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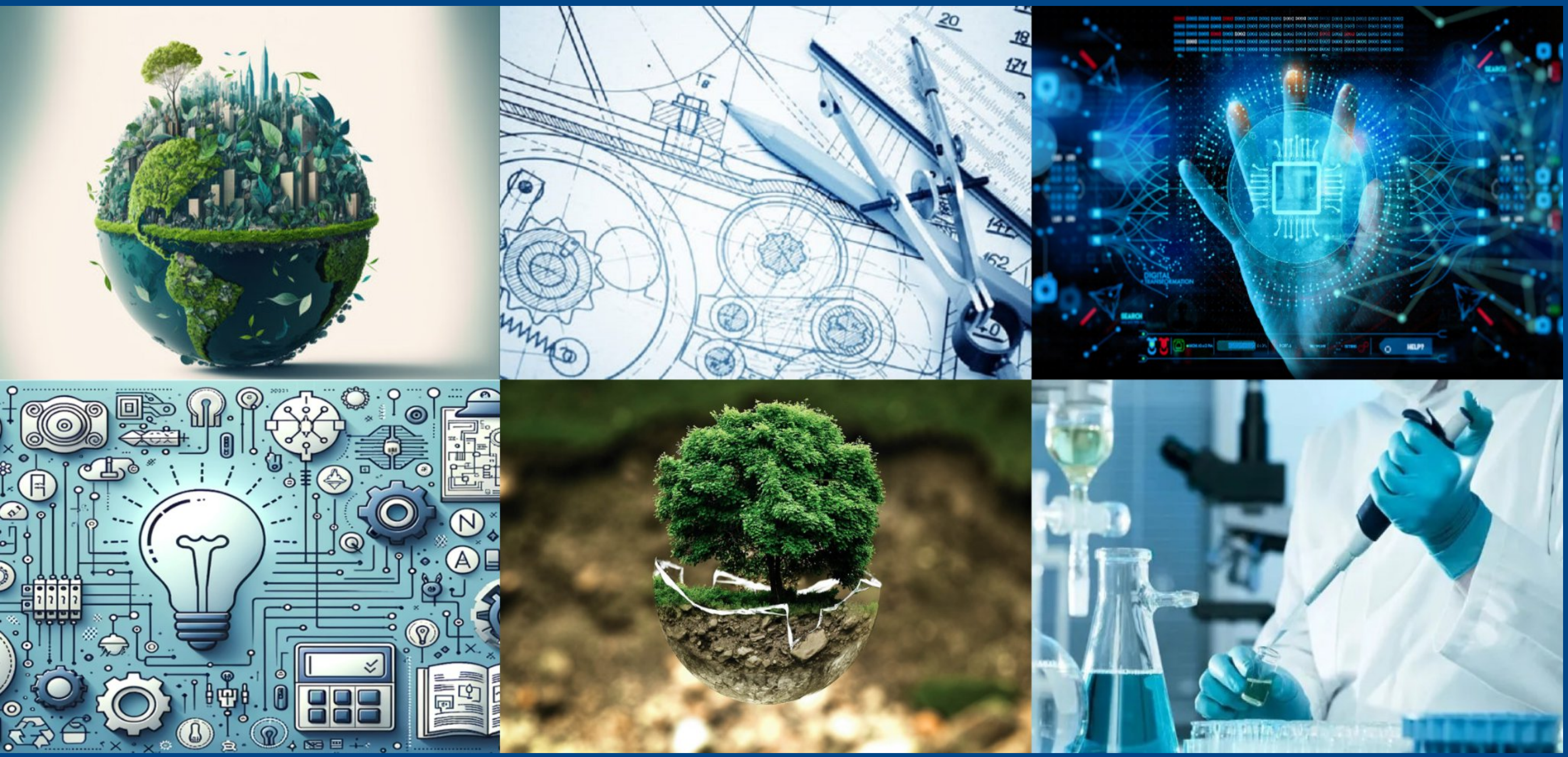

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www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

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Smart Temperature Controller for Real-Time Food Drying With Webserver Live Updates

A. Kameswaran, A. Gnanaprakash, T. Ajay, A. Manikandan, S. Paramaguru

Department of ECE, M.P.NachimuthuM.Jaganathan Engineering College, Erode, Tamil Nadu India

ABSTRACT: Food preservation is an essential process in maintaining food quality, extending shelf life and reducing post-harvest losses. Among various preservation techniques, drying is one of the oldest and most widely used methods. However, traditional drying methods such as open sun drying and conventional electric dryers suffer from several limitations including inconsistent temperature control, contamination risk, nutrient degradation and lack of real-time monitoring. To overcome these challenges, this project presents the design and implementation of a **Smart Temperature Controller for Real-Time Food Drying with Webserver Live updates. The** proposed system integrates embedded system technology with Internet of Things (IoT) capabilities to provide precise temperature regulation inside a controlled drying chamber.

A temperature sensor continuously monitors the internal chamber temperature and sends real-time data to the microcontroller. The controller processes the data and automatically regulates the heating element through a relay mechanism to maintain the desired set temperature. This closed-loop control mechanism ensures uniform moisture removal, improved drying efficiency and enhanced product quality.In addition to automated temperature control, the system incorporates Wi-Fi connectivity to enable real-time data transmission to a webserver. The developed system is energy-efficient, cost-effective and suitable for small-scale food processing units, agricultural applications and household food preservation. Experimental results demonstrate stable temperature maintenance with minimal deviation and improved drying consistency compared to conventional methods. The project highlights the practical implementation of automation and IoT technologies in food processing, offering a scalable and future-ready solution for smart agricultural and food preservation systems.

I. INTRODUCTION THE SMART TEMPERATURE CONTROLLER FOR REAL-TIME FOOD DRYING

Food preservation is a critical aspect of human civilization, enabling the storage and consumption of food over extended periods without significant deterioration in quality. Among various preservation techniques, drying is one of the oldest and most widely used methods.

It works by removing moisture from food materials, thereby inhibiting the growth of microorganisms and enzymatic activities that cause spoilage. Drying is extensively used in agriculture, food processing industries, herbal medicine production and emergency food preparation systems.

Traditional drying methods, such as sun drying and open-air drying, are still commonly used, especially in rural and small-scale applications. While these methods are cost-effective and simple, they suffer from several limitations. Environmental factors such as fluctuating temperature, humidity, dust, insects and contamination can adversely affect the quality of dried products. Moreover, the lack of control over drying conditions often leads to uneven drying, loss of nutrients, poor texture and reduced shelf life. These challenges highlight the need for a more efficient and controlled drying system.

With advancements in technology, modern drying techniques have been developed to overcome these limitations. Controlled drying systems use heaters, sensors and automated controllers to regulate environmental conditions such as temperature and airflow. However, many existing systems are either expensive, complex or lack real-time monitoring capabilities. Small-scale industries and farmers often find it difficult to adopt such systems due to cost constraints and lack of accessibility.

In this context, the development of a Smart Temperature Controller for Real-Time Food Drying with Web Server Live updatespresents an innovative and practical solution. This system integrates temperature sensing, automated control and

Internet of Things (IoT) technology to provide a reliable and efficient drying process. The primary goal is to maintain optimal drying conditions while allowing users to monitor and control the system remotely.

The proposed system consists of temperature sensors that continuously measure the internal conditions of the drying chamber. These sensors provide real-time data to a microcontroller, which acts as the brain of the system. Based on the input data, the controller regulates the heating element to maintain a predefined temperature range. This ensures uniform drying and prevents overheating or under-drying of food materials.

One of the key features of this system is its web server integration. The collected data is transmitted to an online platform, where it is displayed in real-time. Users can access this information through a web interface using smartphones, tablets or computers. This remote monitoring capability allows users to track the drying process from anywhere, reducing the need for constant physical supervision. In addition, alerts and notifications can be incorporated to inform users about critical conditions, further enhancing system reliability.

The smart temperature controller also improves energy efficiency by optimizing the operation of the heating element. Instead of running continuously, the system activates the heater only when necessary, based on real-time temperature readings. This reduces power consumption and operational costs, making the system economically viable for small-scale users. Furthermore, the automation of the drying process minimizes human intervention, reducing labor requirements and improving consistency.

This system has a wide range of applications across various sectors. In agriculture, farmers can use it to dry fruits, vegetables, grains and spices, thereby reducing post-harvest losses and increasing profitability. Small food processing industries can benefit from improved product quality and standardized production processes. Herbal and Ayurvedic companies require precise drying conditions to preserve the medicinal properties of plants, making this system highly suitable for their needs. Additionally, in military and emergency scenarios, where reliable and long-lasting food supplies are essential, this system can play a crucial role in food preparation and preservation.

Another important advantage of the proposed system is its scalability and adaptability. It can be customized based on specific requirements, such as different temperature ranges for various food products. The system can also be expanded by incorporating additional sensors, such as humidity sensors, to further enhance control over the drying process. Future enhancements may include machine learning algorithms for predictive control and optimization, making the system even more intelligent and efficient.

The integration of IoT technology not only enhances monitoring and control but also enables data analysis and record-keeping. Historical data can be stored and analyzed to identify patterns, optimize drying cycles and improve overall performance. This data-driven approach can help users make informed decisions and continuously improve their operations.

In addition to technical benefits, the system also contributes to sustainability. By reducing energy consumption and minimizing food wastage, it supports environmentally friendly practices. Efficient drying methods can significantly reduce losses in agricultural produce, which is a major concern in many developing regions. This aligns with global efforts to promote sustainable agriculture and food security.

Despite its advantages, the implementation of such a system requires careful design and calibration. Factors such as sensor accuracy, system responsiveness and environmental conditions must be considered to ensure optimal performance. Proper insulation of the drying chamber and efficient airflow management are also important to achieve uniform drying results.

In conclusion, the Smart Temperature Controller for Real-Time Food Drying with Web Server Live updatesrepresents a significant advancement in food drying technology. By combining automation, real-time monitoring and IoT connectivity, it addresses the limitations of traditional drying methods and provides a cost-effective and efficient solution. Its wide range of applications, energy efficiency and scalability make it a valuable tool for modern agriculture and food processing industries. As technology continues to evolve, such smart systems will play an increasingly important role in improving food preservation, reducing waste and enhancing overall productivity.

II. BACKGROUND AND LITERATURE SURVEY

BACKGROUND

Food preservation is essential for extending shelf life, reducing post-harvest losses and ensuring food availability throughout the year. Among various preservation methods, drying is one of the oldest and most widely used techniques. It works by removing moisture from food products, thereby preventing microbial growth and slowing down chemical reactions that cause spoilage.Traditional drying methods, such as sun drying, are still commonly used in agriculture and rural areas.

These methods are simple and cost-effective but have several drawbacks. They depend heavily on weather conditions and are prone to contamination from dust, insects and environmental pollutants. In addition, the lack of control over temperature and humidity often leads to uneven drying, poor quality and nutrient loss.

To overcome these limitations, artificial drying systems have been developed. These systems use controlled heat sources and enclosed chambers to provide a stable drying environment. While they offer better performance compared to traditional methods, many of them lack automation and require manual monitoring. This increases the chances of human error and reduces efficiency.

With advancements in embedded systems and Internet of Things (IoT) technology, smart drying systems have emerged as a promising solution. These systems use sensors to monitor parameters such as temperature and humidity and controllers to regulate the drying process automatically. IoT integration further enables real-time monitoring and remote access, making the system more efficient and user-friendly.

The development of a Smart Temperature Controller for Real-Time Food Drying with Web Server Live updatesis motivated by the need for a cost-effective, reliable and automated drying solution Such a system can provide precise control over drying conditions, improve product quality and reduce energy consumption.

III. LITERATURE SURVEY

a. Traditional and Solar Drying Methods

Initial research in food drying focused on improving traditional methods such as open sun drying and solar drying. Solar dryers were developed to provide better protection from environmental contamination and to improve drying efficiency. These systems use solar energy to heat air, which is then circulated through the food material.

Although solar dryers are more efficient than open drying, they still depend on weather conditions and lack precise control over temperature and humidity. This limits their effectiveness, especially in regions with inconsistent sunlight.

b.Temperature-Controlled Drying Systems

To achieve better control, electrically heated drying systems were introduced. These systems use heaters along with thermostats or microcontrollers to maintain a constant temperature inside the drying chamber. Research shows that controlled temperature drying improves product quality by preserving color, texture and nutrients.

microcontroller-based systems have become popular due to their flexibility and low cost. They allow automatic regulation of temperature based on sensor input. However, many of these systems are limited to local control and do not provide real-time monitoring or remote access.

c.Sensor-Based and Smart Drying Systems

Recent developments have focused on integrating sensors into drying systems. Temperature sensors and humidity sensors provide continuous feedback, enabling precise control of the drying process. The controller adjusts the heating element based on real-time data, ensuring consistent drying conditions.These smart systems reduce manual intervention and improve efficiency. They also help prevent overheating and under-drying, which can affect product quality. However, most sensor-based systems still operate independently without connectivity to external monitoring platforms.

d.IoT-Based Drying Systems

The introduction of IoT technology has significantly enhanced drying systems. IoT-enabled systems use wireless communication modules to transmit data to web servers or mobile applications. This allows users to monitor the drying process remotely in real time.

Research shows that IoT-based systems improve operational efficiency by providing live updates, alerts and data logging features. Users can track temperature variations, analyze historical data and optimize drying conditions. These systems are especially useful in industrial and large-scale applications.Despite these advantages, challenges such as system cost, network dependency and complexity need to be addressed to make these solutions accessible to small-scale users.

e.Research Gaps

From the literature review, several gaps can be identified

- Lack of integrated systems combining temperature control and real-time web monitoring
- Limited availability of cost-effective solutions for small-scale industries
- Insufficient user-friendly interfaces for easy operation
- Need for improved energy-efficient designs

The proposed system aims to address these gaps by providing an affordable, automated and IoT-enabled temperature-controlled drying solution with web server live updates.

Table 1 Summary of literature survey

Feature	**Description**
Core Objective	To design and implement an automated temperature control system that ensures optimal drying conditions for food products while providing remote monitoring via a web interface.
Technological Stack	Utilizes an **MCU (like ESP32/Arduino)** for logic, **DHT22/DS18B20** for precision sensing and **Relay modules** to toggle heating elements. IoT integration is achieved through **WebSockets or MQTT** for live data streaming.
Problem Solved	Eliminates the risk of "case hardening" (surface drying too fast) or microbial growth due to under-drying by maintaining a constant, user-defined thermal environment.
Key Innovation	The shift from "offline" drying to **“Data logging and Graphical Analysis”**, allowing users to monitor humidity and temperature trends from any location, reducing manual labor and wastage.

f.Summary

The evolution of food drying systems shows a transition from traditional methods to advanced smart and IoT-based solutions. While modern systems offer improved performance and control, there is still a need for affordable and user-friendly designs that can be widely adopted.

The proposed smart temperature controller system combines automation, sensor-based control and real-time web monitoring to provide an efficient and reliable drying solution. It is suitable for applications in agriculture, food processing, herbal industries and emergency food preparation, making it a valuable contribution to modern food preservation technology.

IV. PROPOSED METHOD

The proposed system, Smart Temperature Controller for Real-Time Food Drying with Web Server Live Updation, is designed to provide an efficient, automated and controlled environment for drying food products. The system integrates temperature sensing, microcontroller-based control, heating mechanisms and IoT-based web monitoring to ensure optimal drying conditions.

The main objective of this method is to maintain a consistent temperature within the drying chamber while allowing users to monitor the process in real time through a web interface. This approach improves drying efficiency, reduces human intervention and ensures better quality of dried products is shown in fig.1.

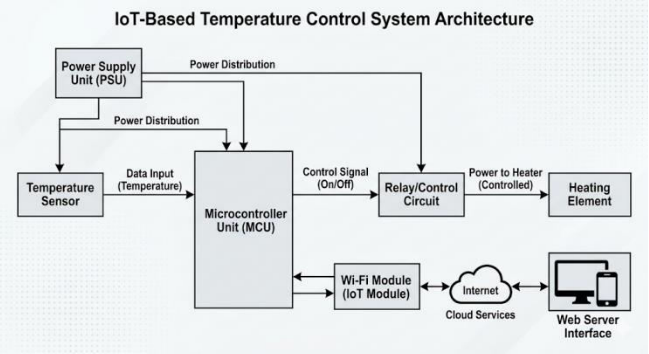

Fig. 1 Architecture of the Proposed System

The temperature sensor continuously measures the internal temperature of the drying chamber. This data is sent to the microcontroller, which processes the input and compares it with the predefined temperature setpoint. Based on this comparison, the controller activates or deactivates the heating element using a relay circuit.

At the same time, the system transmits real-time data to a web server using a Wi-Fi module. The user can access this data remotely through a web browser, enabling live monitoring and control of the drying process.

Working Principle

The working of the proposed system can be explained in the following steps:

Step 1: Temperature Sensing
A temperature sensor (such as LM35 or DHT series) is placed inside the drying chamber. It continuously measures the temperature and converts it into an electrical signal.

Step 2: Data Processing
The sensed temperature data is sent to the microcontroller (such as Arduino or ESP-based controller). The controller reads the data and compares it with the preset temperature value required for drying.

Step 3: Temperature Control
If the measured temperature is lower than the desired setpoint, the microcontroller activates the heating element through a relay. If the temperature exceeds the setpoint, the heater is turned off. This process maintains a stable temperature within the chamber.

Step 4: Real-Time Data Transmission
The system uses a Wi-Fi module to send temperature data to a web server. This allows real-time updates of the drying process.

Step 5: Web Monitoring
The web interface displays parameters such as current temperature, system status (heater ON/OFF) and drying progress. Users can access this interface remotely using smartphones or computers.

Step 6: Continuous Feedback Loop
The system continuously monitors temperature and updates the control actions, forming a closed-loop control system. This ensures consistent drying conditions throughout the process.

Control Strategy
The proposed system uses a simple feedback control mechanism. The microcontroller continuously compares the actual temperature with the desired setpoint and adjusts the heating element accordingly.

If Temperature < Setpoint → Heater ON
If Temperature ≥ Setpoint → Heater OFF

This ON/OFF control method is simple, cost-effective and suitable for small-scale applications. It ensures that the temperature remains within a safe and effective range for drying.

For future improvements, advanced control techniques such as PID (Proportional-Integral-Derivative) control can be implemented to achieve more precise temperature regulation.

IoT and Web Server Integration
A key feature of the proposed method is the integration of IoT technology. The system uses a Wi-Fi-enabled microcontroller or external module to connect to the internet.

- Data is transmitted to a web server in real time.
- The server stores and displays the data.
- Users can monitor the system remotely.
- Alerts can be generated for abnormal conditions.

The web interface is designed to be user-friendly, displaying essential parameters in a clear and simple format. This feature reduces the need for physical presence and allows better management of the drying process.

Advantages of Proposed Method
The proposed method offers several advantages:

- Automation: Reduces manual intervention and human error
- Real-Time Monitoring: Enables remote tracking through web interface
- Improved Product Quality: Maintains uniform drying conditions
- Energy Efficiency: Heater operates only when required
- Cost-Effective: Suitable for small-scale industries and farmers
- Scalability: Can be expanded with additional sensors and features

Applications
The proposed system can be used in various fields:
- Agriculture (drying fruits, vegetables, grains, spices)

- Small-scale food processing industries
- Herbal and Ayurvedic product drying
- Military and emergency food preparation
- Domestic food preservation systems

The proposed method presents a smart and efficient approach to food drying by combining temperature control, automation and IoT-based monitoring. The system ensures optimal drying conditions, improves product quality and reduces energy consumption.

By integrating real-time web updates, the system provides greater flexibility and convenience to users. Overall, this method offers a practical and modern solution to the limitations of traditional drying techniques and can be widely adopted across various sectors.

V. SIMULATION OUTCOMES AND DESIGN CALCULATION

Simulation plays an important role in validating the performance of the proposed Smart Temperature Controller for Real-Time Food Drying System before practical implementation.

It helps in analyzing system behavior under different conditions, verifying control logic and ensuring proper operation of components such as sensors, microcontroller and heating elements.

In this project, the simulation focuses on temperature sensing, control response, heater operation and real-time data flow. The results obtained from simulation confirm the effectiveness of the system in maintaining desired temperature levels and providing stable drying conditions.

Simulation Setup

The system is simulated using microcontroller simulation tools (such as Proteus or similar platforms). The following components are included in the simulation model:

- Temperature sensor (LM35/DHT11 equivalent)
- microcontroller (Arduino/ESP-based)
- Relay module (for heater control)
- Heating element (represented using a load or bulb)
- Display/serial monitor (for output visualization)

The temperature sensor provides input to the microcontroller, which processes the data and controls the heater through the relay. The system is programmed with a predefined temperature setpoint (e.g., 50°C–60°C suitable for food drying).

Simulation Outcomes

1.Temperature Monitoring

The simulation shows that the temperature sensor continuously reads the chamber temperature and sends accurate data to the controller. The readings are updated in real time and displayed on the output interface.

- Initial temperature: 30°C (room temperature)
- Desired setpoint: 55°C
- Temperature increases gradually when heater is ON

This demonstrates proper sensor operation and real-time data acquisition.

2.Heater Control Response

The microcontroller successfully controls the heater based on the setpoint value:

- When temperature is below 55° C → Heater turns ON
- When temperature reaches or exceeds 55° C → Heater turns OFF

This ON/OFF control mechanism maintains the temperature within a desired range, preventing overheating.
The simulation confirms that the system behaves as a closed-loop control system with continuous feedback.

3.Stability and Accuracy

The system maintains temperature within a small range around the setpoint (±2° C). This ensures stable drying conditions and avoids fluctuations that may affect food quality.

- Minimum fluctuation observed
- No sudden spikes or drops in temperature
- Consistent control action

This indicates that the proposed method is reliable for maintaining uniform drying conditions.

4.Response Time

The time required to reach the desired temperature depends on the heating element capacity. In the simulation:

- Time to reach 55° C ≈ 3–5 minutes (depending on assumed heater power)

The system responds quickly to temperature changes and adjusts the heater status accordingly.

5.IoT Data Simulation (Conceptual)

Although full web integration may not be simulated in all tools, the data transmission process is verified conceptually:

- Temperature values are sent periodically
- Data can be displayed on a web dashboard
- Real-time updates are achievable

This ensures that the system supports remote monitoring functionality.

6.Design Calculations

a.Temperature Sensor Calculation

For LM35 sensor:

- Output voltage = 10 mV/° C
- At 50° C → Output = 50 × 10 mV = 500 mV
- At 60° C → Output = 600 mV

The microcontroller converts this analog voltage into digital values using an ADC.

b.ADC Conversion

For a 10-bit ADC (Arduino):

- Resolution = 1024 levels (0–1023)
- Reference voltage = 5 V

Formula:Temperature= (ADC Value x 5 x 100) / 1024

c.Heater Power Calculation

Power required for heating depends on the drying chamber size and temperature rise.

Formula:

Where:

- Heat energy (Joules)
- Mass of air (kg)
- Specific heat capacity of air (~1005 J/kg·° C)

Assume:

- Chamber air mass = 1 kg
- Temperature rise = 25° C

Q=1 x 1005 x 25 = 25125J

If heating time = 300 seconds:

Power = Q/t = 25125 / 300 =83.75 W

Thus, a heater of approximately 100 W is sufficient for small-scale drying.

d.Relay Rating Calculation

The relay must handle the heater current:

I = P / V

For 100 W heater at 230 V:

I = 100 / 230 =0.43 A

Thus, a 5 A or 10 A relay is sufficient for safe operation.

e.Efficiency Consideration

Efficiency depends on heat losses:

- Heat loss through chamber walls
- Air leakage
- Insulation quality

Efficiency can be improved using proper insulation and controlled airflow.
The simulation results demonstrate that the proposed system effectively maintains the desired temperature using a feedback control mechanism. The heater responds accurately to sensor input, ensuring stable and uniform drying conditions.

Design calculations confirm that the system components, including sensor, heater and relay, are properly selected for efficient operation. The integration of IoT further enhances the system by enabling real-time monitoring and control.
Overall, the simulation validates the feasibility, reliability and effectiveness of the proposed smart temperature-controlled food drying system.

VI. CONCLUSION AND FUTURE SCOPE

The project Smart Temperature Controller for Real-Time Food Drying with Web Server Live updates presents an effective solution to improve traditional food drying methods by incorporating automation and modern technology. The system successfully maintains the desired temperature inside the drying chamber using a sensor-based feedback mechanism and a microcontroller. This ensures uniform drying, better product quality and reduced chances of overheating or under-drying.

One of the major advantages of the system is its ability to provide real-time monitoring through a web server. Users can track temperature and system status remotely, which reduces manual effort and improves convenience. The system is also energy-efficient, as the heater operates only when required. Its simple design and low cost make it suitable for farmers, small-scale industries and other applications such as herbal product drying and emergency food preparation. Overall, the project demonstrates how IoT and embedded systems can enhance efficiency, reliability and control in food preservation processes.

Looking ahead, there is significant scope for further improvement. The current ON/OFF control method can be upgraded to advanced techniques like PID control for more accurate and stable temperature regulation. Additional sensors such as humidity and moisture sensors can be integrated to achieve better control over the drying process. The system can also be enhanced by developing a dedicated mobile application with real-time alerts and remote control features.

Future versions may include cloud storage and data analytics to monitor historical performance and optimize drying conditions. The use of renewable energy sources such as solar power can further improve energy efficiency and make the system more sustainable. Moreover, the design can be scaled up for industrial applications by increasing capacity and incorporating advanced safety features like automatic shutdown and over-temperature protection.

In conclusion, the proposed system provides a reliable and cost-effective approach to modern food drying and with further enhancements, it has the potential to become a highly efficient and widely adopted solution in various sectors.

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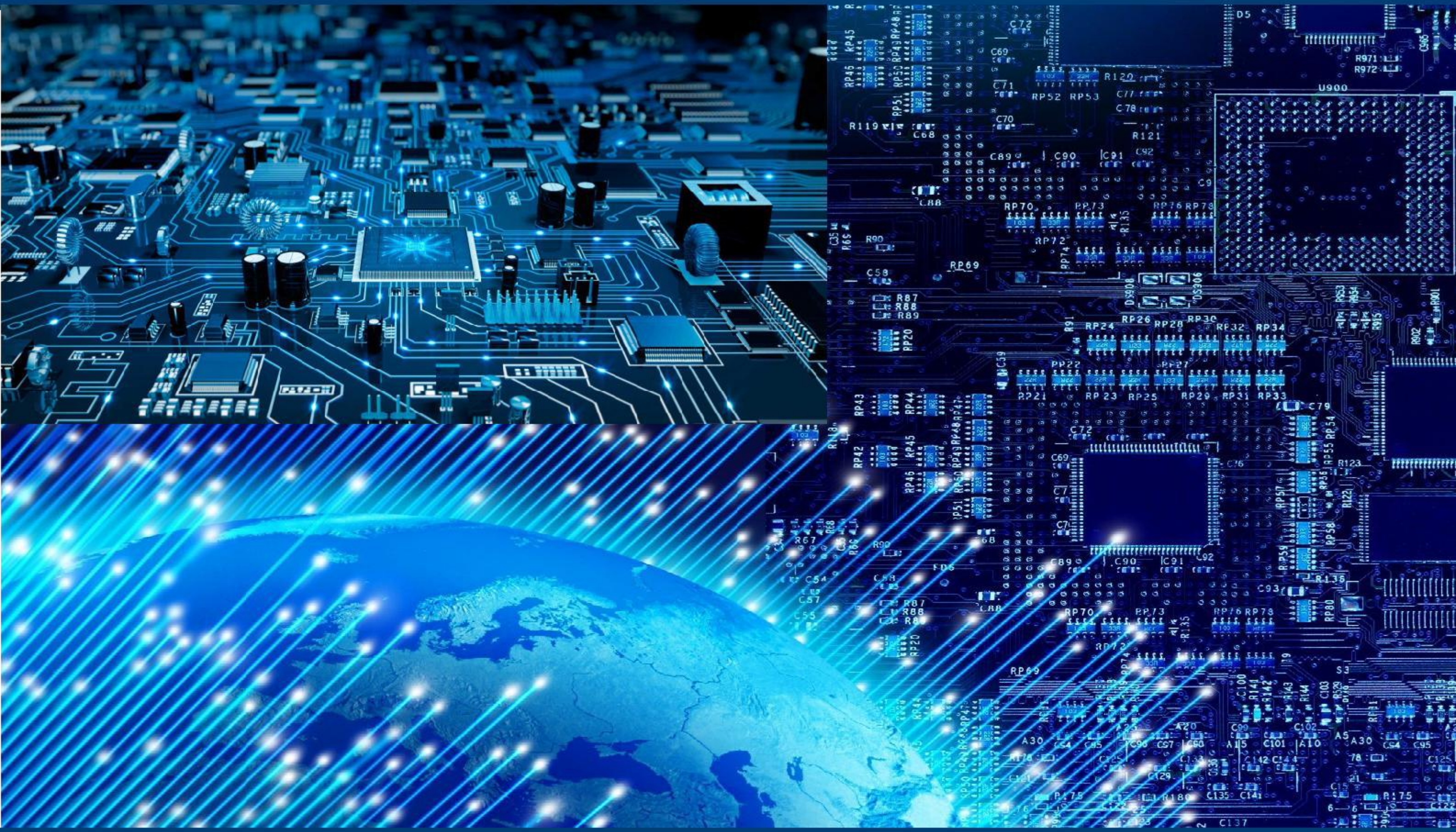

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