A Review Paper on Automated Solar Food Dryer

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***Abstract*— Food preservation plays a vital role in the agricultural and food processing sectors by reducing post-harvest wastage and increasing the storage life of food products. Conventional open-sun drying is commonly practiced due to its low cost and simple operation; however, it has several disadvantages including contamination, non-uniform drying, dependence on climatic conditions, nutrient loss, and extended drying periods. To address these issues, advanced solar drying systems integrated with automation and intelligent control technologies have been developed by researchers. This review paper provides an in-depth analysis of Automated Solar Food Dryer (ASFD) systems that utilize renewable solar energy along with IoT-based technologies, sensor monitoring, and automated control mechanisms. Various categories of solar dryers such as direct, indirect, hybrid, and photovoltaic-assisted dryers are examined in detail. The study also discusses recent developments in automation technologies involving ESP32, Arduino, NodeMCU, temperature and humidity sensors, as well as mobile-based monitoring applications. The review emphasizes the operational principles, benefits, challenges, and future opportunities of automated solar drying technologies. Automated solar dryers have demonstrated improved drying performance, enhanced food safety and hygiene, better product quality, and efficient energy utilization while minimizing labor requirements and operational expenses. Furthermore, emerging technologies including artificial intelligence, cloud-based monitoring, and smart moisture management systems are expected to significantly enhance the efficiency and reliability of future solar drying applications in agriculture and food preservation sectors.**

***Index Terms*— Automated Solar Food Dryer, Solar Energy, Renewable Energy, IoT, ESP32, Smart Drying System, Food Preservation.**

I. INTRODUCTION

Drying is one of the oldest and most effective food preservation techniques used to reduce moisture content in agricultural products. Moisture removal helps prevent microbial growth, enzymatic reactions, and spoilage, thereby increasing storage life and maintaining food quality. Traditionally, food products such as fruits, vegetables, grains, spices, fish, and herbs are dried under direct sunlight.

Although open-sun drying is economical and simple, it has many disadvantages. Food materials remain exposed to dust, insects, birds, rainwater, and environmental contamination. In addition, drying efficiency depends entirely on weather conditions, resulting in non-uniform moisture removal and quality degradation.

To address these issues, solar food dryers have been developed using renewable solar energy. Solar dryers provide enclosed drying environments with controlled airflow and temperature conditions. Recent advancements in automation and IoT technologies have further improved the performance of solar drying systems. Automated Solar Food Dryers integrate sensors, microcontrollers, and airflow control systems to optimize drying conditions without continuous human intervention.

This review paper focuses on the development, classification, working principles, automation techniques, applications, advantages, limitations, and future scope of automated solar food drying systems.

II. TYPES OF SOLAR FOOD DRYERS

Solar food dryers are mainly classified into the following categories:

A. Direct Solar Dryer

In direct solar dryers, food products are directly exposed to solar radiation inside an enclosed chamber.

Sunlight passes through a transparent cover and heats the food material as well as the surrounding air. These dryers are simple in construction and suitable for small-scale applications.

- *Advantages*
- Simple design
- Low manufacturing cost
- Easy operation
- *Limitations*
- Uneven drying
- Risk of overheating
- Lower drying efficiency

B. Indirect Solar Dryer

Indirect solar dryers use a separate solar collector to heat air before it enters the drying chamber. The food products are not directly exposed to sunlight, which improves product quality and nutrient retention.

- Advantages
- Better hygiene
- Improved temperature control
- Higher drying efficiency
- Better color and flavor preservation
- Limitations
- More complex construction
- Higher installation cost

III. COMPONENTS OF AUTOMATED SOLAR FOOD DRYER

An automated solar food dryer generally consists of the following components:

1. Solar Collector

The solar collector absorbs solar radiation and converts it into thermal energy used for air heating.

2. Drying Chamber

The drying chamber contains trays where food materials are placed for dehydration.

3. ESP32 / Arduino Controller

Microcontrollers are used to process sensor data and automate system operation.

4. Temperature and Humidity Sensors

Sensors continuously monitor internal drying conditions and provide real-time feedback.

5. DC Fan

Fans maintain forced air circulation for uniform drying and moisture removal.

6. LCD Display

The display unit shows temperature, humidity, and operational status.

7. Battery and Power Supply

Battery systems store solar energy and ensure uninterrupted operation.

IV. AUTOMATION IN SOLAR FOOD DRYERS

Automation plays an important role in improving solar drying efficiency and reducing manual supervision. Modern automated solar dryers use microcontrollers and sensors to monitor and regulate drying conditions automatically.

A. Sensor-Based Monitoring

Temperature and humidity sensors continuously monitor environmental conditions inside the drying chamber.

B. Automatic Fan Control

The controller automatically switches the fan ON or OFF depending on temperature and humidity values.

C. IoT-Based Monitoring

IoT-enabled systems transmit real-time data to cloud platforms or mobile applications for remote monitoring.

D. Smart Control Systems

Advanced systems use artificial intelligence and machine learning algorithms to optimize drying parameters dynamically.

V. LITERATURE REVIEW

Several researchers have contributed significantly to the development of automated solar drying systems.

[1] Fernandes et al. developed an indirect solar food dryer using recycled materials and Arduino-based monitoring systems. Their work focused on reducing energy consumption and improving sustainability.

[2] Patil et al. proposed an IoT-based solar banana dryer equipped with humidity and temperature monitoring systems connected to a web dashboard for remote observation.

[3] Nagavani et al. introduced a smart solar dryer integrated with NodeMCU and mobile application technology. Their system enabled real-time monitoring and automated fan control.

[4] Metwally et al. conducted mathematical and environmental analysis of an automatic solar dryer for drying dates and demonstrated improved energy efficiency and reduced environmental impact.

[5] Elwakeel et al. developed a PV-operated automatic solar dryer integrated with GSM communication and automatic monitoring systems for agricultural drying applications.

Recent research trends indicate growing interest in AI-based optimization, cloud monitoring, smart sensors, and intelligent control systems for improving drying performance and product quality

VI. ADVANTAGES

- Utilizes renewable solar energy
- Reduces electricity consumption
- Eco-friendly and sustainable
- Improves drying efficiency
- Provides hygienic food preservation
- Reduces contamination risks
- Enhances product quality
- Minimizes labor requirements
- Suitable for rural and remote areas
- Low operational and maintenance cost

VII. LIMITATIONS

Despite their advantages, automated solar dryers also face certain limitations:

- High initial installation cost
- Dependency on solar radiation
- Requirement of technical maintenance
- Limited drying during poor weather conditions
- Complexity of automation systems

VIII. APPLICATIONS

Automated solar food dryers are widely used in:

- Fruit and vegetable drying
- Herbal product preservation
- Fish and meat dehydration
- Spice processing
- Agricultural product storage
- Small-scale food industries
- Rural household applications

IX. FUTURE SCOPE

Future developments in automated solar food drying technology may include:

1. Artificial intelligence-based drying optimization
2. Smart moisture detection systems
3. Cloud-based monitoring platforms
4. Mobile application integration
5. Hybrid solar-electric systems
6. Advanced thermal energy storage

7. Large-scale industrial drying systems
8. Fully autonomous drying control mechanisms

CONCLUSION

Automated Solar Food Dryers represent an advanced and sustainable approach for food preservation using renewable energy resources. Compared to conventional open-sun drying methods, automated dryers provide better hygiene, controlled drying conditions, improved product quality, and reduced drying duration. The integration of IoT, sensors, microcontrollers, and intelligent control systems has significantly improved drying efficiency and reduced manual effort.

The review indicates that automated solar drying technologies have strong potential for agricultural and food processing applications, especially in rural and energy-deficient regions. Continuous advancements in automation, artificial intelligence, and smart monitoring systems are expected to further enhance the performance and reliability of solar food dryers in the future.

REFERENCES

[1] L. Fernandes, J. R. Fernandes, and P. B. Tavares, “Design of a Friendly Solar Food Dryer for Domestic Over-Production,” Solar Journal, vol. 2, no. 4, pp. 495–508, 2022.

[2] P. S. Patil et al., “Development of an IoT-Based Solar Banana Dryer Monitoring and Control System,” International Journal of Mechanical Engineering, vol. 7, no. 1, pp. 4745–4752, 2022.

[3] C. Nagavani et al., “Dehydration of Food Materials Using Solar Dryer with Mobile App Integration,” Journal of Electrical Engineering and Automation, vol. 6, no. 1, pp. 72–81, 2024.

[4] K. A. Metwally et al., “Mathematical Modeling, Diffusivity, Energy and Environmental Analysis of an Automatic Solar Dryer,” Sustainability, vol. 16, no. 8, 2024.

[5] A. E. Elwakeel et al., “Development of a PV-Operated Automatic Solar Dryer for Drying Applications,” Frontiers in Sustainable Food Systems, vol. 9, 2025.

[6] “Design and Implementation of a PV-Integrated Solar Dryer Based on IoT Technology,” Journal of Food Quality, 2023