

Improving Drying Efficiency Of Direct Type Solar Dryer Using Gen AI

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Abstract- Solar drying is a sustainable, eco-friendly, and cost-effective method used for preserving agricultural and food products by utilizing renewable solar energy as an alternative to conventional fuel-based drying methods. However, traditional direct type solar dryers are generally fixed in position and unable to follow the movement of the sun, which results in reduced heat absorption, uneven moisture removal, longer drying time, and fluctuations in chamber temperature that may affect the quality of dried products. To overcome these limitations, this project proposes an improved direct type solar dryer integrated with automatic sun tracking and Generative AI based performance optimization. The system uses LDR (Light Dependent Resistor) sensors to detect the direction of maximum sunlight intensity and an Arduino Uno controller to process sensor data and operate an SG90 servo motor for rotating the dryer towards the sun throughout the day. By maintaining maximum solar exposure, the dryer is capable of achieving higher internal temperature, faster moisture evaporation, and improved drying efficiency. In addition, Generative AI techniques are utilized for conceptual design enhancement, drying parameter prediction, and optimization of system performance. Phase I of the project mainly focuses on design analysis, component selection, control logic development, and expected performance evaluation before prototype fabrication. The proposed system is expected to reduce drying time, improve product quality, minimize manual intervention, and increase energy utilization efficiency when compared with conventional fixed solar dryers. This low-cost and practical solution is highly suitable for small-scale agricultural and food processing applications, especially in rural and remote areas.

Keywords: Solar dryer, direct type solar dryer, Arduino Uno, LDR sensor, servo motor, sun tracking, Generative AI, drying efficiency.

I. INTRODUCTION

Solar drying is one of the oldest and most widely used methods for preserving agricultural and food products by removing moisture content through the use of solar energy. It is an economical, environmentally friendly, and sustainable alternative to conventional drying techniques that depend on electricity, fossil fuels, or other non-renewable energy sources.

In many rural and agricultural regions, solar drying is commonly used for fruits, vegetables, grains, spices, and fish products in order to extend shelf life, reduce spoilage, and improve storage capability. Among the different solar drying methods, the direct type solar dryer is widely preferred because of its simple construction, low maintenance cost, and ease of operation. However, conventional direct type solar dryers are generally fixed in one position and unable to follow the movement of the sun throughout the day. As a result, the dryer receives maximum solar radiation only for a limited period, while reduced sunlight during morning and evening hours leads to lower heat absorption and inefficient drying performance. This causes longer drying time, non-uniform moisture removal, temperature fluctuations, and reduced quality of dried products. In addition, manual adjustment of dryer orientation requires continuous human effort and may not always provide accurate positioning toward sunlight. To overcome these limitations, the proposed system introduces an improved direct type solar dryer integrated with automatic sun tracking and Generative AI based optimization. The system uses LDR (Light Dependent Resistor) sensors to continuously detect the direction of maximum sunlight intensity. Based on the sensor signals, an Arduino Uno microcontroller controls an SG90 servo motor that rotates the dryer chamber toward the optimum solar position. This automatic tracking mechanism ensures continuous exposure to sunlight throughout the day, thereby increasing heat collection efficiency and improving drying performance. The Generative AI component of the project is utilized for system design enhancement, drying parameter analysis, predictive performance estimation, and optimization of dryer orientation and operation. By combining renewable energy utilization with intelligent automation, the proposed system offers a smart and cost-effective solution for efficient drying applications.

II. EXISTING METHODOLOGY

The present drying system mainly depends on traditional open sun drying and fixed direct type solar dryers, which do not provide an efficient and controlled drying process. In open sun drying, agricultural and food products are placed under sunlight in open areas, where they are exposed to dust, insects, rain, and other environmental factors that reduce product quality. This method also requires a long drying time

and depends completely on weather conditions. The existing direct type solar dryers are generally fixed in one position and cannot track the movement of the sun throughout the day. Because of this, the dryer receives maximum sunlight only during certain hours, while reduced solar radiation during morning and evening periods decreases heat absorption. This results in temperature variation inside the drying chamber, uneven moisture removal, and lower drying efficiency. In many systems, manual adjustment is required to rotate the dryer toward sunlight, which increases labor effort and may not always provide accurate alignment. The lack of automatic control and real-time sensing further reduces overall performance. Products dried using these systems may suffer from discoloration, loss of texture, and inconsistent drying quality. In general, the current system has low efficiency, longer drying duration, poor temperature stability, and greater dependence on manual operation, resulting in reduced drying performance and lower product quality.

III. PROPOSED METHODOLOGIES

A smart direct type solar dryer with automatic sun tracking is proposed to improve the drying efficiency of agricultural and food products. The system includes an Arduino Uno controller, LDR (Light Dependent Resistor) sensors, SG90 servo motor, drying chamber, and supporting mechanical structure. The main objective of the proposed system is to continuously align the solar dryer toward the direction of maximum sunlight intensity, ensuring better heat absorption and faster drying performance throughout the day. The LDR sensors are placed on the dryer structure to detect sunlight intensity from different directions. Based on the sensor output, the Arduino Uno processes the signals and controls the SG90 servo motor to rotate the drying chamber toward the brighter light source. This automatic movement allows the dryer to follow the sun's path from morning to evening without manual intervention. By maintaining proper alignment with sunlight, the system provides more stable internal temperature and efficient moisture removal. The Generative AI component is used for conceptual design optimization, airflow analysis, drying time prediction, and improving system performance under different environmental conditions. It helps in selecting better operating parameters and enhances the efficiency of the overall drying process. The central control system ensures smooth coordination between sensing, decision making, and motor actuation. By allowing continuous solar tracking, the proposed system reduces drying time, improves drying uniformity, and enhances product quality compared to conventional fixed solar dryers. Additionally, the automated mechanism minimizes labor effort and maximizes renewable energy utilization. Overall, the

proposed system provides a practical, low-cost, and user-friendly solution for efficient solar drying applications.

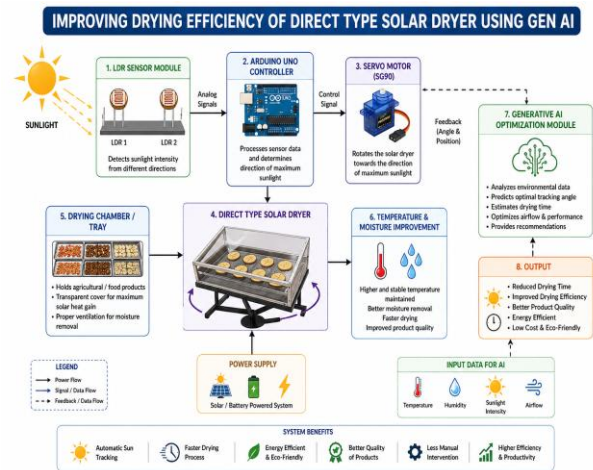


Figure 1: Architecture diagram represent the proposed methodology

IV. METHODOLOGY

Development of the proposed direct type solar dryer utilizes a structured design and implementation methodology. The process starts by analyzing system requirements so that the drying chamber, tracking mechanism, sensors, and control unit can operate efficiently under real-time conditions. Once the requirements are finalized, design work is carried out to define the overall structure, component arrangement, electrical connections, and interaction between hardware modules. After completing the design stage, the system is developed as an automatic solar drying unit incorporating Arduino Uno control, LDR sensor based tracking, and SG90 servo motor movement. All elements of the system work together to achieve continuous alignment toward maximum sunlight for improved drying performance. Functional testing is performed to verify correct sensor detection, motor rotation, temperature improvement, and tracking accuracy. After successful testing, the system can be deployed for practical drying applications with proper maintenance, safety measures, and reliable operation.

Sensor Detection Module

The sensor detection module uses LDR sensors to identify the direction of maximum sunlight intensity. Two or more sensors are placed at suitable positions on the dryer structure for comparing light levels. The sensed values are continuously transmitted to the Arduino Uno controller. This module ensures accurate sunlight detection and supports automatic tracking operation.



Arduino Control Module

The Arduino control module acts as the main processing unit of the system. It receives input signals from the LDR sensors and compares the sunlight intensity values. Based on the programmed control logic, the Arduino sends commands to the servo motor for rotating the dryer toward the brighter direction. This module ensures smooth coordination between sensing and movement.



Servo Motor Tracking Module

The servo motor tracking module is responsible for automatic rotation of the direct type solar dryer. The SG90 servo motor receives control signals from the Arduino and adjusts the angular position of the drying chamber. This movement helps the dryer follow the sun throughout the day. The module reduces manual effort and improves solar energy collection.



Drying Chamber Module

The drying chamber module is used to hold the agricultural or food products during the drying process. It is enclosed with transparent material to allow sunlight entry and heat trapping. The chamber maintains suitable temperature for moisture removal while protecting the products from dust and insects. This module improves hygiene and drying quality.



Temperature and Drying Module

The temperature and drying module utilizes absorbed solar heat for removing moisture from the products placed inside the chamber. Continuous solar tracking helps maintain higher and more stable temperature conditions. This results in faster drying, uniform moisture reduction, and improved product quality. The module increases overall drying efficiency.



Generative AI Optimization Module

The Generative AI module is used for conceptual design improvement, drying time prediction, airflow analysis, and performance optimization. It helps in selecting better system parameters and improving operational efficiency under different weather conditions. This module supports intelligent decision making and future system enhancement.



V. EXPERIMENTAL RESULTS

The experimental results of the proposed direct type solar dryer system prove that the developed model has improved drying efficiency, better temperature stability, and increased utilization of solar energy. During testing, the LDR sensor module was able to accurately detect the direction of maximum sunlight intensity under different daytime conditions. The Arduino control unit successfully processed the sensor inputs and generated proper control signals for automatic tracking operation. The servo motor tracking module was able to rotate the drying chamber smoothly toward the sunlight with minimal delay and satisfactory angular accuracy. Continuous sun tracking enabled the dryer to maintain better solar exposure when compared with conventional fixed dryers. As a result, the internal chamber temperature remained more stable and higher for longer durations during the drying cycle. The drying chamber module was able to remove moisture from agricultural products more effectively, resulting in reduced drying time and improved drying uniformity. The products obtained better texture, color retention, and overall quality due to controlled drying conditions. The enclosed chamber also protected the materials from dust and external contamination during operation. The Generative AI based analysis provided useful predictions regarding drying time, system alignment, and operating efficiency under varying environmental conditions. Acceptable performance results indicated that the system can operate reliably with low power consumption and minimal manual intervention. The overall results demonstrate increased drying performance, reduced workload, improved product quality, and a more efficient solar drying process.

VI. CONCLUSION

The proposed direct type solar dryer provides a practical and efficient solution for improving the drying process of agricultural and food products using renewable solar energy. The integration of automatic sun tracking allows the dryer to continuously follow the movement of the sun and receive maximum solar radiation throughout the day. This improves heat absorption, maintains better drying chamber temperature, and reduces the total drying time when compared

with conventional fixed solar dryers. The system promotes better coordination between sensing, control, and mechanical movement through the use of LDR sensors, Arduino Uno, and SG90 servo motor. As a result, manual intervention is minimized and drying performance becomes more consistent and reliable. In addition, the enclosed drying chamber helps protect the products from dust, insects, and environmental contamination while improving overall product quality. The use of Generative AI further enhances the system by supporting design optimization, performance prediction, and efficient operational planning. Ultimately, the improved direct type solar dryer offers a low-cost, eco-friendly, and easy-to-use drying solution suitable for farmers, small-scale food industries, and rural communities, while contributing to sustainable energy utilization and better food preservation.

VII. FUTURE WORK

A mobile monitoring application could be developed to allow users to observe drying temperature, tracking position, and system performance in real time. In order to improve automation, it would be beneficial to integrate IoT based sensors for measuring humidity, moisture content, and chamber temperature continuously during the drying process. Using weather forecasting data and cloud connectivity would help the system adjust operation according to sunlight availability and environmental conditions. Advanced tracking mechanisms using dual-axis rotation could be implemented to further increase solar energy absorption throughout the day. Sending automated notifications through mobile applications or SMS regarding drying completion status would improve user convenience. The use of predictive data analytics and Generative AI could help estimate drying time, optimize operating parameters, and recommend suitable settings for different food products. Additionally, integrating battery backup or hybrid solar-electric heating systems would improve operation during cloudy conditions. The development of larger capacity dryers with modular design would support commercial scale applications. Multilingual user interfaces and low-cost smart controls would make the system more useful for farmers and small-scale industries in different regions.

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