DIJEMSS: Dinasti International Journal of Education Management and Social Science
E-ISSN: 2686-6331
P-ISSN: 2686-6358
https://dinastipub.org/DIJEMSS dinasti.info@gmail.com +62 811 7404 455
DINASTI PUBLISHER

DOI: https://doi.org/10.38035/dijemss.v7i6

A Real-Time Weight and Color Notification for Chili Inventory Management in Jakabaring Traditional Market

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Abstract: Traditional markets serve as the primary distribution centers for chili peppers but face challenges in efficient stock management due to delays and manual verification processes. This research developed an IoT-based system capable of providing real-time notifications of chili weight and packaging color. The system integrates a load cell sensor for weight measurement, a TCS230 color sensor for packaging identification, and an ESP32 microcontroller for processing and transmitting data. Results are displayed locally on an LCD and sent via WhatsApp notifications to vendors, ensuring rapid and accurate stock information. The research applied the Borg and Gall Research and Development model, focusing on prototype design, testing, and validation. Experimental evaluation showed that the load cell achieved 98.9% accuracy with an error rate below 1.1%, while the color sensor successfully identified packaging origins such as white sacks, brown cardboard, and red sacks. Notifications were consistently received within one to two seconds. These findings demonstrate that the system provides timely, reliable, and user-friendly solutions for traditional market traders. The system reduces manual workload, improves efficiency, and minimizes delays in stock recording. The novelty lies in the integration of IoT monitoring with a widely adopted platform such as WhatsApp, lowering adoption barriers for small-scale vendors. This system has potential for broader applications in perishable goods supply chains where real-time monitoring is essential.

Keywords: Internet of Things, Load Cell, Color Sensor, Real-Time Monitoring, Traditional Market

INTRODUCTION

Traditional markets play an important role in the local economies of many developing countries, including Indonesia. These markets not only function as centers of economic transaction, but also as social spaces that strengthen community ties and preserve local culture . Statistically, traditional markets contribute significantly to job creation, becoming the secondlargest job creation sector after agriculture. According to Indonesia's Central Statistics Agency, around 60% of informal economic transactions in Indonesia take place in traditional markets, highlighting the importance of traditional markets in income distribution and grassroots economic stability. However, the existence of traditional markets is increasingly threatened by the rapid expansion of modern retail, which grew by 17.57% per year between 2007 and 2011, while traditional markets declined by 8% per year during the same period . This decline threatens the livelihoods of millions of small traders and weakens the foundations of the local economy.

In addition to these external challenges, traditional markets also face internal problems, particularly inefficiencies in the supply chain. Indonesia's supply chain and logistics are considered inefficient, with logistics costs exceeding 23% of GDP, one of the highest in Southeast Asia . This inefficiency, exacerbated by inadequate infrastructure and complex administrative processes, causes significant delays and higher costs . For the agricultural sector, the consequences are severe, reflected in massive food loss and waste (FLW). Indonesia is estimated to discard around 23 to 48 million tons of food per year, equivalent to 115-184 kg per capita . For perishable commodities such as chili peppers, which are a staple ingredient in Indonesian cuisine, the problem is even more severe. Post-harvest losses can reach 50-60% in unfavorable conditions such as transportation disruptions, storage delays, and poor handling. The main challenge for traders is information imbalance, particularly uncertainty about the arrival time of stock from suppliers. Traders often wait passively or rely solely on informal communication, resulting in unproductive waiting times, delays in preparing goods for sale, and ultimately increased spoilage and financial losses.

The development of Internet of Things (IoT) technology offers new opportunities to overcome these challenges. In the agricultural sector, sensor-based smart farming technology has been widely applied to crop monitoring, livestock management, and precision irrigation, which have proven to provide significant benefits . However, most of these technologies are designed for large scale and are often too expensive or complicated for small traders in traditional markets to adopt. In addition, the limited digital literacy of micro-scale traders is also an obstacle to adoption. This has created a research gap, namely the need for IoT-based solutions that are affordable, easy to use, and specifically tailored to the context of traditional markets.

This study aims to address this gap through the design, development, and validation of a low-cost stock monitoring system intended for small traders. This system is specifically designed to reduce uncertainty regarding the arrival of goods by providing real-time information on the weight and origin of incoming stock. This information is sent directly via WhatsApp, a platform that is already familiar to traders, eliminating the need for special applications or intensive training. By lowering financial and technical barriers, this approach is expected to increase the adoption and use of the system in daily trading activities.

Previous studies have focused more on digital scales with basic IoT functionality for weight monitoring, as conducted by Suparman et al. and Wira Indani et al., or the application of weight measurement in other contexts, such as gas cylinder capacity monitoring and passenger counting. Several other studies only discuss simple digital scales without advanced IoT integration, such as in the research by Putri Rachmawati and Unang Achlison . Thus, the explicitly identified gap is the absence of studies that integrate secondary sensors, such as TCS230 for color detection, to automatically identify the type or origin of a product. Furthermore, no previous research has been found that utilizes popular and easily accessible communication platforms, such as WhatsApp, for sending notifications, even though this feature could be a key element in increasing the likelihood of adoption by end users.

The uniqueness of this study does not lie in individual technological components, such as load sensors, color sensors, or ESP32 microcontrollers, but in their holistic integration into an affordable and accessible system, designed in collaboration with end users in a traditional market environment. The main contribution is a validated practical tool that directly improves operational efficiency, reduces information asymmetry, and ultimately supports economic sustainability and micro-entrepreneurial resilience in the traditional food supply chain.

METHOD

The system design in this study can be seen in Figure 1. The system follows the Research and Development (R&D) framework proposed by Borg & Gall , which consists of ten structured steps. This iterative approach is instrumental in ensuring that the final product is not only technically valid but also highly relevant to user needs. The primary phases encompass data collection through a literature review and needs analysis at Pasar Induk Jakabaring, initial field testing involving trader interviews to validate the concept and gather early feedback, and main field testing involving prototype feasibility validation by academic experts (supervisors). Product revisions are made in both the operational and final stages, where hardware and software refinements are made based on testing feedback, such as adding a stable platform and adjusting the color sensor function according to real market practices.

The experimental validation protocol was designed to quantitatively measure the system's performance. The evaluation process involved two primary tests: (1) Weight Accuracy Validation, wherein the performance of the load cell sensor was assessed through the repeated measurement of a single item with a known reference weight (10 times) to evaluate precision and reliability, as well as the measurement of ten distinct items with the same weight to assess durability and consistency ; and (2) Notification Performance Validation, in which the end-to-end IoT functionality was evaluated by recording the latency time from the placement of an item on the scale to the receipt of a WhatsApp notification on a smartphone. This evaluation was executed within a genuine market setting, thereby emulating authentic operational circumstances.

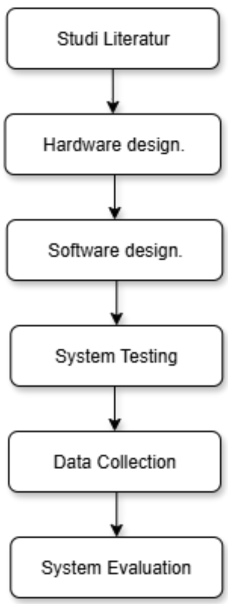

Figure 1 Borg & Gall Development Waterfall

Data Collection

Data is obtained from the development of an automatic weighing apparatus that integrates a Load Cell and a TCS230 sensor, combined with IoT features for remote monitoring of chili pepper types and arrivals at the Jakabaring Central Market. During the planning stage, the device was designed using a load cell for weighing and a TCS230 for product classification based on packaging color (e.g., red for chili peppers, white for green chili peppers, and brown for red chili peppers). The preliminary product model was conceived as a substitute for manual scales, with the objective of enhancing operational efficiency for merchants in Figure 2.

Figure 2 The product has been tested in a preliminary trial

Initial trials were conducted through interviews with local merchants, who stated that the device would be very useful, as there is currently no efficient system to monitor the arrival of goods, as shown in Figure 3.

Figure 3 The Interview process with merchants

Data Pre-processing

Subsequent to this, the initial prototype underwent testing and development until it reached 70% completion. The feasibility testing was conducted by two experts using a 1–5 scale, resulting in an average score of 4.5 for ease of use, 3.5 for measurement accuracy, 4.0 for display design, and 4.5 for overall feasibility, with relatively small variation in ratings (SD ≤ 0.707), as shown in the SPSS application in Table 1 and Table 2.

Table 1. The Assessment results from 2 respondents

VAR00001	VAR00002	VAR00003	VAR00004
4.00	3.00	4.00	4.00
5.00	4.00	4.00	5.00

Table 2. The overall score results.

Variabel	N	Minimum	Maximum	Mean	Std. Deviation
Kemudahan Penggunaan	2	4.00	5.00	4.5000	0.70711
Akurasi Pengukuran	2	3.00	4.00	3.5000	0.70711
Desain Tampilan Alat	2	4.00	4.00	4.0000	0.00000
Kelayakan Secara Umum	2	4.00	5.00	4.5000	0.70711
Valid N (listwise)	2	-	-	-	-

The device's stability was enhanced through the incorporation of a plywood base, thereby demonstrating a commitment to enhancing its structural integrity . Implementation tests were conducted in the market setting by transmitting IoT data via WhatsApp in real time, thereby quantifying the delay level and evaluating the efficacy of monitoring the arrival of goods. During the final revision stage, the TCS230 sensor demonstrated suboptimal performance in detecting chili types. Consequently, its function was modified to detect the origin of shipments based on packaging color (e.g., red = Lampung, white = Pagar Alam, brown = Java). The results of the detection process were subsequently transmitted to both the LCD and the WhatsApp application. The culminating dissemination and implementation phase demonstrated the device's readiness for utilization at the Jakabaring Central Market, exhibiting precise load cell weighing outcomes and packaging identification customized to user requirements.

System Architecture

A block diagram is a visual representation of a system's structure that facilitates comprehension of the relationships between components and the overall data flow within the system. In a designed system, a block diagram illustrates how hardware and software interact to produce the expected output. Figure 4 presents the block diagram of the IoT-based chili weight and color monitoring system developed in this study.

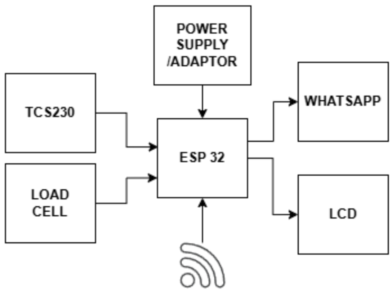

Figure 4 Block diagram

In this system, the power source is derived from an adapter or power supply that provides a stable voltage and current to the entire circuit, particularly the ESP32 microcontroller. The microcontroller functions as the primary control center, processing all data received from the sensors and regulating the system's output. Two primary sensors are connected to the ESP32, namely:

The load cell sensor is employed to ascertain the weight of chili peppers.The TCS230 Sensor is an instrument designed to detect the color of chili peppers.

Both sensors transmit analog and digital data to the ESP32 for processing. Subsequent to data processing, the ESP32 locally displays the weight and color information on an LCD display, which functions as the device's direct output . Furthermore, the ESP32 employs Wi-Fi connectivity to access the internet. This integration enables the ESP32 to automatically transmit data notifications to the WhatsApp application utilized by merchants as end-users.The transmitted information encompasses the results of chili pepper weight and color readings, thereby enabling merchants to monitor inventory in real-time via mobile devices. Consequently, the sequence of events commences with the reception of data from the sensors (Load Cell and TCS230) by the ESP32, followed by its subsequent processing and transmission to two designated output channels . The primary channel entails the display of data on the LCD, whereas the secondary channel involves the transmission of data to the WhatsApp application via the internet.

Hardware Implementation

The system design stages related to mechanical and electronic design in the system are intended to provide real-time weight and color notifications to facilitate chili stock recording at the Jakabaring Central Market. The field of mechanical design encompasses the conceptualization and development of the tangible form of the human activity identification system tool, which is specifically designed for the purpose of facilitating real-time chili stock. The creation and design of a system frame that is the appropriate size and proportionate to the components used is paramount to ensure proper functionality and prevent interference with the system's monitoring . A three-dimensional representation of the tool is provided in Figure 5 below.

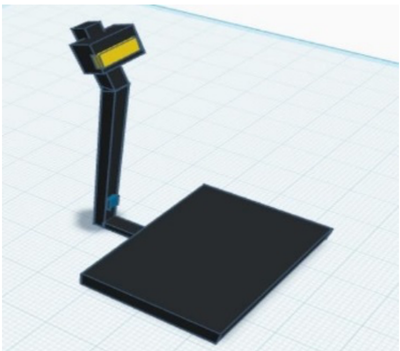

Figure 5 3D Sketch Image

Electronic design encompasses the process of creating circuits and wiring diagrams that illustrate the configuration and interconnections between components that comprise the integrated system in a remote monitoring device utilized for the identification of chili weight and variety.

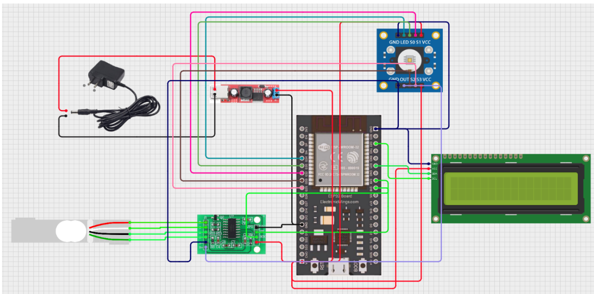

Figure 6 *Circuit Diagram*

As illustrated in Figure 6, the schematic diagram developed in the web circuit designer reveals that the pink cable represents the VCC current, which facilitates the connection between multiple components, while the yellow cable signifies the ground current. The adapter provides 12V and 3A to the Stepdown LM2596, which was selected due to its flexibility for the incorporation of additional sensors in the future. The TCS230 sensor converts color intensity (red, green, blue) into a frequency signal. Pins S0 and S1 are connected to G25, and pins S2 and S3 are connected to G32 and G33, respectively. The former adjusts the frequency scale, and the latter selects the detected color. The OE pin is connected to G14, thereby activating the color sensor. The Load Cell Sensor is composed of four wires that are connected to the HX711 module . The CLK pin is linked to G18, facilitating data acquisition control, while the DAT pin is connected to G19 to facilitate the reception of weight data. The LCD with the I2C module utilizes the SDA pin on G21 for data communication and the SCL pin on G22 for synchronization . The ESP32 pin assignments include GPIO 25 and 26 (DAC1 and DAC2) for analog output, GPIO 32 and 33 for ADC, GPIO 18 and 19 for clock and data, and GPIO 21 and 22 for LCD serial communication. The electronic components are housed within a protective enclosure (Box X5) to shield them from the dust and humidity characteristic of a market environment . The key electronic components and their specifications are detailed in Table 3.

Table 3. System Component Specifications

Components	Model/Type	Key Specification	Function in System
Microcontroller	ESP32-WROOM-32	Dual-core, 240 MHz, Wi-Fi/Bluetooth	Central processing, sensor data acquisition, and internet communication.
Weight Sensor	Single-Point Load Cell	180 kg Maximum Capacity, 2.0 mV/V Sensitivity	Measures the gross weight of the chili peppers by converting force into an electrical signal.
Amplifier	HX711 Module	24-bit ADC, programmable gain	Amplifies and digitizes the weak analog signal from the load cell for accurate reading by the ESP32.
Color Sensor	TCS230	RGB color detection, 8x8 photodiode array, digital frequency output	Identifies the dominant color of the chilies (red or green) for classification.
Local Display	LCD 16x2 with I2C	16 characters x 2 lines	Provides an immediate, on-site visual readout of the measured weight and color.
Power Supply	Adaptor & LM2596	12V 3A input, 5V/3.3V output	Provides stable, regulated power to the ESP32 and all connected modules.

Error, Accuracy, and Mean

An error can be defined as the discrepancy between the measurement result of a system and its actual value or reference value . In the event that the measurement result exceeds the ideal value, the error is designated as positive. Conversely, if the result obtained is less than the expected value, then the error is negative. To ascertain the magnitude of the error, the following percentage error formula can be employed by Equation 1.

$$\%\ Error = \left|\frac{Value_{Reference} - Value_{Measured}}{Value_{Reference}}\right| \times 100\% \quad (1)$$

Accuracy, or precision as it is more commonly referred to, is a crucial aspect in the design of sensor systems, especially in measurement and monitoring devices . Accuracy is defined as the maximum possible error that may be incurred when a sensor measures a variable. Accuracy is defined as the degree to which a measurement instrument provides a reading that is proximate to the true value of the variable being measured. The accuracy level of a system is determined by referring to a specific calculation by Equation 2.

$$Accuracy = 100\% \times \%\ Error \quad (2)$$

The following formula is used to calculate the arithmetic mean in Equation 3.

$$\mu = \frac{|d_1|+|d_2|+....+|d_n|}{n} \quad (3)$$

Software Design and Protocols

A significant component of the research process for this system pertains to the design of software. The tool improvement process involves the utilization of various software programs, ranging from the creation of programs to the control of these programs through several Arduino IDE-based applications. The Arduino IDE is composed of the Java programming language and is equipped with a C or C++ library, which facilitates input and output operations . Subsequently, a series of applications will be employed for the purposes of simulation and data collection.

A flowchart is a diagram that illustrates the workflow of a system. The primary function of a flowchart is to monitor and track the steps of the system design that has been determined. Furthermore, a flowchart can illustrate the various potential scenarios that may arise during system operations. Data, including values and hypotheses related to the system, must also be clearly represented in a flowchart.

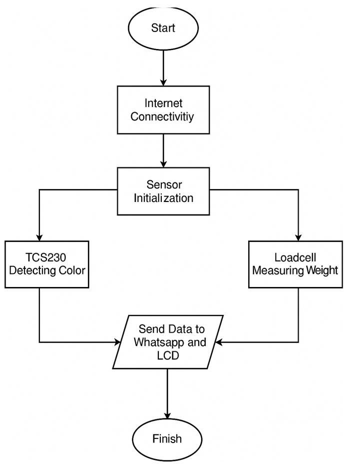

Figure 7 Flowchart

As illustrated in Figure 7 the initial step in initiating the device is to ensure internet connectivity, as the system is only operational when connected to the internet to transmit data received by the sensor to WhatsApp. In addition to transmitting data to WhatsApp, the LCD also receives data from sensors transmitted by the load cell and TCS230 without the need for an internet connection.

RESULTS AND DISCUSSION

Results

This section presents empirical results from system performance validation and a comprehensive discussion of its technical and practical implications.

Weight Measurement Performance

The accuracy of the Load Cell and HX711 module was validated through two sets of tests. The initial assessment entailed the repetitive measurement of a standard item (a sack with a reference weight of 31 kilograms) on ten separate occasions to evaluate the reliability of the measurement process. The second test involved measuring ten different items of similar weight to assess the robustness of the scale across varied objects. The results, summarized in Table 2, demonstrate exceptional accuracy and precision.

Table 4. Weight Measurement Accuracy and Error Analysis

Test Type	No. of Trials	Average Reference Weight (kg)	Average Measured Weight (kg)	Average Error (%)	System Accuracy (%)
Repetitive Measurement	10	31.00	30.66	1.11	98.89
Varied Measurement	10	31.1	30.80	1.00	99.00
Overall	20	31.05	30.73	1.05	98.95

The system demonstrated an average accuracy of nearly 99% across all trials, with an average percentage error of just over 1%. The calculation of this level of performance is determined by the Equation 1. The system's accuracy is then derived as 100% minus the error. This result is significantly more favourable than that of analogous IoT weighing systems documented in extant literature, such as the 98.97% accuracy reported by Suparman et al , thus validating the efficacy of the hardware selection and calibration process.

Color- Based Product Identification

The TCS230 sensor's capacity to categorize products according to their packaging color constituted a pivotal innovation of this research. During the research and development (R&D) process, it was determined through interviews that vendors associate specific packaging with different chili origins: brown cardboard for chili from Jawa, white sacks for chili from Pagaralam (PGA), and red sacks for chili from Lampung (LPG). The system was calibrated to recognize these colors. The performance of this classification is detailed in Table 5.

Table 5. TCS230 Sensor Identification Performance

Packaging Color/ Material	Calibrated RGB Logic	Designated Product Origin	Observed Field Performance
White Sack	red > 50 && green < 115 && blue > 12	Pagaralam (PGA)	Consistently successful identification.
Brown Cardboard	red < 190 && green > 220 && blue < 230	Jawa	Generally successful, with occasional delays due to color variations/printing on the cardboard.
Red Sack	red > 125 && green > 358 && blue < 295	Lampung (LPG)	Untested in the field due to no deliveries with this packaging during the testing period.

The system demonstrated an ability to accurately and reliably identify products in white sacks (PGA) and brown cardboard boxes (Jawa). A minor limitation was observed with the cardboard packaging, where variations in color or the presence of printed text sometimes required minor physical adjustments of the box to achieve a clean reading. This finding underscores a potential avenue for future enhancement, which might be realized through the implementation of software algorithms that facilitate the averaging of multiple readings. The red sack classification could not be tested in the field because no deliveries of that type occurred during the study period. This limitation is inherent to real-world field research.

Discussion

The discussion of the results not only looks at technical figures, but also discusses the real benefits and compares them with previous studies. The system's accuracy of 98.95% is significantly better than similar IoT weighing systems documented in the existing literature, such as the 98.49% accuracy reported by Suparman et al. , thus validating the effectiveness of hardware selection and calibration processes. A detailed comparison with other relevant studies is presented in Table 4, which highlights the unique contribution of this research in integrating color-based identification and notifications through a commonly used platform.

Table 6. Comparison with Previous Research

Research	Algorithm	Hardware	Context	System Accuracy (%)	Contribution
Rachmawati (2023)	System Design & Prototyping	HX711,ESP3, Buzzer	General Digital Scale Simulation	Functional (Qualitative)	Detect basic load with audible warning
Suparman et al. (2024)	Design Method	Load Cell, Microcontroller, IoT	General IoT Scales	99,49%	IoT integration for remote weight reading on smartphones
Achlison & Suhartono (2020)	Metode Eksperimen	Load Cell, Arduino	Weighing Rice, Packages, Fruit	~96% (concluded from an error margin of ±4%)	Fundamental analysis of load cell accuracy for general goods
Aryuni et al. (2021)	SVM Experiments & Classification	Load Cell	Classification of Boarding/Alighting Passengers	Focus on the method (Not quantified)	Load cell data application for human activity classification
Indani et al. (2022)	Design Method	Load Cell, IoT	Weighing Palm Oil Fruits	99,28%	High-capacity IoT scales for specific agricultural commodities
Suwardoyo & Fahriyanto (2022)	Design Method	Load Cell, IoT	Gas Cylinder Capacity Monitoring	97,17% (disimpulkan dari eror 2,83%)	IoT-based monitoring of consumer goods capacity with notifications

Findings regarding color sensor performance highlight potential for future improvement; limitations observed in cardboard readings can be overcome through the application of software algorithms that facilitate averaging of multiple readings to improve reliability. The inability to test red bag classification due to logistical constraints in the field is an inherent limitation of real-world research.

This system directly translates its technical performance into operational and economic benefits. Immediate notifications eliminate unproductive waiting time, freeing up labor for other tasks, such as serving customers or setting up kiosks. For perishable items such as chili peppers, speeding up processing from delivery to display minimizes spoilage and quality degradation, thereby maintaining the market value of the product. Additionally, WhatsApp messages generate automatic digital logs of incoming inventory, providing a simple tool for stock and financial management. This system can be more than just a monitoring device; it can be a business optimization tool that improves efficiency and profitability for small entrepreneurs in the traditional food supply chain..

CONCLUSION

From the results of the experiments and validation, this study demonstrates that the proposed Internet of Things (IoT) based system successfully addresses the challenges of stock management in traditional markets by providing real-time notifications of product weight and origin. The integration of the load cell sensor, color sensor, and WhatsApp notification mechanism was validated in real operational environments and exhibited strong performance. The findings indicate that weight measurements achieved an accuracy of nearly 99%, while color detection proved to be reliable in classifying various packaging types. Most importantly, notification delivery through WhatsApp occurred with a minimal delay of only 1–2 seconds, confirming the system's effectiveness in enhancing logistics and operational efficiency within conventional markets. The main contribution of this research lies in offering a practical, validated, and accessible technological solution that empowers small-scale traders. By transforming raw data into actionable information and delivering it through a ubiquitous platform, the system directly reduces uncertainty, saves time, and has the potential to minimize economic losses. Future research should focus on improving the resilience and functionality of the system. First, integrating more advanced identification methods, such as computer vision, could enable the system to handle more complex scenarios, including barcode reading or defect detection, thereby enhancing its practical value. Second, extending the system to monitor additional environmental variables critical for perishable goods, such as temperature and humidity, would provide an extra layer of protection against spoilage. Lastly, developing a data analytics backend could transform historical notification logs into predictive insights, assisting traders in anticipating stock arrival patterns and optimizing their sales strategies. These future efforts are expected to further bridge the digital divide and strengthen the economic resilience of vital actors within the global food supply chain.

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