. The owner must walk directly to the warehouse room and calculate the stock of goods manually. This process is time-consuming and physically demanding, especially if it has to be done repeatedly throughout the day. In addition, manual calculations are highly susceptible to miscalculation or human error, such as incorrect counting, recording errors, or oversight due to fatigue. These errors can accumulate over time and result in inaccurate inventory records.

The impact of these problems is not limited to operational inefficiency but can also have a negative effect on business decision-making. Inaccurate stock information can lead to poor planning, such as incorrect purchasing decisions or delays in fulfilling customer orders. In the long term, this can reduce customer trust and competitiveness in the market. Therefore, improving the efficiency of time and labor in monitoring sugar availability and warehouse conditions becomes an urgent need for Pak Adib’s shop.

In addition to stock quantity issues, warehouse environmental conditions also play a significant role in maintaining sugar quality. Based on a study using Scanning Electron Micrograph (SEM) analysis, it was found that temperature and humidity of a room can significantly affect the physical properties of sugar during storage [2]. High humidity levels can cause sugar crystals to absorb moisture, leading to caking or coagulation. This condition reduces the quality of sugar and makes it less desirable for consumers. The study states that ideal room conditions for sugar storage can be achieved with a room temperature of approximately 30°C and relative humidity of 67.89% [2].

If warehouse environmental conditions are not controlled properly, sugar can deteriorate even if the stock quantity is sufficient. Therefore, monitoring environmental parameters such as temperature and humidity is just as important as monitoring stock levels. Unfortunately, in many UMKM-scale warehouses, environmental monitoring is often neglected or carried out subjectively based on human perception, which is not accurate and reliable.

Several previous studies have been conducted related to inventory monitoring and warehouse management systems. One study developed an inventory system using Arduino-based load cell sensors integrated with a Telegram chatbot to monitor stock levels [3]. Another study proposed a digital scale prototype for web-based grocery warehouses to facilitate real-time inventory monitoring [4]. Although these systems provide technological solutions, they still have limitations, particularly in warehouse environments that require stable internet connectivity. In areas with limited or unstable internet access, such systems may not function optimally.

In terms of environmental monitoring, a previous study discussed the use of the Ubidots application for control and monitoring systems in Arduino Uno-based sugar warehouses [5][6]. While the system was able to monitor temperature and humidity, it relied on third-party application services that require subscription fees for full feature access. This becomes a drawback for UMKM actors, as additional operational costs can be a financial burden. Furthermore, dependence on external platforms can reduce system flexibility and long-term sustainability.

To overcome these limitations, a more efficient, low-cost, and independent technology-based monitoring system is required for monitoring sugar stock availability and warehouse environmental conditions. One promising approach is the use of a Wireless Sensor Network (WSN). WSN is a wireless network consisting of multiple sensor nodes that can collect, process, and transmit data wirelessly [7][8]. This technology is suitable for monitoring applications because it can operate with low power consumption and cover a wide area.

In this research, the WSN method is implemented using Long Range (LoRa) communication technology. LoRa is a low-power wide-area network (LPWAN) technology that is capable of transmitting data over long distances with minimal power consumption. LoRa communication modules, such as the SX1278, have power consumption ranging from 10 mA to 12 mA and can achieve communication distances of up to 5 kilometers in open areas [9][10]. These characteristics make LoRa highly suitable for warehouse monitoring applications, especially in locations where the distance between the warehouse and the monitoring center is relatively far.

The implementation of LoRa-based WSN can be effectively applied in the Pak Adib Shop Sugar Agent, where the warehouse is located approximately 10 meters away from the owner’s house. Although the distance is relatively short, the use of LoRa ensures reliable communication with minimal power usage and does not depend on continuous internet connectivity at the sensor node level. This provides flexibility and reliability in data transmission [11][12].

To monitor sugar stock levels, a load cell sensor is utilized. Load cell sensors work by converting mechanical force (weight) into electrical signals, which can then be processed to determine the weight of stored sugar [13][14]. By placing sugar packages on a load cell-based weighing platform, real-time weight data can be obtained automatically without manual counting. This significantly reduces the risk of human error and saves time and labor.

In addition to stock monitoring, the environmental conditions of the warehouse are monitored using a DHT22 sensor. The DHT22 sensor is capable of measuring temperature and humidity with relatively high accuracy, making it suitable for warehouse environment monitoring [15]. By integrating the DHT22 sensor into the WSN system, real-time data on temperature and humidity can be collected and transmitted wirelessly via LoRa.

The data obtained from the load cell and DHT22 sensors is then processed and displayed through the Telegram application using the ChatBot feature. Telegram ChatBot is chosen as the user interface because it is widely used, free of charge, and easy to access via smartphones. Through the ChatBot, the warehouse owner can receive real-time information about sugar stock levels and environmental conditions without having to physically visit the warehouse. This approach improves monitoring efficiency and supports faster decision-making [15].

II. METHOD

In the creation of an inventory system and monitoring the sugar warehouse environment in a case study UMKM Pak Adib Kabupaten Kediri, shown by the following diagram block, Fig. 1.

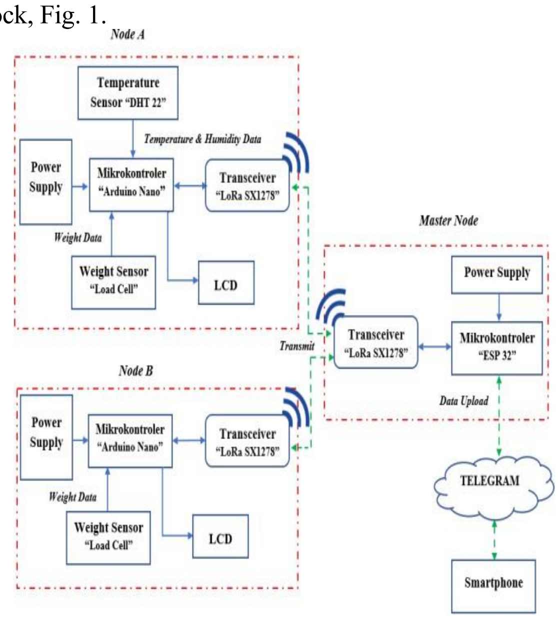

Figure 1. System Block Diagram

Fig. 1 shows the systematics of the tool's operation, with inputs from the Slave Node in the form of a loadcell sensor and a DHT22 sensor. The loadcell sensor with the help of the HX711 Module can display the weight of the sugar load. The DHT22 sensor is used to display temperature data in the form of Celsius and room humidity with a percentage unit. Data read by the Slave Node is also displayed on the LCD. The Microcontrollers used include Arduino Nano and ESP32. The Arduino Nano is used on Nodes A and B (slave nodes) to process the results from the sensor to be transmitted through the LoRa SX1278. ESP32 is used on the master node to process the results of the slave node through the LoRa SX1278 to be uploaded to Telegram.

A. How the tool works

How this tool works utilizes the Wireless Sensor Network (WSN) method with the following diagram, Fig. 2.

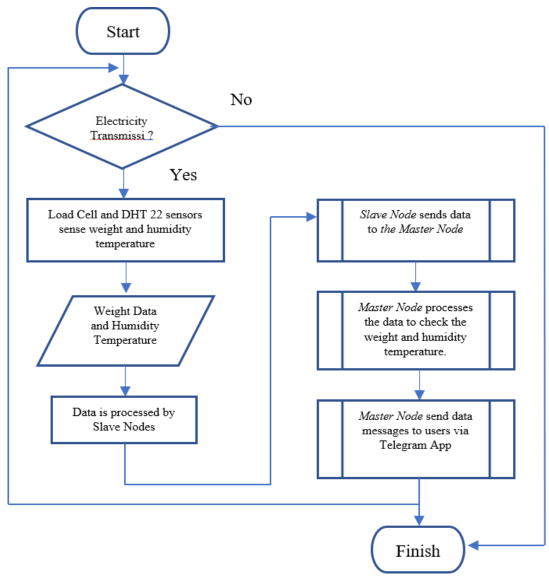

Figure 2. System Flow Diagram

The first thing is that the appliance is electrically connected? otherwise the appliance will not work. If there is electricity, the device will work and perform data sensing. The loadcell and DHT22 sensors sense the weight and humidity temperature. The output will be processed by *the slave node* on the Arduino Nano and ready to be transmitted through LoRa SX1278 when *the master node* makes *a data request*. *The master node* captures the information from the slave node through LoRa SX1278, then the data is converted into the form of pcs quantity and load weight.

The Slave Node listens to the traffic conditions on a signal, with the LoRa module set to CAD mode. If the data traffic condition is still present, the slave node does not send data and waits for a while and tries to listen again. Before sending the data, the slave node sends an RTS (Ready to Send) packet to the master node first to declare that the node is ready to send the data. If the Master Node receives the RTS packet, then the Master Node replies to the CTS (Clear to Send) packet. And if the Slave Node has not received the CTS packet, then the Slave Node waits a while before resending the RTS packet. After the Slave Node receives the CTS package, the data in the form of weight and humidity temperature will be sent to the Master Node. Once the data is received, the Master Node sends an ACK packet to the data sending node to notify the node (ESP32) that the sent packet has been received by the Master Node. The diagram is shown in Fig. 3.

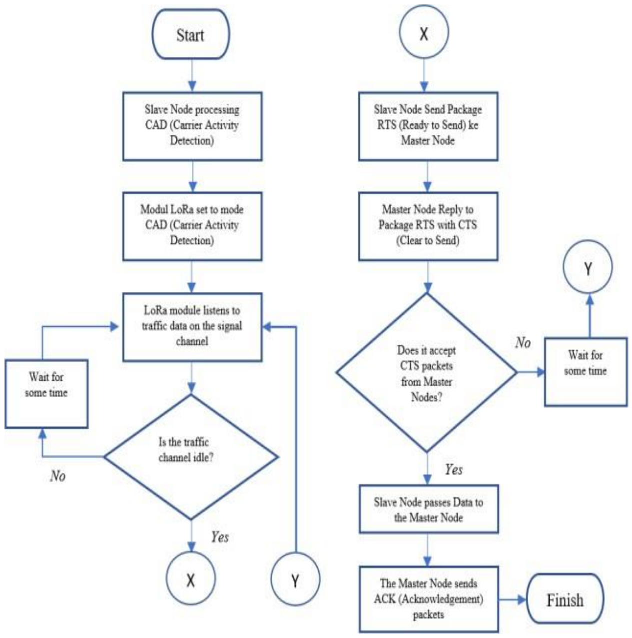

Figure 3. Slave Node System Diagram Sending Data to the Master Node

The DHT22 sensor has temperature and humidity data, if the temperature is not in the range of 25-32 ºC or humidity in the range of 60-85%, the system displays unsafe environmental conditions. If it is around a set point, the sensor sensing returns. The Load Cell Sensor displays weight data in kilograms (kg), like shown in Fig. 4.

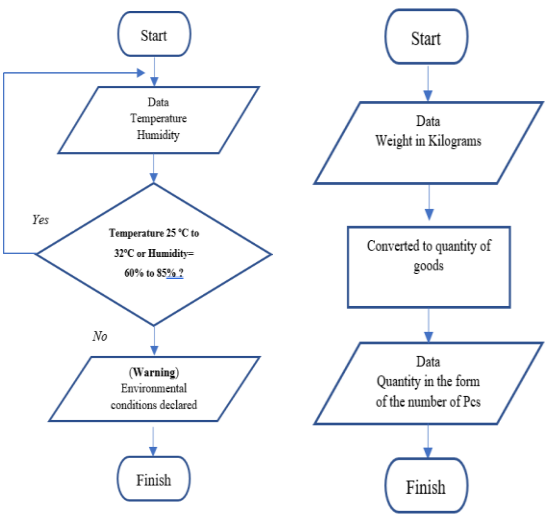

Figure 4. Master Node System Diagram Processing Data to Check Weight Conditions and Humidity Temperature

The master node on ESP 32 sends messages to Telegram users containing data on the quantity of stock pcs and the weight of the load as well as the temperature and humidity of the environment. The system sends the data received in the form of a message template along with information on the amount of stock, load weight, and the latest humidity temperature, like shown in Fig. 5.

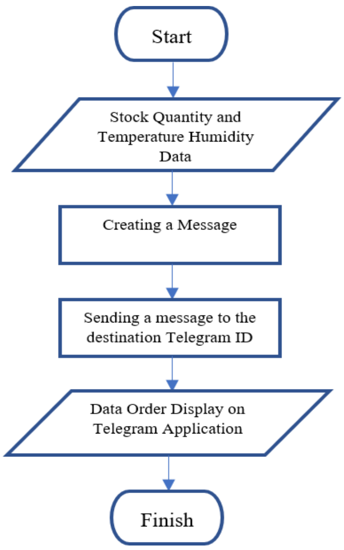

Figure 5. Master Node Sending Data Messages to Users Through Telegram Application

III. RESULTS AND DISCUSSION

A. Hardware Results

There are several hardware results on each node that can be shown in the following Fig. 6, Fig. 7, and Fig. 8.

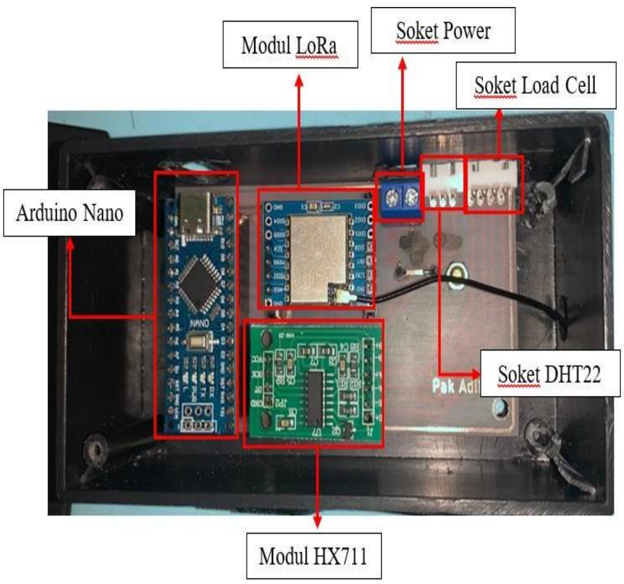

Figure 6. Node A Components

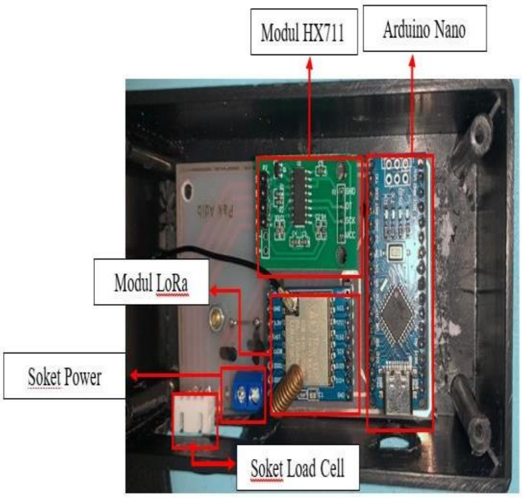

Figure 7. Node B Components

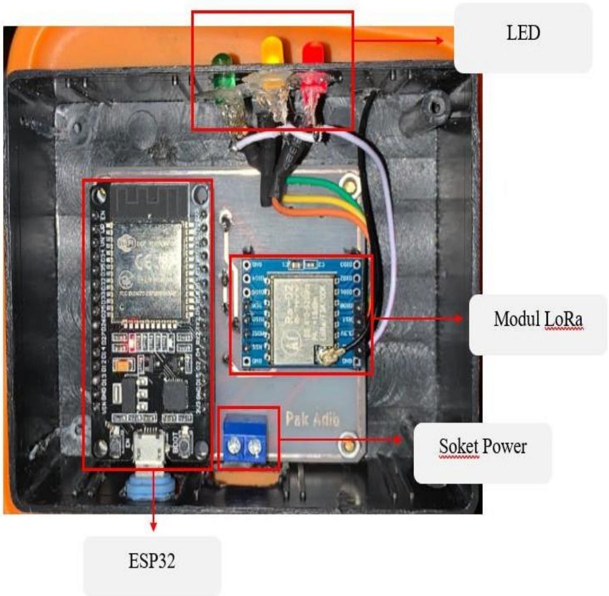

Figure 8. Master Node Components

The results of the manufacturing of component boxes in each node use acrylic boxes, which have a size of 12 cm x 6 cm on Nodes A and B, and 10 cm x 8 cm on the master node. The components *of Nodes A* and *B* consist of Arduino Nano, LoRa SX1278 Module, HX711 Module, loadcell socket, and power socket. There is a DHT22 sensor socket that is only on *Node A*. The master node consists of ESP32, LoRa SX1278 Module, LED, and power socket.

The result of making wooden boards (pallets) for the sugar pile base has dimensions of 60 cm x 60 cm with a foot height of 12 cm. Fig. 9 shows the location of the box node next to the pallet board legs, then Fig. 10 shows that there are 4 pieces of keeping load cells with a capacity of 200 kg (@50kg x 4 pieces).

Figure 9. Top View Pallet Board

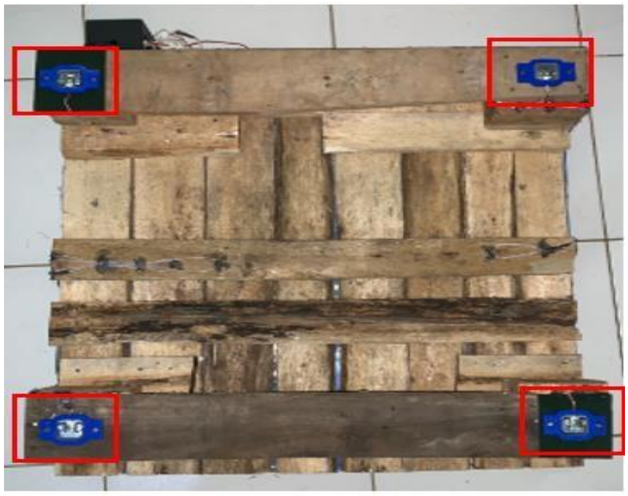

Figure 10. Bottom View Pallet Board

B. *Software Results*

The following software results on the Telegram chatbot can be shown in the following Fig. 11. it shows the appearance of the chatbot which has features including:

- **"/start"** = to call the feature menu
- **"/node1"** = to get the sensor results from *node A*, i.e. weight, temperature, and humidity
- **"/node2"** = to get the sensor result from *node B,* i.e. weight.
- **"/quantity1"** = to get the result of the quantity in the form of pcs on *node A*
- **"/quantity2"** = to get the result of the quantity in the form of pcs on *node B*
- **"/tare1"** = commands the system on *node A* to reset the weight (0 kg)
- **"/tare2"** = command the system on *node B* to reset

the weight (0 kg).

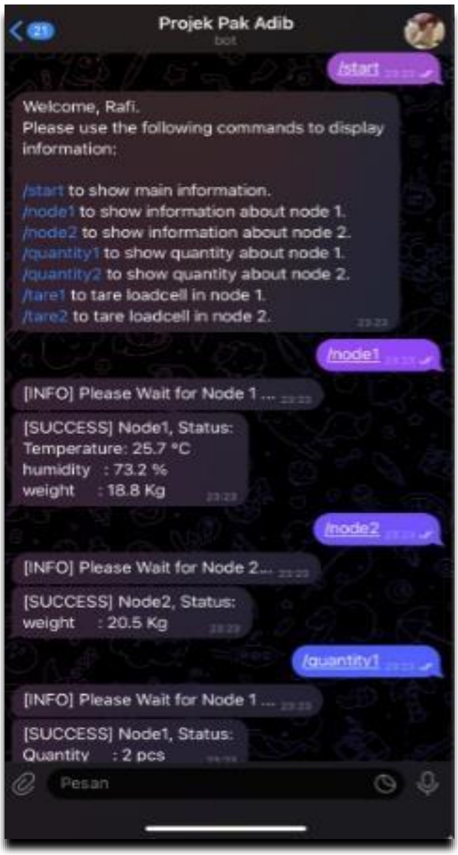

Figure 11. Chatbot Display

C. *Test Results*

The following test results of each node can be seen in the table 1 and table 2 below:

TABLE I
TESTING RESULTS OF NODE A

No	Quantity	Test Results		Information
1	1 Pack Sugar	Readable Weigh	: 10 Kg	Correct
		Pcs readable	: 1 pcs	
		Temperature	: 29°C	
		Humidity	: 72%	
2	2 Pack Sugar	Readable Weigh	: 19.9 Kg	Correct
		Pcs readable	: 2 pcs	
		Temperature	: 29,5°C	
		Humidity	: 72,2%	
3	5 Pack Sugar	Readable Weigh	: 50,2 Kg	Correct
		Pcs readable	: 5 pcs	
		Temperature	: 29,5°C	
		Humidity	: 71%	
4	6 Pack Sugar	Readable Weigh	: 19,9 Kg	Correct
		Pcs readable	: 6 pcs	
		Temperature	: 29,5°C	
		Humidity	: 72,2%	
5	8 Pack Sugar	Readable Weigh	: 79,9 Kg	Correct
		Pcs readable	: 8 pcs	
		Temperature	: 29,5°C	
		Humidity	: 72,1%	
6	10 Pack Sugar	Readable Weigh Kg	: 100,4	Correct
		Pcs readable	: 10 pcs	
		Temperature	: 29,8°C	
		Humidity	: 67%	
7	12 Pack Sugar	Readable Weigh Kg	: 120,2	Correct
		Pcs readable	: 12 pcs	
		Temperature	: 29,4°C	
		Humidity	: 66,8%	
8	14 Pack Sugar	Readable Weigh	: 140 Kg	Correct
		Pcs readable	: 14 pcs	
		Temperature	: 29,9°C	
		Humidity	: 66,8%	
9	16 Pack Sugar	Readable Weigh Kg	: 159,9	Correct
		Pcs readable	: 16 pcs	
		Temperature	: 29,4°C	
		Humidity	: 71,4%	
10	18 Pack Sugar	Readable Weigh	: 180 Kg	Correct
		Pcs readable	: 18 pcs	
		Temperature	: 29,4°C	
		Humidity	: 71,5%	

Based on Table 1, it shows that the results of the readings of *the loadcell* sensor and the DHT22 sensor on *Node A* have matched the reading of the number of pcs based on the sample weight and humidity temperature. With parameters in the form of the weight of the object per pack of sugar, which weighs 10kg per pack of sugar.

TABLE II
NODE B TEST RESULTS

No	Quantity	Test Results		Information
1	1 Pack Sugar	Readable Weigh	: 10,1 Kg	Correct
		Pcs readable	: 1 pcs	
2	2 Pack Sugar	Readable Weigh	: 20 Kg	Correct
		Pcs readable	: 2 pcs	
3	5 Pack Sugar	Readable Weigh	: 49,3 Kg	Correct
		Pcs readable	: 5 pcs	
4	6 Pack Sugar	Readable Weigh	: 59,3 Kg	Correct
		Pcs readable	: 6 pcs	
5	8 Pack Sugar	Readable Weigh	: 78,8 Kg	Correct
		Pcs readable	: 8 pcs	
6	10 Pack Sugar	Readable Weigh	: 99,8 Kg	Correct
		Pcs readable	: 10 pcs	
7	12 Pack Sugar	Readable Weigh Kg	: 118,3	Correct
		Pcs readable	: 12 pcs	
8	14 Pack Sugar	Readable Weigh Kg	: 137,8	Correct
		Pcs readable	: 14 pcs	
9	16 Pack Sugar	Readable Weigh Kg	: 158,8	Correct
		Pcs readable	: 16 pcs	
10	18 Pack Sugar	Readable Weigh Kg	: 177,2	Correct
		Pcs readable	: 18 pcs	

Table 3 shows the test of the *get data* to display the sensor reading and give the command to the node successfully.

TABLE III
TESTING OF TELEGRAM CHATBOT DATA GET RESULTS

No	Testing	Information
1	Get data "/start"	Succeed
2	Get data "/node1"	Succeed
3	Get data "/node2"	Succeed
4	Get data "/quantity1"	Succeed
5	Get data "/quantity2"	Succeed
6	Get data "/tare1"	Succeed
7	Get data "/tare2"	Succeed
8	Get data "/log1"	Succeed
9	Get data "/og2"	Succeed
10	Displaying Temperature Warning Notifications	Succeed
11	Displaying Humidity Warning Notifications	Succeed

IV. CONCLUSION

Based on research that has been conducted in "Implementation of WSN with LoRa Communication on Stock Inventory and Environmental Monitoring of Sugar Warehouses", the following conclusions were reached:

1. The implementation of this tool successfully displayed data by testing 10 kg of sugar displaying information on 10 kg of weight, temperature of 29.5°C, humidity of 72%, and on 180 kg of sugar could display information on weight of 180 kg, temperature of 29.5°C, and humidity of 71.5%.
2. This tool can send messages to business owners via Telegram ChatBot with the command "get data" when sugar stocks need to be monitored. Based on the results of the data request test on ChatBot, Node A can display (weight=10 kg), (total quantity=1 pcs), (temperature=29.5°C), and (humidity=72%) in the experiment of 10 kg of sugar. Then for the Node B test, this tool can also display (weight 10.1 kg) and (quantity=1 pcs) in the Chatbot on a 10 kg sugar experiment.
3. The results of the LoRa communication quality test have a maximum result at 20 meters with an RSSI value of - 117 dBm and an SNR of 1.75 dB with the poor category. The distance taken was 10 meters with RSSI results of - 99 dBm and SNR 9.25 dB with the category of moderate RSSI and sufficient SNR. And considering that the location in Mitra is 10 meters away from the sugar warehouse.

ACKNOWLEDGEMENT

Based on the research conducted, here are some suggestions for further development:

1. Perform regular calibration to ensure more precise results. Increased sensor accuracy can improve data obtained from weight measurements and environmental conditions.
2. Adding additional features in the form of an information system to an application, such as a graph display that automatically records the amount of stock for some time

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