



IoT-Based Cassava Slicing Machine Using ESP32 with Smartphone Monitoring

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A B S T R A C T

The rapid advancement of Internet of Things (IoT) technology continues to open new opportunities in the development of automation and monitoring systems, particularly for household applications and small-scale industries. This study presents the design and implementation of an IoT-based cassava slicing machine equipped with smartphone monitoring, where the ESP32 microcontroller serves as the main control unit. The proposed system enables real-time operation and supervision of the machine through a Wi-Fi-connected mobile application. Its key features include remote power control, adjustable slicing motor speed, and direct monitoring of machine status. Experimental results demonstrate that integrating ESP32 with IoT ensures fast, stable, and reliable performance in responding to user commands. Moreover, the monitoring capability enhances energy efficiency and supports operator safety during the slicing process. Therefore, the IoT-enabled cassava slicing machine with smartphone monitoring is highly promising for adoption in small and medium enterprises (SMEs) as part of the transition toward smart and integrated automation technologies.

INTRODUCTION

Cassava (*Manihot esculenta*) is a strategic agricultural commodity in Indonesia with high economic value and a vital role in ensuring national food security. Cassava is widely used as the main raw material for processed products, particularly cassava chips, which are both a popular snack and a key contributor to the local economy. This demand has driven many Micro, Small, and Medium Enterprises (MSMEs) to focus on cassava chip production. However, the slicing process, which is crucial for determining product quality, remains a significant challenge. Manual slicing requires substantial labor and time and often produces slices with inconsistent thickness, directly impacting texture and cooking uniformity [1]. Although conventional slicing machines help reduce manual effort, most operate manually or semi-automatically and lack precise control as well as integrated monitoring features [2].

The advancement of digital technologies, especially the Internet of Things (IoT), has opened significant possibilities for innovation in food processing systems [3]. By enabling automation, real-time monitoring, and remote control, IoT contributes to improved efficiency and product quality [4]. Within the cassava slicing process, the integration of IoT with the ESP32 microcontroller—featuring built-in Wi-Fi, high

processing performance, and straightforward sensor-actuator connectivity—supports the creation of an intelligent slicing machine. Using a smartphone application, operators can remotely control key functions such as switching the machine on and off, regulating motor speed, and tracking operational status in real time. This solution is anticipated to provide a more precise, reliable, and energy-efficient alternative compared to traditional approaches [5].

Within the cassava chips MSME sector, improving production capacity and product quality is essential for ensuring sustainability and strengthening competitiveness. The adoption of IoT-based automatic slicing machines offers a practical solution by enabling faster and more efficient large-scale slicing while reducing dependency on labor and time. In addition, the machine guarantees consistent product quality through uniform slicing, reduces raw material waste, and enhances both hygiene and operator safety. Supported by mass production capabilities and quality consistency, MSMEs are better positioned to expand their competitiveness at regional and national levels. Furthermore, IoT integration provides additional advantages, such as remote monitoring and precise parameter control, which contribute to greater process efficiency and adherence to product standards.

The development of an IoT-based cassava chip slicing machine, integrated with control and sensor monitoring using ESP32,

represents a strategic effort to strengthen the competitiveness of MSME products. Beyond simplifying machine operation and supervision for business owners, the system offers the potential to deliver higher and more consistent product quality that complies with modern production standards. The evolution of the Internet of Things (IoT) has significantly influenced various sectors, including agriculture and food processing. By enabling the connection of physical devices with digital systems through the internet, IoT supports automation, monitoring, and real-time control. Importantly, IoT adoption is not confined to large-scale industries but also holds great promise for small and medium-sized enterprises (SMEs), particularly in improving efficiency, productivity, and workplace safety [6]. In small-scale food processing, cassava slicing machines are still largely operated manually, which leads to challenges such as lengthy processing times, inconsistent slice quality, and operator safety risks. These limitations emphasize the need for an automated solution capable of enhancing machine performance while ensuring energy efficiency and user safety [7], [8]. This study aims to design and implement an IoT-based cassava slicing machine utilizing the ESP32 microcontroller, which offers built-in Wi-Fi, reliable processing performance, and flexible integration with sensors and actuators [9]. The system is intended to enable remote operation through a smartphone application, providing functions such as power control, motor speed adjustment, and real-time monitoring of machine status. The research focuses on three main objectives: (1) designing an IoT system that integrates ESP32 with a cassava slicing machine, (2) evaluating the system's responsiveness to user commands via smartphone, and (3) assessing the accuracy of real-time monitoring. Ultimately, this work seeks to enhance automation and safety in cassava slicing while demonstrating the potential application of IoT technology in small and medium-sized industries.

METHODS

This research employs an applied experimental method with the objective of designing, implementing, and testing an Internet of Things (IoT) system based on the ESP32 microcontroller for a cassava slicing machine. The adoption of the experimental approach is grounded in the research focus, which emphasizes prototype development, performance evaluation, and the assessment of system effectiveness in supporting automation and monitoring functions. The experimental data are analyzed using a descriptive quantitative method to examine the performance of the ESP32-based IoT system in relation to effectiveness, efficiency, and operational safety of the cassava slicing machine [10].

The study specifically concentrates on the development and implementation of a cassava chips slicing machine integrated with IoT technology, with the ESP32 microcontroller serving as the primary control unit. The core issues under investigation include system design and integration, the application of control mechanisms to regulate motor speed and slice thickness, as well as the utilization of sensor monitoring functions to detect machine conditions, slice count, and potential operational disruptions [11]. The hardware components employed consist of the ESP32, an electric motor as the blade driver, current and rotational speed (RPM) sensors for operational monitoring, a relay as a motor control actuator, and a power supply to support the entire system.

From the software perspective, the ESP32 was programmed through the Arduino IDE to handle control logic, communication processes, and sensor integration. Additionally, a Wi-Fi-based mobile application was created, enabling machine operation functions such as switching on and off, adjusting motor speed, and monitoring machine status in real time. The research workflow was conducted systematically, covering hardware assembly, microcontroller programming, mobile application development, system integration, and subsequent functional testing [9].

Data collection was carried out using two main methods: direct measurement of machine performance indicators—including latency, motor speed, and connection stability—and monitoring through the mobile application. The evaluation emphasized several key parameters, namely system responsiveness, connection reliability, monitoring precision, and operational efficiency of the machine. Beyond this, the study examined the system's effectiveness in enhancing production efficiency and ensuring consistent slice quality within the context of Micro, Small, and Medium Enterprises (MSMEs). The central aims of the study are to design a system with real-time control and monitoring capabilities, to validate the performance and accuracy of the developed solution, and to assess its contribution toward improving productivity and maintaining product quality [12].

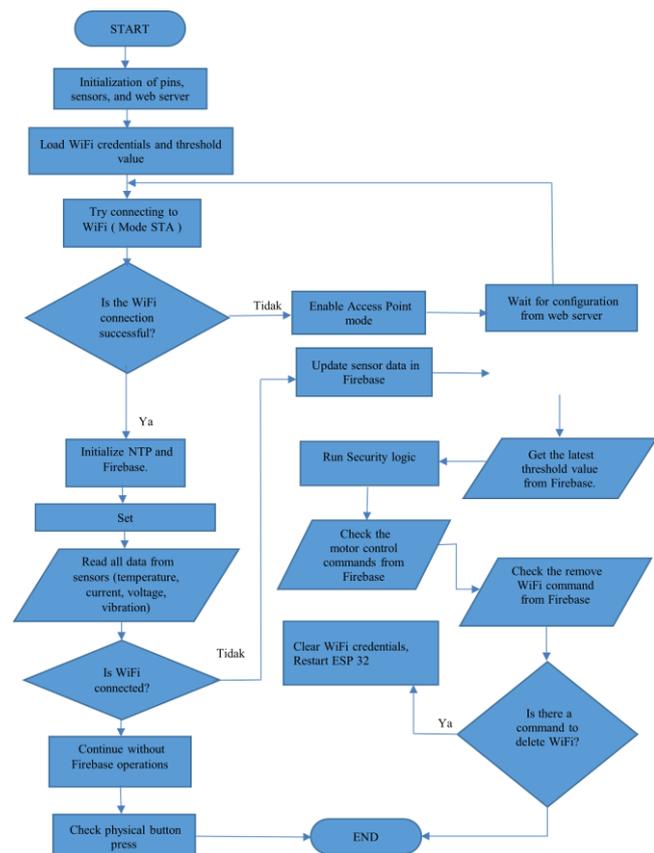


Figure 1. Flowchart ESP32 (Setup Dan Loop)

From the ESP32 flowchart as shown in Figure 1, the explanation is as follows: first, the initialization of pins, sensors, and the web server is carried out. After that, the Wi-Fi credentials are loaded and the threshold value is obtained. Once the threshold value is retrieved, the device will connect to Wi-Fi (STA mode). Then, the question arises: "Is the Wi-Fi connection successful?"

If the answer is “Yes” and the device successfully connects to Wi-Fi, it will proceed to initialize NTP and Firebase.

NTP is a network protocol used to synchronize time between devices within a network, while Firebase in this IoT system functions as a platform where devices (sensors/actuators) typically send data to the server/cloud.

If the device fails to connect to Wi-Fi, then the Access Point (AP) mode will be activated. An AP is a network device that provides Wi-Fi connections, allowing other devices (such as smartphones, computers, and IoT devices) to connect to a local network or the internet. After that, it waits for configuration from the web server and retries connecting to Wi-Fi (STA mode).

Once NTP and Firebase initialization is successful, the system will proceed to the “Set” stage to read all sensors, including temperature, current, voltage, and vibration. Then, the question arises again: “Is Wi-Fi connected?” If the answer is “Yes,” the sensor data will be updated in Firebase and the system will wait for configuration from the web server. After that, it retrieves the latest threshold value from Firebase, executes safety logic, checks motor control from Firebase, and verifies whether there is a command to delete Wi-Fi.

If the question “Is there a command to delete Wi-Fi?” is answered “Yes,” then the Wi-Fi credentials will be deleted, the ESP32 will restart, and the process ends. If the answer is “No,” the process also ends. At the “Is Wi-Fi connected?” stage, if the answer is “No,” the process continues without Firebase operations, and only physical button presses are checked before ending.

RESULTS AND DISCUSSION

The implementation of the Internet of Things (IoT) on a cassava slicing machine using the ESP32 microcontroller demonstrates its capability to perform real-time monitoring and control through a smartphone application. The ESP32 was selected due to its ability to handle both data processing and wireless communication via Wi-Fi, enabling integration with Firebase as a cloud database and time synchronization using the Network Time Protocol (NTP) [13], [14]. Sensor data, including temperature, voltage, current, and vibration, were successfully transmitted continuously to the server, allowing the machine’s operational status to be monitored seamlessly. Experimental results show that the system operates reliably, supporting both Station (STA) and Access Point (AP) modes for network flexibility. The integration with Firebase facilitates data storage, threshold updates, safety logic execution, and motor control, thereby enhancing safety and operational efficiency. Overall, the IoT-based cassava slicing machine contributes to the digitalization of agro-industrial machinery and demonstrates its potential to improve productivity, safety, and energy efficiency in small- to medium-scale food processing industries.

A. Development of an ESP32-Based IoT System for Automatic Cassava Slicing Machines

The automatic slicing machine is an innovation in food processing technology designed to minimize or even eliminate human intervention during slicing operations. Raw materials are placed into the hopper and subsequently processed automatically

according to predetermined settings, supported by advanced sensors and control systems to ensure accuracy and reliability. This machine offers several advantages, including a very high production capacity that enables continuous processing, consistent and precise slicing quality with digitally adjustable thickness, and greater efficiency in terms of time and labor due to minimal manual involvement [15], [16]. Moreover, its design reduces the risk of workplace accidents, as operators are not exposed to moving blades, while also providing better process control through automated adjustments of speed, thickness, and other parameters. Furthermore, the machine has the potential for integration with modern technologies, such as Internet of Things (IoT)-based monitoring systems, which allow real-time remote supervision, thereby aligning with the advancement of smart manufacturing and Industry 4.0 [17].

Table 1. The Tools for Development of the IoT-Based Cassava Slicing Machine using ESP32 with Smartphone Monitoring.

Category	Tools and Materials	Description
Hardware	ESP32 Dev Module	Main microcontroller
	AC Motor	Main actuator
	ACS712 20A Sensor	Current/temperature sensor
	Omron S8VS-01505 Power Supply	Power supply
	SW-420 Vibration Sensor	Vibration detection
	Solid State Relay (SSR 220V AC control DC/AC)	AC load controller
	Machine frame (40 mm angle iron)	Frame structure
	Steel plate cutting blade	Cutting mechanism
	Mechanical components (bearing, pulley, belt)	Motion mechanism
	Jumper wires	Circuit connectors
	Project board	Circuit prototyping
	PCB	Electronic circuit board
	2A Fuse + Fuse holder	Current protection
	AC Cable NYM 2x1.5 mm	AC power cable
	Terminal block	Cable connector
DC Cable	DC power cable	
Electrical tape	Cable insulation	
4.7 kΩ resistor	Electronic component	
10 kΩ resistor	Electronic component	
Software	Arduino IDE	Microcontroller programming
	Kodular IoT Platform	IoT application integration
	ESP32 Libraries (Wi-Fi & sensor)	Connectivity and sensor support

The ESP32 is a microcontroller that is highly suitable for IoT applications, as it can acquire data from various sensors, such as thickness, motor speed, and motor temperature, and transmit it wirelessly to cloud platforms for remote monitoring and analysis. With the support of a dual-core processor, PWM, and GPIO, the ESP32 enables precise motor control and time-sensitive encoder readings, while also allowing local data processing such as

calibration and PID control. Its communication flexibility through Wi-Fi and Bluetooth enhances integration with monitoring systems and peripheral devices. Designed for IoT scalability and connectivity, the ESP32 provides a reliable foundation for intelligent remote monitoring and control solutions. Table 1 presents the tools used in the development of the IoT-Based Cassava Slicing Machine Using ESP32 with Smartphone Monitoring.

Table 2. Average cassava slice thickness under different loads

Load (kg)	Number of Slices (n)	Total Thickness (mm)	Average per Slice (mm)
1 kg	100	121.0	1.210
2 kg	100	120.7	1.207
3 kg	100	120.2	1.202
4 kg	100	119.7	1.197
5 kg	100	120.1	1.201

The experimental findings reveal that the average thickness of cassava slices across load variations from 1 kg to 5 kg remains within a narrow interval of 1.197–1.210 mm as shown in Table 2 which calculate using formula 1. The bar chart illustrates only slight differences between loads, with the minimum thickness recorded at 4 kg (1.197 mm) and the maximum at 1 kg (1.210 mm). These results indicate that the slicing machine is capable of preserving uniform slice thickness despite changes in load, thereby confirming its stability and reliability.

Formula for Slice Thickness Calculation:

$$d = \frac{\sum_{i=1}^{100} di}{100} \quad (1)$$

With explanation:

ddd = average slice thickness (mm)

did_idi = thickness of the i-th slice

100 = number of slice samples

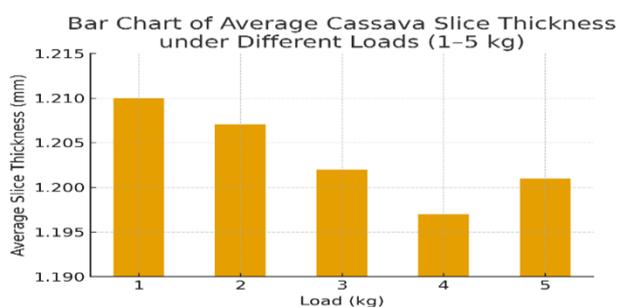


Figure 2. Bar chart illustrating the average thickness of cassava slices

Figure 2 show the bar chart which demonstrates that the average thickness of cassava slices under loads ranging from 1 to 5 kg remains within a narrow interval of 1.197–1.210 mm. The minimal variation observed indicates that load differences exert no significant influence on slice thickness, thereby confirming the stability and reliability of the slicing mechanism. This consistency is particularly important for ensuring uniform frying time and maintaining the overall quality standard of cassava chips in industrial applications.

B. Design and Implementation of an IoT-Based Cassava Chips Slicing Machine

The design and implementation of an IoT-based cassava chips slicing machine were carried out by integrating mechanical, electronic, and software aspects. Mechanically, the machine is constructed using a 40-angle iron frame as the main structure, equipped with a steel plate blade as the primary cutting component [12]. The rotational power of the AC motor is delivered to the blade through a transmission system consisting of a pulley, bearing, and belt, while motor operation is regulated by a solid-state relay (SSR).

As shown in Figure 3, from the electronic and software perspective, the system is managed by an ESP32 Dev Module connected to an ACS712 20A current sensor and an SW-420 vibration sensor, supported by an Omron S8VS-01505 power supply along with additional protective components. Programming is conducted using the Arduino IDE, while a Kodular-based smartphone application provides monitoring and control functions. With Wi-Fi connectivity, the machine is capable of operating automatically and can be monitored and controlled remotely in real time through IoT technology.

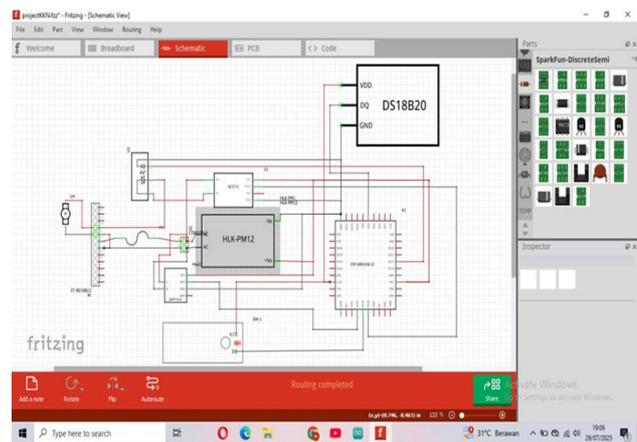


Figure 3. IoT-Based Cassava Chip Slicing Machine Design

The ESP32 functions as the main control unit that integrates sensors, processes data, and transmits instructions to actuators, while also providing connectivity to the IoT cloud platform. The slicing mechanism consists of a drive motor, a transmission system (gear or belt), and a cutting blade, where cassava is driven toward the blade and subsequently sliced into pieces of a specified thickness. The actuator, in the form of a motor driver, regulates both the speed and rotational direction of the cutting motor, thereby ensuring that the slicing process operates effectively and optimally.

C. Schema of Firebase Realtime Database

Firestore Realtime Database is a cloud-hosted database that stores data in JSON format and synchronizes it in real time across all connected clients. In cross-platform application development, including Apple, Android, and JavaScript environments, a single instance of the Realtime Database is employed to automatically accommodate data updates. The structure of the Firestore Realtime Database functions as a bridge between the ESP32 device and the application, where data is stored in an organized

hierarchical JSON format to ensure efficient communication and data exchange.

In this study, the database structure is organized into three main components: sensor_data, status, and threshold as shown in Figure 4. The sensor_data component stores the data transmitted by the ESP32, including machine temperature, current, and voltage values. The status component records the machine's operational state, for example, through the last_shutdown_reason attribute, which logs the most recent reason for shutdown, such as "Overload." This value can be accessed by the application and subsequently cleared after being retrieved. Meanwhile, the threshold component defines the system's control parameters, consisting of batasArus for current, batasSuhu for temperature, batasTeganganMax as the upper voltage limit, and batasTeganganMin as the lower voltage limit.



Figure 4. Firebase Realtime Database Structure

D. User Interface (UI) on IoT Applications/Web

The User Interface (UI) in IoT-based applications or web platforms serves as the primary interaction medium between users and the system, enabling real-time monitoring of sensor data, remote device control, and automated notifications of system anomalies [18]. Designed to be intuitive and responsive, the UI supports data visualization through charts and tables for efficient analysis. In the IoT-based cassava chip slicing machine, the UI provides comprehensive access to machine status, slice count, average thickness, and production history, ensuring effective real-time monitoring and control.

This system design employs an ESP32 microcontroller to continuously acquire data from temperature, current, voltage, and vibration sensors. The collected data is transmitted in real time to the Firebase Realtime Database, which is then accessed by a smartphone application. The application automatically responds to any database updates by displaying the most recent sensor values on its interface, thereby enabling users to monitor machine conditions in real time.

In addition to monitoring, the smartphone application also functions as a control interface. When the ON/OFF button is pressed, the application transmits a binary signal ("1" or "0") to the motor_status tag in Firebase. The ESP32 monitors this tag and immediately executes the corresponding control command upon detecting a change. In the event of an anomaly, such as temperature exceeding a predefined threshold, the ESP32 automatically shuts down the motor and records the shutdown reason in the last_shutdown_reason tag. The application then retrieves this information, displays a warning notification to the user, and clears the tag to prevent repeated alerts.

From a security perspective, the system integrates a primary device authorization mechanism. A unique ID of the authorized device is stored in Firebase, and the smartphone application verifies its own ID against the stored one. If the IDs match, the control button is displayed; otherwise, access to control functions is restricted. This mechanism ensures that only authorized devices can operate the machine, thereby minimizing the risk of unauthorized access.

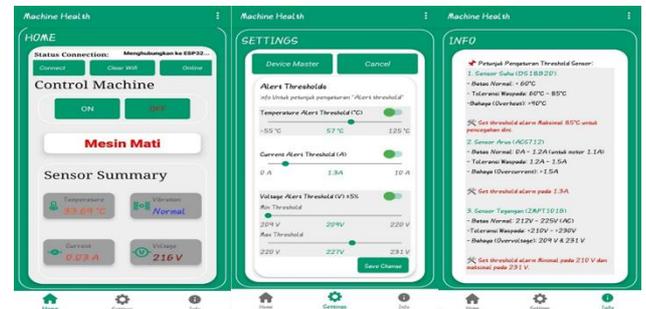


Figure 5. User Interface (UI) on IoT Applications/Web

The designed smartphone application incorporates three primary interfaces that support monitoring, control, and system configuration that show in Figure 5. The Dashboard interface provides real-time visualization of sensor data, including temperature, current, and voltage. Through this interface, users can observe the operational state of the machine and identify when sensor values exceed the predefined thresholds. For authenticated primary devices, an ON/OFF button is available, allowing direct control of the machine.

The Settings interface enables users to define threshold values for each sensor. Any adjustments are stored in the Firebase Realtime Database and automatically retrieved by the ESP32, which applies them within the system's safety mechanism. This ensures that machine operation remains within safe operating limits and enhances system reliability.

The Information interface delivers essential user guidelines, such as instructions for configuring threshold values, and provides access to current sensor data as reference material. This feature assists users in performing more effective monitoring while maintaining consistent system performance.

E. Design and Interface Results of an Automatic Cassava Slicing Machine Based on ESP32 and IoT

The integration of distance sensors for thickness measurement, encoders for motor speed detection, and temperature sensors for motor condition monitoring requires a controller capable of simultaneously managing data acquisition, monitoring, and control. In this context, the ESP32 represents an appropriate platform. The ESP32 can interface with various sensors through GPIO, ADC, I2C, or SPI, and transmit the collected data wirelessly via Wi-Fi to cloud servers such as MQTT brokers, databases, or IoT dashboards. This mechanism enables remote machine condition monitoring, data analysis, and real-time visualization. Figure 4 presents the integration of ESP32 for sensor control and monitoring in the cassava chips slicing machine.



Figure 6. ESP32-based sensor control and monitoring for cassava chips slicer

Figure 6 present ESP32-based sensor control and monitoring for cassava chips slicer. In terms of actuator control, the ESP32 supports motor operation through PWM and GPIO while receiving speed feedback from encoders. Its dual-core architecture ensures that time-sensitive encoder readings are not disrupted by networking or other concurrent tasks. Continuous monitoring of motor temperature is also possible. When the temperature exceeds a predefined threshold, the ESP32 can send alerts via Wi-Fi or Bluetooth, or even perform automatic corrective actions such as reducing speed or shutting down the motor [19].

Another advantage of the ESP32 lies in its communication flexibility. Wi-Fi can be used for continuous data transmission to the cloud, firmware updates, and backend integration, while Bluetooth serves for initial configuration, local debugging, or communication with nearby peripheral devices. Furthermore, the ESP32's dual-core processor provides sufficient computational capacity to process data locally on the device, including filtering, calibration, and even implementing PID control algorithms, before transmitting the processed data to the cloud. Hence, the ESP32 functions not only as a data transmitter but also as a processing unit. Overall, the ESP32's ability to connect to the internet makes it highly suitable for IoT applications. This capability supports the development of robust, adaptive, and scalable remote monitoring and control systems. Figure 5 illustrates the design of a cassava slicing machine integrated with IoT technology and equipped with a control and monitoring system based on the ESP32.



Figure 7. IoT-based cassava slicing machine using ESP32 with slice thickness of 1.197–1.210 mm.

Figure 7. presents the design of a cassava slicing machine integrated with Internet of Things (IoT) technology, utilizing an ESP32 microcontroller as the core control and monitoring unit.

The slicing mechanism employs a stainless-steel rotary blade driven by an electric motor, equipped with an adjustable blade setting that enables operators to regulate the thickness of slices according to production requirements. Performance testing demonstrated that the machine is capable of producing cassava slices with an average thickness ranging from 1,197–1,210 mm, depending on the motor speed configuration and blade adjustment. Uniform slice thickness plays a crucial role in ensuring consistent frying time, product texture, and overall quality, particularly in cassava chip production. These findings indicate that the proposed design fulfills the precision requirements of food processing industries.

The integration of the ESP32 enables real-time monitoring and control of operational parameters such as motor speed, blade rotation status, and production output. Data collected by the system are transmitted via Wi-Fi to a cloud-based dashboard or mobile application. The IoT-based system provides several advantages, including remote process monitoring, adjustable motor speed to achieve the desired thickness, automated notifications in case of system malfunction or overload, and data storage for performance evaluation and process optimization. Furthermore, the user interface is designed to be intuitive, reducing the need for manual recalibration and allowing operators with limited technical expertise to operate the machine effectively. This ease of use enhances operational efficiency while supporting data-driven production management. Overall, the integration of IoT technology into the cassava slicing machine significantly improves automation, precision, and efficiency. Beyond functioning as a slicing device, the machine operates as an intelligent system that supports decision-making through real-time data acquisition and analysis. This design is considered suitable for both small-scale enterprises and industrial-scale applications, thus contributing to the advancement of smart food processing technologies and improving competitiveness in the agro-industrial sector.

CONCLUSIONS

This study successfully designed and implemented an Internet of Things (IoT)-based cassava slicing machine utilizing the ESP32 as the main control unit. The developed system is capable of acquiring data from temperature, current, voltage, and vibration sensors, and transmitting this information in real-time to a cloud-based database. Integration with a smartphone application enables users to monitor machine conditions, receive notifications when anomalies occur, and directly control the motor through ON/OFF commands.

The experimental results demonstrate that the system improves operational efficiency, enhances machine safety, and provides convenient remote monitoring. Furthermore, the machine produces cassava slices with consistent thickness and uniform quality, thereby contributing to improved product standards.

In addition, the proposed design shows strong potential to support Micro, Small, and Medium Enterprises (MSMEs) in the food sector, particularly cassava chips producers, by increasing productivity, maintaining product quality, and facilitating digital transformation in small- and medium-scale industries.

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