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Automated Solar Food Dryer

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Abstract— **Traditional open-sun drying methods for agricultural products suffer from several limitations such as contamination, uneven drying, dependency on weather conditions, nutrient loss, and longer drying duration. To overcome these drawbacks, an Automated Solar Food Dryer (ASFD) has been developed using renewable solar energy and automated control techniques. The proposed system utilizes solar thermal energy for heating and photovoltaic energy for powering the electronic components such as ESP32 microcontroller, DC fan, temperature sensor, and display unit. The dryer maintains controlled temperature and airflow conditions to ensure efficient and hygienic drying of food products. Temperature and humidity sensors continuously monitor the drying chamber, while the ESP32 automatically controls the fan and heating mechanism based on real-time conditions. Experimental observations indicate that the system significantly reduces drying time compared to traditional sun drying and preserves food quality, color, texture, and nutritional value. The system is eco-friendly, cost-effective, and highly suitable for rural and agricultural applications.**

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

I. INTRODUCTION

Food preservation plays an important role in agriculture and food processing industries. Drying is one of the oldest and most effective preservation methods used to reduce moisture content in food products such as fruits, vegetables, herbs, fish, and grains. Traditional open-sun drying methods are still widely used in rural areas due to their low cost and simplicity. However, these methods expose food products to contamination by dust, insects, birds, microorganisms, and unpredictable weather conditions.

The increasing demand for energy-efficient and hygienic food preservation systems has encouraged the development of solar-powered drying technologies. Solar drying uses renewable solar energy to generate heat for moisture removal. An Automated Solar Food Dryer improves conventional drying by integrating sensors, microcontrollers, and automatic control systems. The proposed system uses solar energy as the primary heat source and an ESP32 microcontroller for automation. The system continuously monitors temperature and humidity inside the drying chamber and automatically controls airflow using a DC fan. This improves drying efficiency, reduces human effort, and enhances food quality.

II. OBJECTIVES OF THE PROJECT

The main objectives of the Automated Solar Food Dryer are:

1. To utilize renewable solar energy for food drying.
2. To reduce drying time compared to traditional sun drying.
3. To provide hygienic and contamination-free drying.
4. To maintain controlled temperature and airflow.
5. To implement automation using sensors and ESP32.
6. To preserve nutritional quality and shelf life of food products.
7. To develop a low-cost and eco-friendly drying system.
8. To support rural and agricultural communities.

III. LITERATURE REVIEW

Several researchers have worked on solar food drying systems integrated with automation and IoT technologies.

Fernandes et al. developed an indirect solar food dryer using recycled materials and Arduino-based monitoring systems. Their design reduced operating costs and improved drying quality.

Pandit S. Patil et al. developed an IoT-based solar banana dryer with temperature and humidity monitoring through a web dashboard. The system achieved improved drying efficiency and better product quality.

Nagavani et al. proposed a solar dryer integrated with NodeMCU and a mobile application for monitoring drying conditions remotely. The system improved hygiene and reduced drying duration.

Recent studies also focused on AI-based and IoT-enabled smart dryers for optimizing temperature and humidity conditions. These systems demonstrate the growing importance of automation in renewable energy-based food preservation.

IV. METHODOLOGY

A. System Overview

The Automated Solar Food Dryer consists of the following major components:

- Solar Panel
- Battery
- ESP32 Microcontroller
- Temperature Sensor (DHT11)
- DC Fan
- LCD Display
- Adapter and Power Supply

The solar panel converts sunlight into electrical energy and charges the battery. The stored energy powers the electronic control system. The DHT11 sensor measures temperature and humidity inside the drying chamber and sends data to the ESP32 controller. Based on sensor readings, the ESP32 controls the fan and heating system automatically.

B. Working Principle

The system works on the principle of solar heat collection and forced air circulation.

1. Solar radiation heats the solar collector.
2. The heated air enters the drying chamber.
3. Food placed on trays loses moisture due to hot airflow.
4. The DC fan circulates air uniformly.
5. The DHT11 sensor measures temperature and humidity.
6. The ESP32 processes sensor data and controls the fan automatically.
7. Moist air exits through the exhaust vent.

This closed-loop automated system ensures efficient and uniform drying.

V. HARDWARE IMPLEMENTATION

A. ESP32 Microcontroller

ESP32 acts as the central controller of the system. It processes sensor data and controls the operation of the fan and heater.

B. DHT11 Sensor

The DHT11 sensor measures temperature and humidity inside the drying chamber.

C. DC Fan

The DC fan maintains continuous airflow for uniform drying and moisture removal.

D. Solar Panel and Battery

The solar panel generates renewable energy, while the battery stores power for uninterrupted operation.

E. LCD Display

The LCD display shows real-time temperature and humidity values.

VI. RESULTS AND DISCUSSION

The Automated Solar Food Dryer successfully achieved controlled drying conditions with improved efficiency.

Food Item	Open Sun Drying	Automated Solar Dryer
Tomato	2–3 Days	8–10 Hours
Chili	2 Days	6–8 Hours
Banana	2–3 Days	10–12 Hours

The system maintained chamber temperatures between 45°C and 65°C. Automated fan control improved airflow and moisture removal. The dryer reduced drying time by approximately 50–70% compared to traditional methods.

Advantages observed:

- Better food hygiene
- Reduced contamination
- Improved texture and color retention
- Lower operational cost
- Energy-efficient performance

VII. ADVANTAGES

- Uses renewable solar energy.
- Reduces electricity consumption.
- Provides hygienic drying conditions.
- Reduces drying time.
- Preserves food nutrients and quality.
- Low operating and maintenance cost.
- Eco-friendly and sustainable.

VIII. APPLICATIONS

- Drying fruits and vegetables.
- Preservation of medicinal herbs.
- Fish and meat drying.
- Agricultural product processing.
- Small-scale food industries.
- Rural and household applications.

IX. FUTURE SCOPE

Future improvements in the Automated Solar Food Dryer may include:

1. IoT-based remote monitoring through mobile applications.
2. AI-based drying optimization.
3. Hybrid solar-electric heating systems.
4. Improved thermal energy storage.
5. Large-scale industrial drying applications.
6. Smart moisture detection systems.
7. Portable and modular dryer designs.

X.CONCLUSION

The Automated Solar Food Dryer is an effective and sustainable solution for food preservation using renewable energy. The integration of ESP32-based automation, temperature sensing, and controlled airflow significantly improves drying efficiency and product quality. The system reduces drying time, minimizes contamination, and operates with minimal energy consumption. It is highly suitable for farmers, rural communities, and small-scale food processing industries. The project demonstrates the successful integration of renewable energy and automation technologies for sustainable agricultural applications.

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