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Systematic modernization of fish smoking method with the implementation of smoked fish machine based on Internet of Things technology

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Abstract

The traditional process of smoking fish, which is widely used in coastal regions, poses significant challenges due to its labor-intensive nature, constant supervision, and difficulty maintaining stable temperatures. These issues often result in inefficiencies, inconsistent product quality, and potential safety hazards. Given the importance of the smoked fish industry in sustaining local economies in the coastal area of Indonesia, there is a critical need for more advanced, reliable, and efficient methods of fish smoking. This study addresses these challenges by developing an Internet of Things (IoT)-integrated monitoring and control system for the smoked fish machine. This study was conducted to develop a monitoring and control system for machines which includes turning on/off machine components, temperature monitoring, and blower revolutions per minute (RPM) control. The results of the study showed that the implementation of IoT can activate machine components such as a blower, a servo motor, and a light. Moreover, IoT can monitor the machine temperature from a smartphone in real-time by integrating a temperature sensor. The temperature difference between the sensor and the analog thermometer was found to be 0.1 – 0.5ºC, proving that the temperature on the IoT system is not very different from the analog thermometer. Furthermore, the blower RPM control results showed that the system could maintain the temperature in the optimal range (75 – 90ºC) for smoking the fish, with a maximum deviation of 1°C, and the blower RPM can be adjusted through the control in the IoT system. In general, the use of IoT can simplify machine operation for users.

Keywords: Control, Fish, Internet of Things, Machine, Monitoring, Temperature

1. Introduction

Technological advancements have led to significant innovations that have profoundly impacted human life (Sánchez & Hartlieb, 2020). The rapid pace of technological progress has resulted in widespread smartphone ownership (Bauer et al., 2020; Lesher, 2021; Senjam et al., 2021; Tapiero et al., 2020), which in turn supports the development of digital technologies such as the Internet of Things (IoT) (Khanh et al., 2022; Mahmood, 2021; Sami et al., 2020). The IoT gained popularity in 2010 by introducing the "smart home" concept and Nest's launch of a smart thermostat controllable via mobile phones (Verma et al., 2021). Today, nearly everyone possesses a smartphone connected to the internet, facilitating the IoT concept by allowing devices to connect to the internet and communicate autonomously, without human intervention (Baiyere et al., 2020; Karthick & Pankajavalli, 2020). These devices range from household appliances and vehicles to industrial machinery and even simple objects equipped with sensors capable of sending and receiving data (Chen & Setiawan, 2023; Laghari et al., 2021).

The primary function of IoT is to enhance the ease of human life (Setiawan et al., 2021). Through IoT, various devices and systems can be integrated and remotely controlled, offering increased efficiency and convenience (Salih et al., 2022; Shafique et al., 2020; Shammar & Zahary, 2020). Users can remotely monitor and control devices such as temperature regulators, irrigation systems, and security apparatus through IoT-enabled mobile devices (García et al., 2020; Quy et al., 2022; Yasin et al., 2021). IoT facilitates the practical use and control of machines, enabling remote operation and monitoring, thereby reducing direct human involvement and minimizing potential hazards (Kim et al., 2020; Molaei et al., 2020; Wójcicki et al., 2022).

The smoked fish industry, which sustains the livelihoods of many in Indonesia's coastal areas, is an example of an industry that could benefit from IoT technology (Kruijssen, 2020; Ng et al., 2022; Suwandhahannadi et al., 2024). Currently, most smoked fish enterprises in Indonesia rely on traditional fish smoking methods using stoves (Haryanto et al., 2021). However, these traditional methods are often less effective, efficient, and hygienic compared to modern, controlled solutions. Traditional fish smoking requires continuous supervision and takes a longer time to complete, with unstable temperatures often leading to product damage (Dash et al., 2022). With technological advancements, more practical smoked fish machines have been developed. Research by Al Hudha et al. (2018) indicates that these machines can be integrated with IoT technology to enhance user convenience. IoT-enabled smoked fish machines can be remotely controlled and monitored, allowing operators to oversee the smoking process in real-time (Al Hudha et al., 2018). The technological development of this sector is crucial for Indonesia, a maritime nation with abundant fishery resources (Setiawan et al., 2023).

The integration and implementation of IoT into smoked fish machines are expected to streamline operations, allowing users to monitor and control the machines in real-time via mobile devices. IoT can save time and energy, as users can perform necessary monitoring and control without being physically present at the site. Additionally, data generated by IoT-enabled smoked fish machines can be analyzed to enhance productivity and efficiency in the production process.

2. Literature Review

The first study, conducted by Rahman et al. (2020), implemented a temperature monitoring system using DHT11 sensors within an IoT framework. The system employed an Arduino, an ethernet shield, and a DHT11 sensor to transmit data to the AT&T M2X IoT platform via a RESTful API. The M2X platform's trigger feature was integrated with the IFTTT service, enabling the system to send notifications via email, SMS, and mobile push notifications when extreme changes in temperature and humidity were detected. Data analysis revealed significant temperature and humidity variations across different locations and a strong negative correlation between temperature and humidity, highlighting the need for improved data center layout design (Rahman et al., 2020).

In the second study, Jayanti et al. (2019) developed an oven for smoking fish using the cold smoking method, which incorporated an Arduino Uno-based monitoring system. This study introduced a temperature monitoring system for a smoked fish machine capable of tracking the temperature within the smoke chamber. The Arduino Uno microcontroller connected a temperature sensor, which could accurately read the internal temperature, and an LCD that displayed real-time temperature conditions (Jayanti et al., 2019).

The third study involved the development of a smoked fish machine with an IoT-based control system by Al Hudha et al. (2019). The machine utilized an IoT system to activate machine components and monitor temperature, thereby enhancing user access to the machine's features. Based on the findings from these three studies—each of which explored the application of the DHT11 temperature sensor, Arduino Uno microcontroller, and IoT in control and monitoring systems—it is evident that these components can be effectively and efficiently implemented. Consequently, integrating these technologies into a smoked fish machine is both feasible and advantageous.

3. Research Methodology

This study employed a research and development (R&D) methodology and utilized the stages of IoT system development as delineated by Dilmegani (2024), as illustrated in Fig. 1.

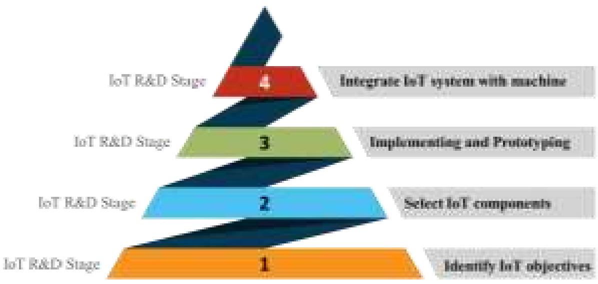

Fig. 1. IoT research and development Stages (Dilmegani, 2024).

The research process encompasses four distinct phases of IoT development, which are elaborated upon as follows:

3.1. Identify Internet of Things Objectives

At this stage, it is crucial to define the primary objectives of IoT system development clearly. Generally, the application of IoT in smoked fish machines aims to provide a user-friendly interface that facilitates remote monitoring and control of the smoking room. The specific objectives to be achieved include:

a) Controlling the activation and deactivation of the blower, servo motor for driving the machine's shaft, and the machine's lighting.
b) Real-time monitoring of the temperature within the fish smoking room (inside of the smoking tube).
c) Regulating the heat in the combustion chamber by adjusting the blower's revolutions per minute (RPM).

As depicted in the flowchart in Fig. 2, these objectives represent the visualized goals of the IoT system that will be implemented in the smoked fish machine for this study. Three objectives include machine components, temperature monitoring, and the blower's RPM.

3.2. Selection of IoT Component

Once the objectives for the IoT system were established, the next crucial step involved selecting the necessary components. This research identifies six key components essential for preparing the IoT system:

a) The microcontroller serves as the central processing unit of the IoT system, responsible for processing data from sensors and controlling other connected components.
b) The DHT11 temperature sensor is employed to accurately and continuously measure the temperature and humidity within the fish smoking chamber in real-time.

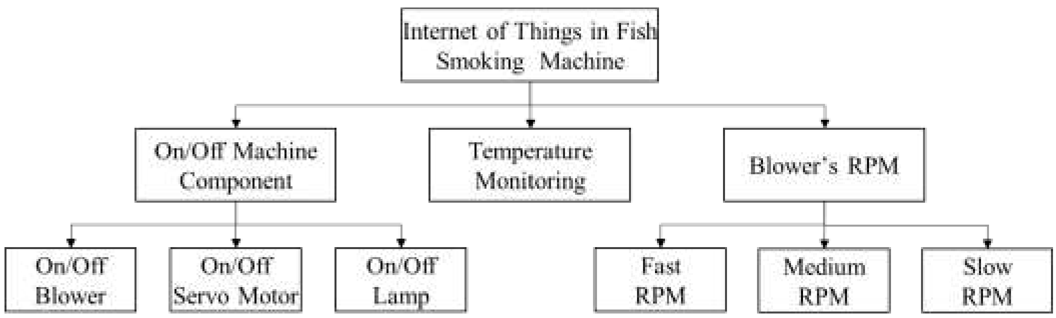

Fig. 2. Internet of Things objectives in this study.

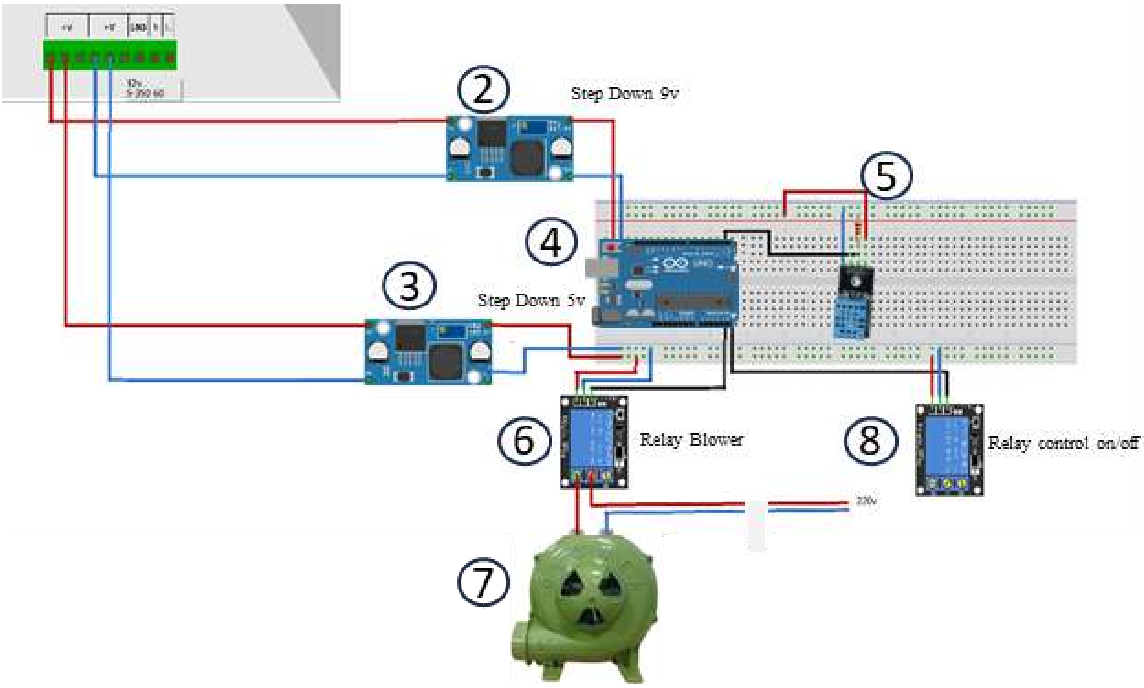

Fig. 3. Internet of Things electrical system design plan.

c) The blower's electronic system, which manages air circulation within the smoking chamber, is automatically integrated with the IoT system for optimal operation.
d) A WiFi or Ethernet module is required to connect the IoT system to the internet, enabling remote data transmission and reception.
e) The user interface on a mobile smartphone provides the platform for users to interact with and control the IoT system.

After identifying the primary components for the IoT system in the fish smoking chamber, a comprehensive design was developed, incorporating both essential and supporting components. The electronic circuit design, as illustrated in Fig. 3, presents the complete schematic of the IoT system, detailing the integration of various components, including sensors, microcontrollers, communication modules, and output devices.

The detailed schematic of the IoT components depicted in Fig. 3 is further elaborated in Table 1, which comprehensively explains their specifications.

3.3. Implementation and Prototyping

Following the selection of IoT components and the completion of the system design, the next stage involves the implementation and prototyping process. This stage is divided into two distinct activities: hardware prototype implementation and software prototype implementation.

Table 1. Internet of Things electronic system components.

No	Detail part
1.	Power supply 12 V Microcontroller
2.	Modul step down 9 V
3.	Modul step down 9 V
4.	Microcontroller Arduino Uno
5.	Temperature Sensor DHT 11
6.	Relay setting RPM Blower
7.	Blower 2" 220 V
8.	Relay on/off Machine

a) Hardware Prototype Implementation

All IoT components are assembled and integrated for hardware prototyping implementation according to the finalized design specifications. The process begins with connecting the DHT11 temperature sensor to the Arduino Uno microcontroller. Subsequently, program code is developed to acquire real-time temperature data from the sensor and transmit it to the user interface via an internet connection. Additionally, the blower RPM and timer system are integrated with the microcontroller, with a corresponding program code designed to regulate the blower RPM automatically based on the target temperature. The system also includes programming for the on/off activation of the blower, servo motor, and additional components.

A WiFi or Ethernet module is integrated into the microcontroller to facilitate internet connectivity for the IoT system. User interfaces, such as web or mobile applications, are then developed to enable remote monitoring of temperature and humidity and control of temperature settings, fan speeds, and timers. Upon integration of all components, the IoT system prototype undergoes rigorous testing. This testing involves simulating various temperature conditions and smoking scenarios to ensure that the system operates as intended and meets all functional requirements.

Fig. 4. Box panel and Internet of Things component assembly.

Fig. 4 illustrates the design of the control printed circuit board circuit, which is intended to be integrated into the IoT system for monitoring and controlling the fish-smoking process. This electrical system is installed on the machine's control panel, with careful attention to both functionality and safety. The design includes several key components: a power supply, a step-down module, a DHT11 temperature sensor, a timer sensor, an Arduino Uno microcontroller, an IoT communication module, the machine's heating system, and the Blynk IoT platform. The DHT11 temperature sensor is integral to the system, providing real-time temperature measurements during the smoking process. Its selection was based on its accuracy in measuring both temperature and humidity, as well as its capability for digital communication with the microcontroller. The Arduino Uno microcontroller facilitates wireless communication via a Wi-Fi network, enabling seamless integration with the IoT system.

b) Software Prototype Implementation

Fig. 5 illustrates the coding process for the oven temperature monitoring system, which employs the DHT11 sensor in conjunction with an Arduino Uno microcontroller and the Blynk platform.

Fig. 5. Internet of Things coding on smoked fish machine

The program is designed to read temperature data from the DHT11 sensor, display it on an LCD screen, and transmit it to the Blynk application for real-time monitoring. Blynk facilitates the display of both current temperature and local time, with the program also incorporating functionality to retrieve local time using the TimeZone API.

The user interface is designed to enable interaction with the system through a custom application. This application allows users to monitor the smoking process temperature and regulate the blower's RPM and speed control. Access to the monitoring system requires users to log in with credentials previously created. The integration of the IoT system with the Blynk application is depicted in Fig. 6, which provides a visual representation of the system's status and functionality.

Fig. 6 illustrates the design results of the IoT monitoring and control system utilizing the Blynk platform. This stage is critical for the effective implementation of the system. The Blynk platform facilitates real-time data transmission from the temperature sensor to the Blynk cloud server via the Arduino Uno IoT communication module. Subsequently, this data is accessible and visualizable through both the Blynk mobile application and web interface. Blynk's user interface offers an intuitive and user-friendly display for real-time sensor monitoring, including features such as historical temperature graphs and notification alerts for parameter deviations.

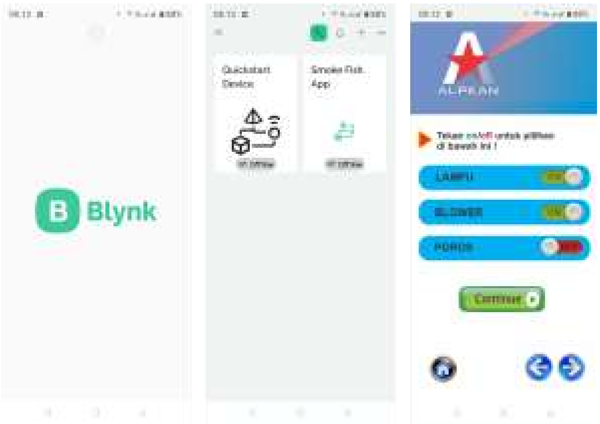

Fig. 6. Internet of Things user interface design display.

Additionally, the Blynk interface enables remote control of the blower's RPM through virtual buttons and allows users to set target temperatures. The system's IoT connectivity relies on a stable Wi-Fi network. Connectivity performance was assessed by monitoring the reliability of data transfer from the microcontroller to the Blynk platform. Security considerations are integral to the system's design, with the Blynk platform providing robust authentication and data encryption to safeguard communications between devices and cloud servers. Access to the Blynk user interface is secured with password protection, ensuring that only authorized users can monitor and control the system. Testing results confirm that data transmission is stable and efficient, with minimal or no significant data loss.

3.4. Integrate Internet of Things System with Smoked Fish Machine

Following the successful implementation of the IoT system prototype for the smoking machine, the subsequent phase involved integrating the system with the operational machine. This study required the IoT system to be interfaced with both the smoked fish machine and a smartphone. The IoT system was designed for remote monitoring and control, provided that the machine is connected to a nearby Wi-Fi router and the user's smartphone has an active internet connection. In scenarios where Wi-Fi is unavailable, users can employ an alternative IoT connectivity solution by enabling tethering on a smartphone, which connects to the IoT panel on the machine within a maximum distance of 30 meters.

Fig. 7 shows the integration process between the IoT system and the smoked fish machine components. This stage is crucial for ensuring that the IoT application on the smartphone and the IoT panel on the smoking machine function cohesively. Calibration procedures were also performed at this stage to verify the validity and accuracy of data measurements.

Fig. 7. Integrating the Internet of Things with a smoking fish machine.

4. Result and Discussion

4.1. Internet of Things Implementation to Turn On / Off Machine Components

The flow diagram depicted in Fig. 8 illustrates the operational sequence of the IoT system applied to a smoked fish machine for component activation. The process initiates with the manual powering on of the machine, followed by the application of power through a supply unit that converts 220 V to 12 V. This is further regulated by a step-down converter that reduces the voltage to 9 V, ensuring that the current is within safe operational limits for the Arduino Uno microcontroller. Once the machine is successfully powered on, the user must engage in the IoT mode by pressing the designated IoT button on the smoked fish machine. The user can control the machine remotely by establishing a connection between the machine and the smartphone via the IoT system. The IoT system facilitates the activation and deactivation of three components: the blower, servo motor, and light.

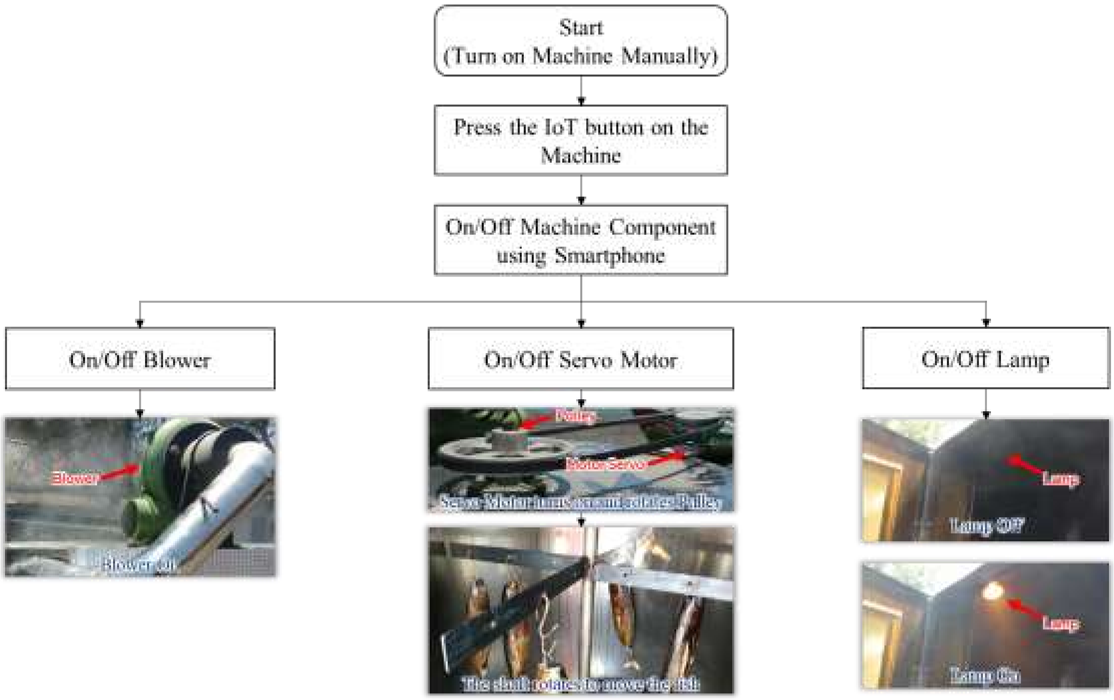

Fig. 8. Internet of Things system to activate components in the smoked fish machine.

4.2. Internet of Things Performance Testing on Temperature Monitoring

The microcontroller plays a pivotal role in the IoT system by collecting data from the DHT11 temperature sensor, processing this data, and transmitting it to the Blynk IoT platform via the communication module. The Blynk application is utilized to monitor the temperature data collected. The microcontroller also regulates the blower’s RPM to maintain an optimal level for effective smoking. Additionally, a timer system is integrated to cease smoking once the designated time has elapsed automatically. Following the installation of the IoT system on the smoking machine, a thorough evaluation was conducted to assess the performance of the RPM blower monitoring and control system during the fish-smoking process. Initial tests focused on evaluating the accuracy of the DHT11 temperature sensor in monitoring the parameters of the smoking process.

Table 2 presents the test results, demonstrating that the DHT11 temperature sensor exhibits high accuracy, with an average deviation of 0.1–0.5°C compared to the analog thermometer used for comparison. This level of accuracy is crucial for ensuring that the temperature data obtained accurately reflects the actual conditions within the smoking machine.

Table 2. Temperature monitoring performance testing.

No	Machine temperature (°C)		Status machine/gas solenoid mode
	IoT application	Analog thermometer	
1	34.1	34.4	off
2	43.5	43.3	on / Fast RPM Blower
3	48.8	48.6	on / Fast RPM Blower
4	58.7	58.2	on / Fast RPM Blower
5	62.6	62.5	on / Fast RPM Blower
6	69.2	69	on / Fast RPM Blower
7	73.8	73.6	on / Fast RPM Blower
8	79.3	79	on / Medium RPM Blower
9	85.3	85.2	on / Medium RPM Blower
10	94.6	94.5	on / Slow RPM Blower
11	100.7	100.5	on / Slow RPM Blower

4.3 Internet of Things Implementation to Control Blower’s Revolutions Per Minute

A blower control system, based on RPM, is employed to regulate hot air circulation during the fish-smoking process. This system integrates a DHT11 temperature sensor with IoT technology and a microcontroller to monitor the temperature within the dryer continuously. The effectiveness of this monitoring system in maintaining optimal temperature levels during smoking was assessed through testing. The blower system is calibrated to sustain a temperature range of 75 – 90°C. Test results indicate that the RPM control system effectively maintains the temperature within the specified range, with a maximum deviation of 1°C. Additionally, the system demonstrated prompt responsiveness to changes in the smoking conditions, adjusting the blower RPM rapidly in response to significant temperature fluctuations within the smoking chamber. This real-time parameter control enhances the efficiency and effectiveness of the smoking process.

Fig. 9 illustrates the components installed for controlling the blower's RPM, including a dimmer silicon-controlled rectifier and a mini servo. This system integrates a dimmer and a servo motor to regulate power settings automatically. The servo motor adjusts the dimmer lever, enabling automated RPM control without manual intervention, thereby enhancing blower efficiency.

Fig. 9. Blower RPM control system installation.

The RPM control system modulates air circulation in the smoking machine based on the temperature within the drying chamber. When the temperature exceeds 100°C, the RPM is reduced to 500 to prevent overheating, which could damage the fish. At temperatures between 75 – 90°C, considered optimal for smoking, the blower operates at a medium speed of 1,500 RPM to maintain the ideal conditions. If the temperature falls below 75°C, the system increases the blower RPM to 2,500, facilitating rapid replacement of the air with hotter smoke to raise the temperature in the smoking chamber effectively.

Fig. 10 depicts the operational scheme of the RPM blower control system. This automated control system is designed to stabilize and optimize the heat generated from combustion smoke, ensuring that the temperature within the smoking processing tube remains consistently within the target range of 75 – 90°C. The Blower RPM Control System is integrated with the IoT framework to regulate temperature fluctuations throughout the smoking process. This integration allows for precise adjustments to the temperature, either increasing or decreasing it as necessary.

The system's design aims to maintain the temperature in the smoking processing tube efficiently, adhering to the optimal range of 75 – 90°C as established in the literature (Tahir et al., 2020). Automating the temperature regulation process ensures that the fish smoking procedure operates at peak efficiency and effectiveness.

5. Conclusion

This study successfully developed and implemented an IoT-integrated monitoring and control system for a smoked fish machine. The IoT system allows for precise control of the machine's

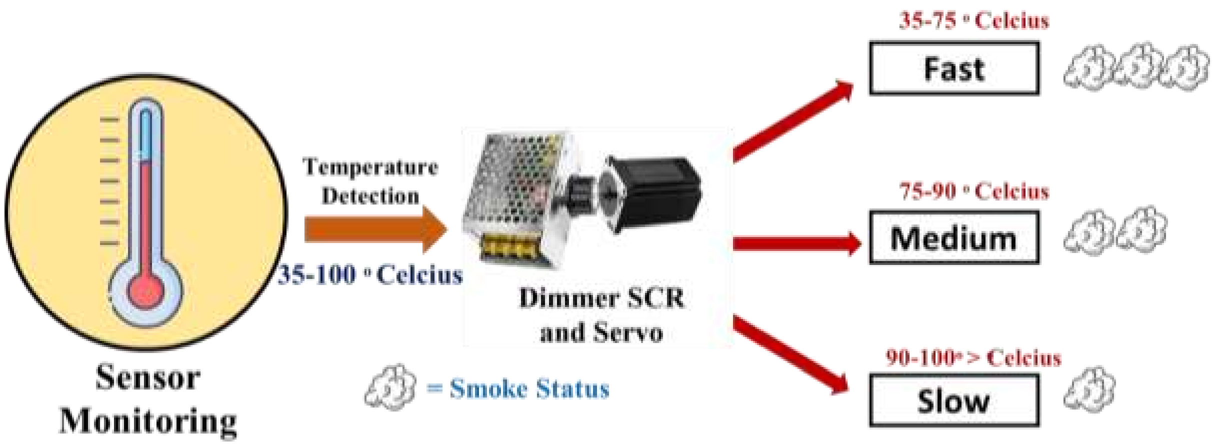

Fig. 10. Working scheme for silicon-controlled rectifier dimmer and revolutions per minute blower control system design.

components, enabling users to turn them on or off remotely. Additionally, the system facilitates real-time temperature monitoring within the fish smoking room. It also regulates the heat in the combustion chamber by adjusting the blower's RPM.

Implementing the IoT system to the machine offers users significant flexibility in monitoring and controlling the fish-smoking process from remote locations, eliminating the need for physical presence at the machine's site. Performance testing revealed that the IoT system operates optimally, with only a brief delay of approximately one second when activating machine components, such as a blower, servo motor, and light, via a smartphone interface.

Moreover, testing demonstrated that the IoT-connected DHT11 sensor accurately measures temperature and humidity, with an average discrepancy of just 0.1 – 0.5°C compared to an analog thermometer. The blower RPM control system was also found to be effective in maintaining the temperature within the optimal range, with a maximum deviation of 1°C, while efficiently adjusting hot air circulation based on the temperature conditions.

Overall, the results of this study indicate that the application of IoT technology to smoked fish machines has considerable potential for enhancing operational efficiency and control. Future development efforts could focus on integrating additional features, such as advanced data analysis and predictive maintenance systems, to optimize the system's performance further.

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