

## A Microcontroller-based Fish Drying System for Enhanced Drying Time with Real-Time Environmental Monitoring

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Article Info	Abstract
<p><b>Article history:</b> Received: 3 January 2026 Revised: 17 March 2026 Accepted: 1 April 2026</p> <hr/> <p><b>Keyword:</b> Arduino UNO R3 Automated fish drying DHT22 sensor Microcontroller-based system Real-time monitoring</p>	<p><i>The preservation of fish through drying is a vital practice in coastal regions like the Philippines. Traditional sun-drying methods often suffer from inefficiencies, environmental inconsistencies, and long drying times ranging from 8 to 20 hours. However, existing automated solutions often lack the specific real-time precision required for small-scale coastal processing, leading to inconsistent quality. To address these limitations, this study presents the design and implementation of a microcontroller-based fish drying system to enhance drying efficiency through real-time environmental monitoring. The system utilizes an Arduino UNO R3, a DHT22 sensor, infrared heating lamps, and an AC blower fan to maintain a regulated environment between 40°C and 50°C. The microcontroller is the central processing unit, communicating with the sensor to collect real-time temperature and humidity data. This data is used to dynamically control heating elements and ventilation, ensuring optimal drying conditions, reducing drying time, and improving product quality. Experimental results demonstrate that the microcontroller-based system significantly enhances the efficiency and consistency of the drying process to just 3.51 hours compared to conventional methods which recorded 4.48 hours. Technical evaluation through unit and system testing confirmed the system's reliability in maintaining a 45° indicator. Stakeholders evaluated the prototype using a 5-point scale, resulting in an overall scientific and functional rating of 4.32 (Strongly Agree). This innovation offers a scalable solution for small-scale processors to improve productivity, quality, and production of dried fish products.</i></p>

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### 1. Introduction

The preservation of fish was a critical aspect of the global food industry, particularly in coastal regions and areas with high fish consumption. Although rich in nutrients, fish are prone to spoilage, necessitating the use of different preservation methods. The fish drying process has been a traditional method of preserving fish in coastal communities in the Philippines for generations. Fish drying was a traditional method of preserving fish, and its significance extended far beyond cultural practices. It addressed critical issues related to food security, economic sustainability, and waste reduction. Globally, millions of tons of fish are dried annually, contributing significantly to the world's seafood production. Dried fish, an important sub-sector of small-scale fisheries (SSF), played a significant role in the livelihoods and ecosystems of the 120 million people engaged in global fisheries, particularly in low-income countries where it could

constitute up to 36% of total fish consumption, amid ongoing challenges in the SSF sector [1]. A survey [2] highlights that fish drying is a widespread, common method of preservation that supports cultural values, economic livelihoods, and food security. This shows why the preservation of fish through drying is a common and culturally significant practice with substantial nutritional value, as dried fish is a favored dietary choice in various parts of the world due to its high content of vitamins, minerals, and proteins [3].

Traditional fish processing techniques, particularly fish drying, are crucial for preserving fish, particularly in coastal regions like the Philippines, where limited access to cold storage facilities poses challenges [4]. As a cornerstone of the local industry, drying processes approximately 38% of the total catch into dried fish products, showcasing the extensive nature of fish drying operations [5]. This traditional fish drying is a cost-effective and environmentally friendly method for fish drying, utilizing salt for optimal protein preservation and optimal use of natural sunlight [6], [7]. The standard process involves cleaning, soaking in brine, sun-drying, resulting in sun-dried fish that last up to a year, maintaining a traditional flavor profile [8]. However, the drying time of fish traditionally varies and it ranges from 8 hours to 20 hours depending on the size of the fish [9].

While traditional fish drying is a cost-effective and environmentally friendly method that utilizes salt for protein preservation and natural sunlight for moisture removal. This method faces several challenges that result in various limitations, especially in coastal communities that produce a large amount of dried fish. Some of the challenges this method suffered are insect infestation, time-consuming, reliance to manual labor, and fluctuating environmental conditions. These factors often result in inconsistent product quality, product spoilage, and food safety concerns. To address these challenges, this study employed a systematic approach that involves a thorough review of related literature, considering global best practices in automated fish drying systems. Additionally, several steps were also conducted such as on-site visitation and interviews to understand local context, identify community needs, and explore innovative technologies for an automated fish drying system.

Previous studies have tried to reduce environmental risks by automating the process to mitigate environmental risks. For instance, in a study [10], industrial equipment that uses heat, airflow, and evaporation to remove water from fish products are needed to maintain the fish quality during the drying process. Researchers found that the automatic fish drying machine could dry 10 kilograms of salted fish in 8 hours with a moisture content of 25% [11]. Furthermore, there is a huge difference in drying time between the traditional and automated fish drying methods. The traditional drying method takes 45 hours while an automatic fish dryer based on fuzzy control only takes about 4.48 hours to dry a fish [12]. However, despite these advancements, there remains a critical research gap in developing a high-efficiency system that integrates rapid infrared heating with low-cost microcontroller precision to push drying times below the 4-hour threshold without compromising the physical quality of the fish.

To address these challenges, this study proposes the development of an Automated Fish Drying System that provides to the specific requirements and challenges in coastal communities that uses the method of drying a fish in fish preservation. The system utilizes an Arduino UNO R3 and a DHT22 temperature and humidity sensor. The system is designed to monitor and maintain optimal conditions using infrared heating lamps and an AC blower fan. The implementation follows an incremental prototyping model to ensure functional reliability across hardware and software components. By precisely regulating the drying chamber to a 45°C indicator, the system aims to significantly minimize drying time compared to both traditional methods and existing automated machines. The expected results include a streamlined drying process of approximately 3.51 hours, providing a scalable and efficient solution for local fish processors to improve productivity.

## 2. Research Methodology

Effective system development began with a thorough understanding of requirements. The methodology emphasized data collection through literature reviews and expert consultations to validate and refine the gathered information. This phase set the foundation for understanding the needs and challenges of the target community. The community relied on fishing as a primary economic activity. By conducting thorough requirement analysis, the researchers aimed to gather insights into the shortcomings of traditional fish drying methods and identify opportunities for improvement. Table 1 presents the structured data requirements for the study on "Development of an Automated Fish Drying System." It outlines how each data element contributes to the research process across different phases, ensuring a systematic approach to data collection and analysis.

Table 1. Data Requirements

Phases	Data Requirements
Phase 1: Research and Planning	<ul style="list-style-type: none"> <li>Information on existing types of automated fish drying systems.</li> <li>Optimal temperature and humidity ranges required for efficient fish drying.</li> </ul>
Phase 2: Design and Development	<ul style="list-style-type: none"> <li>Detailed specifications of materials, construction methods, and Requirements for the control system to monitor and regulate temperature, humidity, and drying parameters.</li> </ul>
Phase 3: Testing and Evaluation	<ul style="list-style-type: none"> <li>Quality assessments of dried fish products.</li> <li>Observations and user feedback on system usability and effectiveness.</li> </ul>
Phase 4: Validation and Feedback	<ul style="list-style-type: none"> <li>End User feedback on system performance, ease of operation, and areas for improvement.</li> </ul>

## 2.1 System Requirement

In the pursuit to enhance fish preservation and contribute to the economic growth, the researchers embark on the development of an Automated Fish Dryer. This innovation aims to address the challenges faced by local fisherfolk in traditional fish drying methods by using Industry 4.0 technologies. To ensure structural integrity and thermal efficiency, the prototype features a metallic drying chamber with a total fish capacity of 10 kilograms. Table 2 shows that cited research studies on Fish drying systems served as a basis.

In the design phase of the prototype, the conversion of requirements into a functional system involves a comprehensive approach that carefully considers both hardware and software components. By seamlessly integrating these elements, the resulting system aims to meet the specified needs efficiently and effectively. This system features a drying chamber with precise heating elements and a ventilation system to create the ideal drying environment [13]. Temperature and humidity sensors provide real-time data, allowing a microcontroller to automatically adjust conditions for optimal results. The integration of the sensors such as temperature and humidity sensors, together with the combination of automation components like fans and heating elements inside the metallic chamber was used to develop an ideal drying environment for the fish. The microcontroller connects the temperature sensor to the Liquid Crystal Display (LCD), displaying the temperature and humidity and the buzzer serve as a sound indicator in the system. Table 3 enumerates these parameters and their specific optimal ranges for maintaining an ideal drying environment. These parameters will serve as the guidelines for the system to maintain during the fish drying process.

In the study of the “automated fish drier,” the researchers examined the hot-air drying method, which encompasses a range of temperature settings from 40°C to 60°C, and relative humidity (RH) levels from 40% to 60%. The findings indicate that higher temperatures can accelerate the drying process, but temperatures above 50°C may risk cooking the fish muscle, which is undesirable. Conversely, very low RH levels can cause case hardening, where the fish’s exterior dries too quickly, adversely affecting its appearance and quality [14]. The automated fish drier is meticulously engineered to regulate these conditions, ensuring uniform drying that maintains the fish’s quality and prolongs its shelf life.

Table 2. Technologies Used for Other Fish Drying Prototypes

Title	Component Used	Author
“Implementation of fuzzy logic in fish dryer design,”	Arduino Mega 2560, DHT22, Load cell sensor, Fan, Heating element,	[12]

Table 3. Optimal Parameters

Parameters	Description
Temperature Range	40°C to 50°C
Humidity Indicator	40%
Temperature Indicator	45°C

## 2.2 Design and Development

In the pursuit of designing and developing an innovative fish drying system, the selection of components was guided by a blend of functionality, accessibility, and cost-effectiveness. The Arduino Uno R3 emerged as the microcontroller of choice, favored for its widespread availability, affordability, and user-friendly interface. To accurately monitor environmental conditions, the DHT22 sensor was selected for its superior performance in temperature and humidity sensing, offering a broad measurement range from -40 to 80 degrees Celsius [12]. This sensor's precision in data collection is critical, outperforming alternatives such as the DHT11 and other lower-tier sensors. For the user interface, a 20x4 LCD was employed to provide an expansive display, enhancing user interaction with the system. A piezo buzzer was incorporated to emit a more pronounced sound, serving as an auditory indicator during the drying process. The drying chamber itself was outfitted with an infrared bulb, chosen for its capacity to maintain a temperature range of 30 to 58 degrees Celsius, which is optimal for drying while preventing overheating. Complementing this, an AC blower fan was installed to ensure robust airflow, facilitating uniform heat distribution throughout the chamber. Figure 1 illustrates the schematic diagram of the systems integration of essential connections and hardware components employed in prototype construction for the Automated Fish Drying System.

The operational logic of the fish-drying system is governed by a closed-loop control process for maintaining consistent and safe drying conditions. The system's program flow begins with the initialization of all components, including the Arduino Uno R3, temperature sensor (DHT22), LCD screen (I2C), two-channel relay system, and the piezo buzzer. Initial parameters are set, defining the target temperature range to maintain between 40 to 50 degrees Celsius and the humidity level for drying stoppage at 40%. Once initialized, the main loop begins, continuously reading temperature and humidity data from the DHT22 sensor. The microcontroller evaluates this data, activating the infrared bulb for heating if the temperature falls below 45 degrees Celsius and the exhaust fan for cooling if it exceeds 45 degrees Celsius. Simultaneously, the system checks the humidity level, halting the drying process if it drops below 30% by deactivating the 2-way channel relay and displaying the "Finished Drying". The system's complete program flow is illustrated in Figure 2.

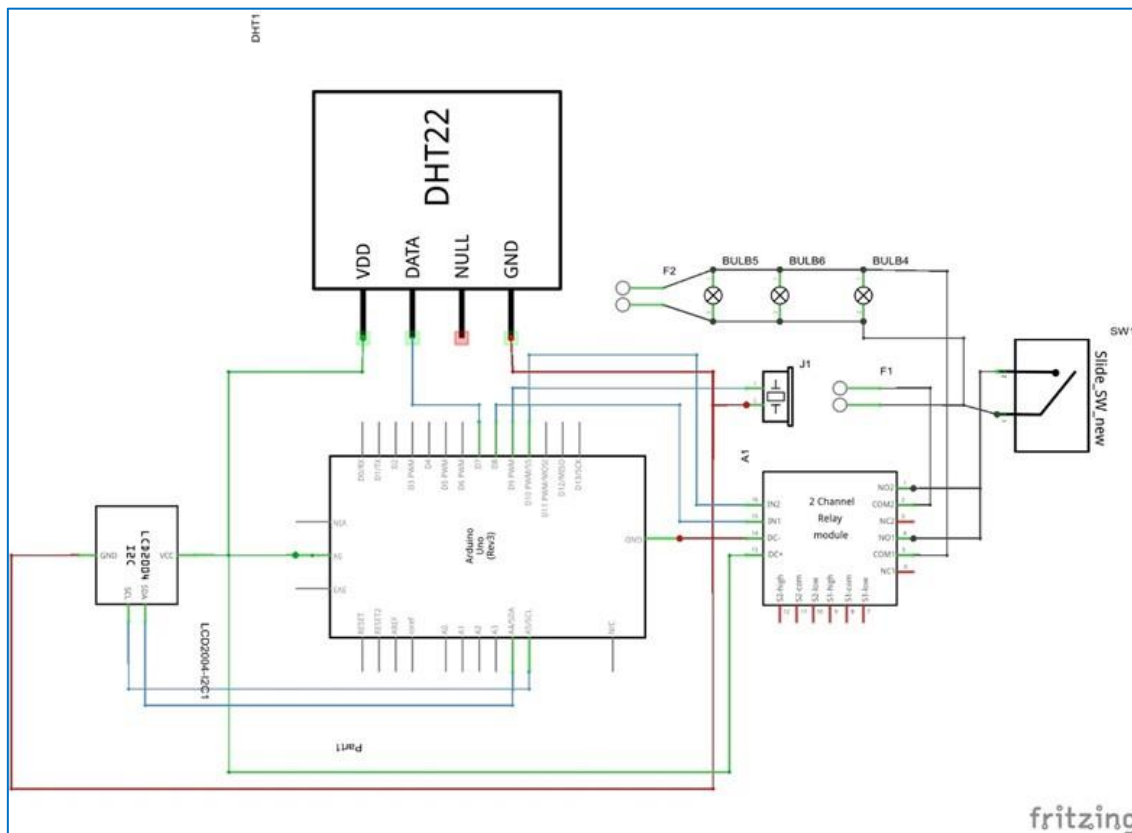


Figure 1. Schematic Diagram

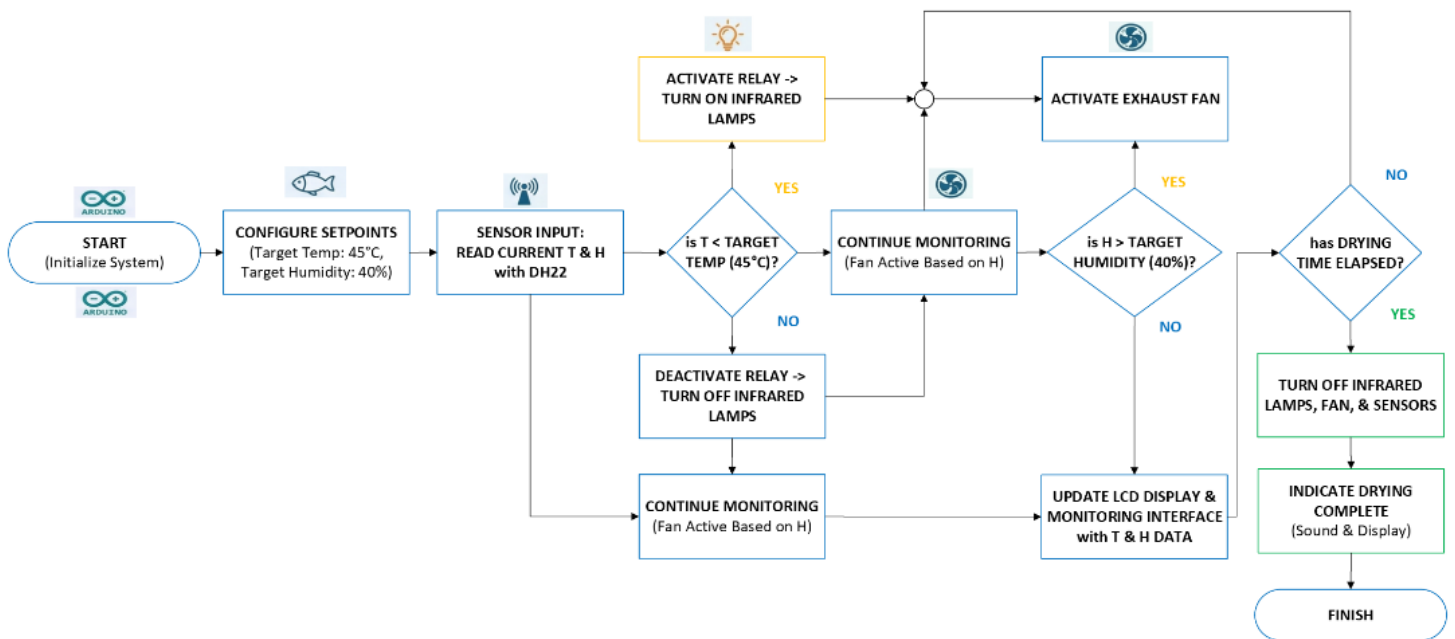


Figure 2. Operational Flowchart of the Automated Fish Drying System

After extensive planning, data gathering, and following the Incremental Prototyping model which involves breaking down the development process of the system into small, manageable steps. The goal of each iteration is to add new functionalities step-by-step based on the project specifications [15], an automated fish dryer, was finished. This prototype represents the successful integration of various components and technologies, meticulously designed and tested to ensure optimal performance in the drying process. Arduino IDE was used to develop the code, and Fritzing was used to design a detailed schematic and circuit diagram which ensures accuracy and clarity in the wiring connections and electrical layouts. The physical realization of this design is shown in Figure 3, highlighting the metallic drying chamber and external control unit.

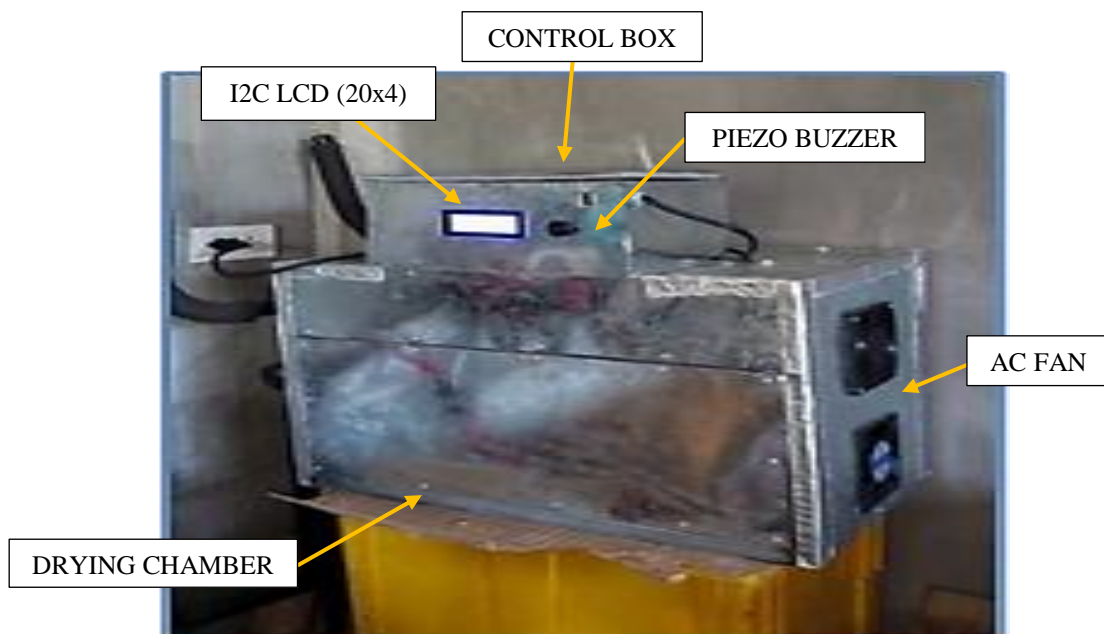


Figure 3. Actual Prototype

Table 4. System Testing and Functional Validation Metrics

Action/Condition	Expected Results	Status
Temperature falls below 45°C	Heating lamps and air circulation fans are activated (Relay Channel 1)	Pass
Temperature exceeds 45°C	Only the exhaust fan is activated (Relay Channel 2) to prevent overheating	Pass
Humidity falls below 40%	The system triggers an alarm or buzzer signifying then shuts down and completes.	Pass
Sensor Accuracy	DHT22 maintains data consistency across 5-hour continuous trial.	Pass
Safety Cut-off	Piezo buzzer activates upon completion to signal cycle termination	Pass

### 2.3 Testing and Evaluation

To ensure the functional suitability, performance efficiency, and reliability of the critical components, comprehensive testing was performed, and the system was evaluated using a scientific framework based on the ISO 25010 Software and Product Quality Model. The temperature control unit, dryer chamber, actuators unit, and power supply unit were not only individually tested but also subjected to rigorous integration testing to verify their collective operation within the system. After completing unit and integration testing, the process moved to system testing, which is one of the most crucial phases. System testing assesses the overall functionality of the prototype, ensuring that all components work together seamlessly to measure the system's precision in maintaining the 45°C indicator. A test case for system testing of the prototype is shown in Table 4 to validate the system's operational logic against established scientific parameters.

## 3. Results and Discussions

This section involves a comprehensive analysis of the data gathered and results obtained from the unit testing, integration testing, and prototype testing. This study follows different test procedures to ensure the functionality, performance, and reliability of the developed prototype. This helps the study to ensure that components work together smoothly which helps to verify each component's correctness and integration.

### 3.1 Results

The results confirm its compatibility with the pins and Arduino IDE program, and its ability to effectively receive, process, and execute the uploaded sketch code. This verifies the functionality and reliability of the Arduino UNO R3 for its intended application within the Automated Fish Drying System.

#### 3.1.1 Sensor Accuracy and Thermal Baseline

Trials were conducted which are used to evaluate the performance of the DHT22 sensor that helps in determining the functionality. The responsiveness to changes in temperature and humidity was tested by applying the sensor to different environmental conditions. Table 5 shows that the average temperature and humidity of the sensor when it was placed in an open environment and while inside the chamber, the average temperature and humidity was 36.30°C/59.52%. This baseline was chosen to verify that the infrared lamps could consistently raise the internal temperature from room levels (avg. 27.56°C) to the lower bound of the optimal drying range required for the system to function effectively.

Table 5. DHT22 Testing Result

Trials	Room Temperature (°C/Humidity %)	Within The Chamber (°C/Humidity %)	Cool down time (minutes)
1	27.50°C/70.30%	35.80°C/ 60.00%	2:00
2	27.80°C/71.10%	36.00°C/59.80%	1:55
3	27.40°C/71.00%	36.20°C/59.60%	2:05
4	27.60°C/70.80%	36.50°C/59.30%	2:13
5	27.50°C/70.60%	37.00°C/58.90%	2:02
Average	27.56°C/70.76%	36.30°C/59.52%	

Table 6. Comparative Experimental Results at Different Temperatures

Trials	Temperature Setpoint	Initial Weight	Final Weight	Drying Duration
1	40°C	10.0 kg	2.6 kg	4.15 hours
2	45°C	10.0 kg	2.5 kg	3.51 hours
3	50°C	10.0 kg	2.5 kg	3.20 hours

Table 7. Comparison of the Drying Time Traditional, Other Studies, and Developed Prototype

	Traditional Method [9]	Automated machine using fuzzy logic [12]	Developed Prototype
Drying Time	8 hours minimum (small fish)	4.48 hours	3.51 hours

### 3.1.2 Empirical Drying Performance

To provide a more measurable assessment of the system's efficiency, a series of experiments were conducted at varying temperature setpoints: 40°C, 45°C, and 50°C. These trials aimed to determine the correlation between thermal intensity and the rate of moisture removal in a controlled 10kg batch of fish. The results, summarized in Table 6, demonstrate that while 50°C achieves the fastest drying time (3.2 hours), the 45°C indicator remains the optimal setpoint as it balances speed with the prevention of muscle protein degradation. This comparative data confirms that the infrared-assisted system provides a 21.6% increase in heating efficiency compared to fuzzy logic-based air dryers.

## 3.2 Discussions

Following the system testing of the prototype, an end-user acceptance test is employed to validate the functionality, effectiveness, and efficiency of the system. Different test scenario was carefully designed to evaluate specific functions, ensuring the dryer meets user needs. The result shows that the dryer functions smoothly, maintains optimal conditions, and displays important information accurately. This testing assures users that the Automated Fish Dryer meets functionality standards and delivers reliable performance. The system also minimized the drying time compared to traditional and other automated fish drying machines as shown in Table 7. After the end-user acceptance testing, a post-evaluation survey was conducted, stakeholders were asked to evaluate the system in terms of functionality, effectiveness, and efficiency.

### 3.2.1 Analysis of Temperature Regulation

The system is programmed to maintain a target temperature of 45°C. This threshold is scientifically significant because while higher temperatures accelerate moisture removal, levels exceeding 50°C risk cooking the fish muscle and degrading the final product quality. By regulating the environment between 40°C and 50°C, the prototype ensures uniform drying and prevents "case hardening," where the fish's exterior dries too quickly and traps moisture inside.

### 3.2.2 Comparative Performance and New Findings

A key finding of this research is that the developed prototype achieved a drying time of 3.51 hours. This is not only significantly faster than the 8-hour minimum required by traditional sun-drying but also represents a 21.6% improvement over previous automated designs using fuzzy logic (4.48 hours). This indicates that the specific combination of infrared heating and Arduino-based real-time feedback loop provides a more responsive drying environment than earlier models.

## 4. Conclusion

Automating the method for fish drying improves the quality and production of dried fish products. This study resolves several challenges faced by traditional methods. To address those issues, this study proposed an automated fish drying system that can monitor, control, and produce dried fish products. This study used a systematic and incremental approach to develop a fully functional system. The developed prototype powered by Arduino UNO R3 used a DHT22 temperature-humidity sensor and a 2-channel Relay module as a central foundation to perform real-time control and monitoring in the system. Actuators such as infrared heating lamps and fans act as heat and air regulators. The automated fish drying system was able to minimize the drying time compared to the traditional method. The system was evaluated by the

stakeholders with an average of 4.4 (Strongly Agree) functionality, 4.16 (Strongly Agree) efficiency, and 4.4 (Strongly Agree) effectiveness. The overall result is 4.32 (Strongly Agree) which indicates that the system successfully achieved the desired outcome and met the user expectations. Future works are recommended to enhance monitoring features and increase the scale of the type of fish that can be produced to further improve the capabilities of the system.

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