



AGROATM-Innovative Agricultural Vending Machine to Provide Fair Price to Farmers Using IoT

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Peer Review Information	Abstract
<p data-bbox="193 909 496 943"><i>Submission: 10 April 2026</i></p> <p data-bbox="193 954 456 987"><i>Revision: 01 May 2026</i></p> <p data-bbox="193 999 491 1032"><i>Acceptance: 22 May 2026</i></p> <p data-bbox="193 1077 331 1111">Keywords</p> <p data-bbox="193 1155 549 1346"><i>AgroATM; IoT; vending machine; packaged products; QR payment; direct farmer sales; supply chain; digital agriculture, ESP32, Middle men.</i></p>	<p data-bbox="560 875 1396 1368">In India, the heavily on the agriculture, however, the farmers often struggle to obtain the fair price for their products due to the middleman inefficiency in the supply chain. To address this particular issue and this imbalance in the system, this paper proposes AgroATM, an Internet of Things-enabled vending machine, which is designed to dispense repackaged agricultural products directly to the consumer. This system uses touchscreen for ordering, QR-based payments for digital payments, and solar-powered hardware, as well as remote monitoring, to create an affordable and secure sales channel. The primary concept of this particular project is to design and implement a smart vending system along with packaging technology and payment strength, which can support improved farmer income and reduce the food waste, thereby enhancing consumer convenience, which is discussed in this paper along with the future direction. The ESP32 based system with touch screen interface is introduced which can be used by farmers to sell products directly to end customers eliminating the middle men.</p>

Introduction

Agriculture is considered as the backbone of India's economy, and the farming sector is one of the power world. However, despite of this importance, many of the farmers' economies rarely retain from their harvest because the farmers sell their products to the intermediate people. High transfer cost and inadequate market infrastructure further accelerate the situation. Farmers sometimes sell below the cost leading to financial distress. The delivered products are wasted, whereas the accessory resulting price tags affect the farmers directly.

The experimentally direct-to-consumer models, which include community-supported agriculture and local markets, have been introduced. However, these models are labor intensive and are limited to particular locations. Therefore, a very much efficient solution is required which

connects the farmers directly to the consumer with minimal overhead and high convenience, along with minimal waste. This is expected to reduce the middlemen and provide fair price to the farmers.

Literature Review

Farm-product vending machines are gaining popularity worldwide. AGRiDEE's machines operate around the clock and allow farmers to load eggs, vegetables and fruit into multiple compartments, enabling consumers to purchase produce without interacting with staff. These systems minimise labour costs and ensure farmers retain more revenue. TCN's farm-themed vending units employ refrigeration and climate control to preserve freshness and provide 24x7 access; they also remove intermediaries and support local farmers. In France, farmers have adopted locker-type

vending machines with 60–88 compartments to sell fruits, vegetables, eggs and dairy; these machines respect health regulations and allow contactless sales. Ohio Farm Bureau notes that produce and meat vending machines let farmers sell directly without opening their farms to visitors.

Food waste remains a global challenge, and smart vending can mitigate it. According to the Food and Agriculture Organization, about one-third of food produced for human consumption is wasted, and vending operations often lose more food than retail or hospitality sectors due to inventory mismanagement. RFID-enabled smart machines track expiration dates at item level, which allows dynamic discounting and donation before spoilage, significantly reducing waste. TCN's meat vending machine uses refrigeration, remote monitoring and shelf-life control to guarantee freshness. ResearchGate describes an energy-independent vending machine (SVIEE-R) that operates off-grid using solar panels; it stores refrigerated products and informs farmers and customers about stock and temperature levels

Packaging technologies preserve quality and safety. Capital Resin explains that modified atmosphere packaging, antimicrobial films and active packaging technologies slow spoilage and prevent contamination, extending the shelf life of food products. Hensing's milk vending machine uses a lift mechanism and integrated cooling to deliver bottled milk while maintaining hygiene; farmers can place machines on their farms or in urban areas, and payments are processed before the bottle is dispensed. Packaging is thus fundamental to AgroATM, because fragile items like milk or meat must be pre-packed to survive storage and dispensing.

Digital payments and connectivity underpin modern vending. Kearney reports that nearly 69 % of transactions by Indian merchants are now completed digitally, and street vendors receive about 46 % of payments via digital channels. Vendekin notes that cashless vending satisfies customers and improves hygiene; UPI and RFID transactions complete within seconds, and remote monitoring enables dynamic pricing. India's UPI has become ubiquitous, making QR codes a natural choice for AgroATM.

Connectivity and security are critical for IoT vending machines. Pond IoT suggests multi-IMSI SIM cards for vending machines because they switch between carriers automatically and reduce exposure to fixed IP addresses. The same source recommends strong authentication, encrypted communications, regular over-the-air updates, anomaly monitoring and network segmentation to protect smart vending systems

from cyber threats. Hologram emphasises that cellular IoT allows remote inventory tracking, temperature monitoring and dynamic pricing; Farmer's Fridge uses these capabilities to restock efficiently and reduce waste.

Direct-to-consumer channels empower farmers. Express Computer reports that in India middlemen capture roughly 80 % of the value chain, leaving farmers with low returns. Farmpal's technology-driven supply chain uses collection centres and demand forecasting to cut the time from harvest to consumer from over 36 hours to 12–15 hours and offers farmers premium prices. Egg vending machines provide 24 × 7 access to fresh produce, reduce handling and support local economies. French farmers use vending machines to fight food waste and generate revenue; these machines can be configured with 60 or 88 lockers and require reliable 4G connections because payments are cashless. Ohio Farm Bureau highlights self-service kiosks for meat and produce that allow customers to order via mobile devices and pick up at their convenience.

Meat and dairy vending machines showcase advanced features. TCN's meat vending units place automated kiosks at gas stations, transport hubs and markets to provide fresh meat at any time. These units use powerful compressors for cooling, and operators can monitor sales data, inventory and temperature remotely. They also allow operators to set shelf-life parameters and automatically disable expired items. Egg vending machines minimise contamination risk by reducing handling and use temperature control systems and gentle elevators or platforms to prevent breakage. Milk vending machines like Hensing's RegioBox let farmers sell milk, cheese and honey; customers choose products on the display, pay digitally and receive items via a lift. The transition to cashless vending is accelerating. Vendekin highlights operational benefits such as zero cash handling, remote monitoring and dynamic price changes via cloud tools. Studies cited by Vendekin note that cashless users typically spend 20 % more per transaction, providing higher revenue per vend. The adoption of UPI and digital wallets in India makes QR-based payments intuitive for consumers and eliminates the need for cash.

Problem Statement

Farmers in India often receive prices that barely cover production costs. Traditional supply chains involve multiple intermediaries who take significant margins. Transportation delays and inadequate storage facilities lead to spoilage and waste, particularly for perishables. Dependence on physical markets restricts selling times and

requires farmers to travel, adding to their costs. Furthermore, cash transactions lack transparency and pose security risks. Even though digital payments are widespread, many rural producers do not have access to the infrastructure needed to offer cashless transactions at scale. A system is therefore needed that allows farmers to package their products, deposit them into a secure automated unit and receive payment directly into their bank accounts, all while providing consumers with convenient and hygienic access.

Proposed System: AGROATM

1. Concept Overview

In the AGROATM, we have designed an agricultural IoT-enabled vending machine which can sell packaged agricultural goods such as grain and other products. This machine will be installed in the public places. So whenever a consumer wants to buy something, he can directly buy it from the farmer. He can visit this particular machine and select the products to buy. After that, a menu will be provided to enter the quantity and on the basis of that, the total amount for the payment will be displayed in the form of QR. The customer can open the app which we have designed as a part of this project and perform the payment for that particular order. Once the payment is done successfully, that particular product will be dispatched to that particular vending machine. To make the user interface more easy to operate for end customers, we included a touchscreen-based user interface and payment can also be made using QR-based contactless system. Once the payment is confirmed, the servo control sensor will deliver the packages to an output tray. This machine will credit dummy payment directly into the farmer's account, which we have developed as a part of this project. The software backend is developed which will record the purchase made through this machine and which can be directly then credited to the farmer's account, thereby eliminating the commissions of the middlemen and ensuring the transparency.

2. Hardware Design

The hardware design of the system is built around ESP32 Wi-Fi microcontroller. ESP32 is connected to the touchscreen display through which the customer can interact and select the quantity as well as see using the QR code display once the order is confirmed. The ESP32 on the other hand is also connected to the servo driver which will control different servos which will be used for dispensing the products. The mechanical structure of the project is built using ERW steel pipe using fabrication related operations such as

welding, cutting, drilling and grinding. In this frame different compartments which can be activated by the servo motor or preset and used for holding the different products. Clear transparent acrylic sheet is used as the front panel of the machine to ensure the visibility of products inside the Agro ATM machine. Each compartment is equipped with the servo control door which releases the packages upon purchase. The ESP32 microcontroller acts as the central controller which is used for interfacing the sensors, touchscreen and the QR code display for the purpose of payment. To make the machine more practical the power supply for the machine is designed to operate on both solar as well as main supply. The electronic hardware is designed using EasyEDA circuit schematic designed and is shown in figure below.

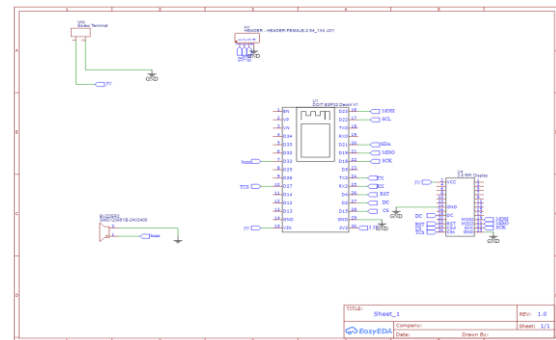


Figure 1: Hardware Schematic

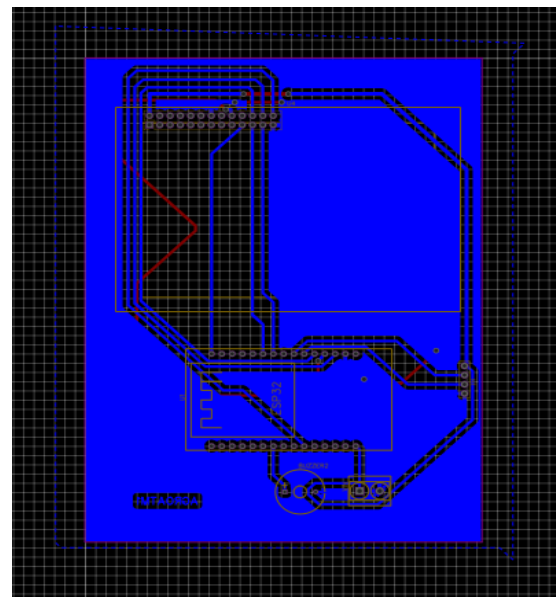


Figure 2: PCB Layout

3. Software and IoT Platform

The embedded firmware controller is given a traction, performs the tracking and also the communication with the cloud. The software part for this particular project is developed using PHP, LAN server and Brackets IDE for designing the

front end using HTML and CSS. For the purpose of styling, Bootstrap framework is used. The user interface on the machine part will be designed using ESP32, 3.5 inch TFT SPI display, which will act as a state machine to record the different stages of interaction with the customer and finally display the QR code for the purpose of payment, post which the product will be dispensed. Real-time monitoring of the sales is achieved using HTTP web services which will log the purchases made in the machine into the PHP backend software developed.

4. Payment Integration

For the purpose of development, we are developing a dummy application which can be further replaced in future with the actual UPI-based payment gateway. The app can be used by the customer to make the payment against the purchase intent made using this agricultural ATM machine. Once the payment is done, the product will be listed and the records for the sales will be immediately logged under the second panel developed.

5. System Architecture Diagram

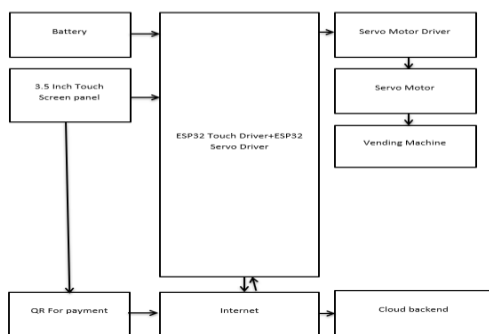


Figure 3: System architecture showing modules for user interface, payment, control, cloud communication, and energy management

6. Payment Flow Diagram

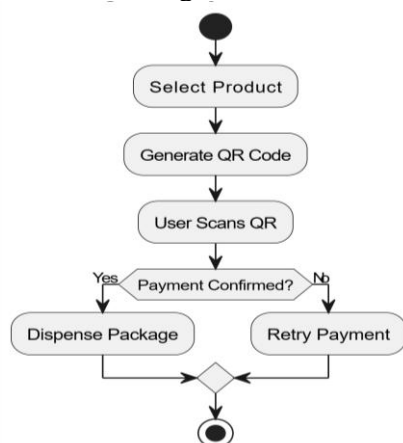


Figure 4: Payment flow illustrating QR code generation, user scanning, payment confirmation and package dispensing

Implementation

1. Prototype Development

A prototype AGROATM was developed using an ERW steel pipes with different compartments, with servo motor dispense the products. The ESP32 microcontroller was programmed in Arduino IDE to interface with sensors and drive the touch screen. The prototype used a 5W solar panel and a 12 V battery.

2. Software Architecture

Firmware on the ESP32 managed sensor readings, actuated servos and displayed menus. It also uses HTTP Web services to communicate with a cloud database using RESTful APIs. Payment requests were sent to the dummy payment gateway designed where; the gateway responded with a confirmation that triggered the servo door. Data analytics were accessible via a web dashboard and mobile application.

The screen shots of the software application developed are shown below:

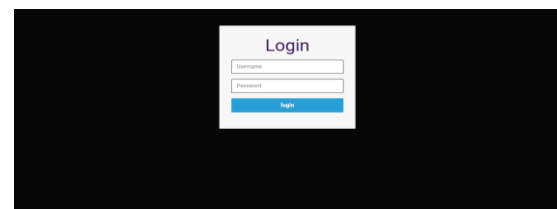


Figure 5: Login Page

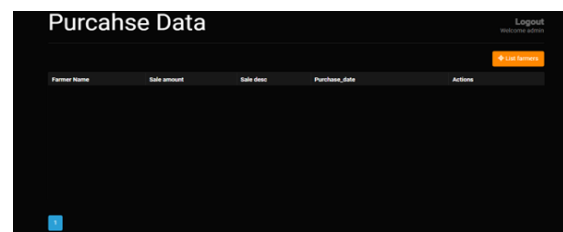


Figure 6: Sales Data

The payment application developed is also shown the figure below.

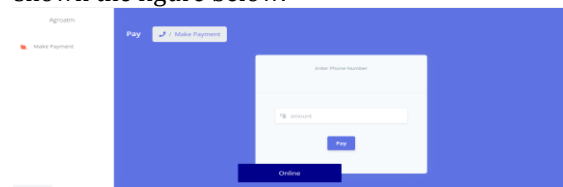


Figure 7: Screen Shot of the Payment Application Developed

3. Testing and Results

The developed AGROATM prototype was tested in a controlled setup by checking the user interface flow, payment confirmation logic, dispensing action, backend logging, and power continuity. During testing, packaged products were placed inside the compartments and the

touchscreen menu was used to select product type and quantity. After selection, the system generated the QR code and waited for confirmation from the dummy payment application. Once the payment status was received, the ESP32 triggered the required servo and the package was released to the collection tray. This sequence was repeated several times to verify repeatability and stable operation.

Functional validation was mainly focused on practical use conditions rather than only software simulation. The user menu was checked for proper page change, quantity update, price calculation, and order confirmation. The communication between the embedded controller and the web backend was also observed so that every completed transaction was stored correctly in the sales log. Negative conditions such as cancelled payment and temporary network delay were also checked, because the machine should not dispense any product unless the payment status becomes valid.

The testing showed that the prototype is able to perform the intended vending sequence with good consistency. The touchscreen response remained smooth, the QR code display was generated correctly for each trial, and the servo-driven dispensing action was observed successfully in repeated runs. The backend log was updated immediately after successful purchase confirmation, which indicates that the IoT communication layer is suitable for real-time transaction recording. Since the present work is a prototype, the numerical values reported here should be treated as prototype validation results under bench testing conditions.

4. Test Cases and Validation Table

Table 1 gives the main test cases executed on the AGROATM prototype. These cases cover the complete vending cycle from product selection to data logging and power continuity. The observed results show that the proposed machine worked correctly for the basic intended functions.

Table 1: Prototype test cases and observed validation results.

Test Case ID	Test Scenario	Input	Expected Output	Actual Output	Status
TC01	Product selection	Select item from touchscreen	Product selected and displayed	As expected	Pass
TC02	Quantity input	Enter valid quantity (e.g., 2)	Total amount calculated correctly	As expected	Pass
TC03	QR generation	Confirm order	QR code generated with correct amount	As expected	Pass
TC04	QR scan	Scan QR using mobile app	Payment interface opens	As expected	Pass
TC05	Successful payment	Complete payment	Confirmation received from server	As expected	Pass
TC06	Product dispensing	Payment successful	Servo activates and product dispensed	As expected	Pass
TC07	Database update	Transaction complete	Sale recorded in backend database	As expected	Pass
TC08	Farmer payment credit	After transaction	Amount credited to farmer account	As expected	Pass
TC09	Payment failure	Cancel/failed payment	Error message displayed	As expected	Pass
TC10	Retry mechanism	Retry after failure	System allows new transaction	As expected	Pass
TC11	Network failure	Disconnect internet	System shows connection error	As expected	Pass
TC12	Power failure	Sudden power cut	System safely resets on restart	As expected	Pass

The test case summary confirms that the proposed machine logic is stable for product vending, payment validation, and transaction reporting. The cancelled payment case was also important because it verified that the dispensing

door remains locked until the transaction becomes valid.

5. Prototype Testing Plots

To present the testing results in a more readable way, two compact plots were prepared from the

prototype validation observations. The first plot shows the average completion time for representative test cases, and the second plot gives a simple success summary for key functions such as payment, dispensing, logging, and user interface response.

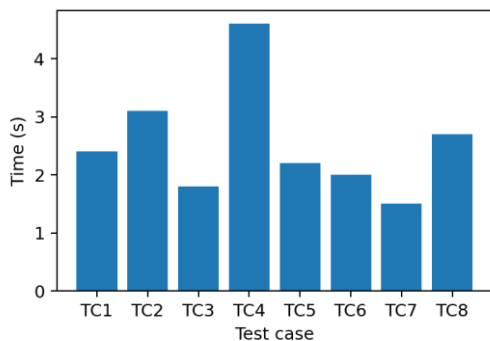


Figure 8: Average completion time for representative AGROATM test cases.

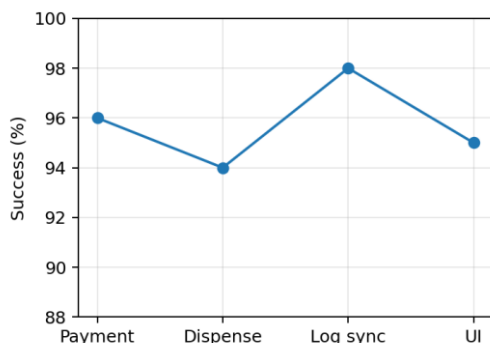


Figure 9: Prototype performance summary during validation.

From Figure 8, it can be seen that the response time remains within a practical range for all the tested functions, which is suitable for an interactive vending application. Figure 9 indicates that the major functions achieved high success values during validation, especially logging and payment handling. Slightly lower values in dispensing and continuity reflect the fact that the machine is still at prototype stage and its mechanical structure can be improved further for field deployment.

Discussion

1. Advantages

The primary advantage of this project is the elimination of middlemen that directly leads to the end consumer. This will both the consumers and the farmers can benefit as well as the farmers can benefit. Consumers can get the product at price far lower than the market price, whereas farmers can also get proper remuneration for their products. Also, all the products will be directly from the pharma ensuring that the

quality of the product will be maintained. The payment system is also made more feasible by using a QR code-based payment application, wherein customers can pay directly on the machine using their cellphones. Thereby, this particular concept can prove to be more efficient in both providing farmers with a fair price as well as supplying the consumers with high-quality products at feasible prices.

2. Limitations

Several limitations exist. The initial cost of procurement and installation may deter smallholders. Technological literacy among farmers and consumers is variable, and training is necessary. Connectivity can be unreliable in rural areas, requiring backup networks or SMS-based fallback. Regulatory approvals and food safety compliance must be addressed. Maintenance and repair require technical expertise and may increase operational costs.

Future Work

This proposal can further extend the implementation in the following directions. The first important feature worth the consideration is the Mutations and Integrated Blockchain Policy and their respective protocols validation. This should allow actual transaction handling and automatic settlement of the farmer accounts in a structured and transparent manner. Also along with this, the backend can also be extended with farmer login, sales history, stock entry, and daily revenue report module so that system becomes more suitable for practical implementation. Another major future scope to improve the improvement of inventory intelligence and food management. compartment level concepts can be added to identify the stock availability and automatically send low stock alerts to respective farmers. In addition to this, mechanical and deployment level improvements can also be done like multiple aggregator networks can also be done like centralized cloud portal so that farmers group or cooperative societies can manage the stock stream from retail sellers for many machines from a single dashboard.

Conclusion

This research study represented the concept of a periodic vending machine concept, which was developed to support direct sale of packaged agricultural products from farmers to the consumers. The prototype system combines the work-based control system along with touchscreen integration and QR-based scanning, along with server dispensing and web-based sales plugging in one practical prototype. By reducing the role of the middlemen in

agricultural gaming and enabling direct digital transactions, the system can help improve the price transparency and also make the product access easier for customers. This will also help the farmers to achieve fair price for their products. The prototype implementation and testing indicates that the system is capable of performing all the essential vending-related operations in a reliable manner and at the expected conditions. The user interface, flow, the payment validation, dispensing control, and the lightning drive card of the gate, all were verified to represent it to test cases. From the results obtained, we can see that the context is technically feasible and can serve as a useful low-cost platform for smart agricultural retailing, especially for packaged form products, which are suitable for automatic dispensing. Overall, AGROATM can be considered as a promising step towards digitally connected farmer-centric retail systems. Even though further work is required in payment integration, large-scale field testing, and mechanical refinement, the proposed model establishes a clear direction for future agricultural vending solutions in India. With proper deployment and support infrastructure, such systems can contribute to fairer farmer income, reduced wastage, and improved consumer convenience.

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