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IOT-Based Areca Nut Dryer

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ABSTRACT

Efficient and sustainable drying is crucial for preserving the quality of agricultural products like areca nuts. Traditional drying methods often face challenges such as inconsistent heat distribution, high energy consumption, and vulnerability to weather conditions. This project addresses these issues by designing a modern, IoT-integrated areca nut drying system.

This project presents a sustainable areca nut drying system combining IoT technology and renewable energy to optimize drying efficiency and reduce energy consumption. The system features a steel drying chamber equipped with heaters for consistent heat distribution, managed by an Arduino Uno-based thermostat for precise temperature control. A scissor lifter mechanism enhances efficiency by raising the chamber's base, allowing the roof to open and expose the nuts to natural sunlight. This dual-mode drying—electric and solar—minimizes energy use while ensuring uniform drying and protecting the nuts from contamination, adverse weather, and pests. By integrating IoT-driven automation with renewable energy, this system represents a cost-effective and eco-friendly innovation. It demonstrates a practical solution for improving drying quality while addressing sustainability and resource conservation in agricultural processing.

KEYWORDS: **Areca nut drying, Sustainable agriculture, Dual-mode drying, IoT technology, Solar-assisted drying, Arduino Uno thermostat, App, Scissor lifter mechanism, Contamination protection, Precision temperature control, Remote Control and Monitoring, Agricultural innovation, Food Preservation, Drying chamber design.**

INTRODUCTION:

Efficient and reliable drying of areca nuts is essential to preserve their quality, market value, and shelf life. In traditional drying methods, such as open sun drying, challenges like uneven heat distribution, dependency on weather conditions, and risks of contamination from dust, insects, and fungi are common. These methods are labour-intensive, time-consuming, and lack precise control over drying conditions, leading to inconsistent results and potential losses for farmers. Addressing these issues requires a modern, automated solution that integrates advanced technology with practical usability.

The IoT-based areca nut dryer system introduces a transformative approach to the drying process. At the heart of this system is a steel drying chamber, designed to house the areca nuts securely while providing controlled drying conditions. The chamber is equipped with heaters on both sides to ensure even heat distribution throughout the drying process. Temperature sensors placed within the chamber provide real-time monitoring of the drying conditions, which are managed by an Arduino Uno-based thermostat for precise temperature control.

A unique feature of the system is the scissor lifter mechanism, powered by a motor. This innovation enables the chamber's base to be raised, allowing its roof to open and expose the areca nuts to natural sunlight. This dual-mode drying strategy combines electric heating with solar energy, significantly reducing energy consumption while ensuring consistent drying. The system's reliance on renewable energy not only cuts operational costs but also promotes environmental sustainability.

To enhance user convenience, the system integrates a Bluetooth module for seamless wireless communication. Users can interact with the system via a Dart-based mobile app, which provides an intuitive interface for monitoring temperature, adjusting settings, and controlling the system remotely. This ensures that farmers and operators have real-time control and flexibility, even from a distance.

By incorporating IoT, this system addresses multiple challenges inherent in traditional drying methods. It automates temperature regulation, ensures uniform drying, and minimizes contamination risks. Furthermore, it reduces the dependency on manual labor, streamlines operations, and enhances overall productivity. The integration of sensors, actuators, and communication modules enables smart, data-driven drying, paving the way for a technologically advanced and sustainable agricultural practice.

This IoT-driven solution is expected to revolutionize areca nut drying by improving efficiency, consistency, and quality. In doing so, it not only boosts the economic viability of areca nut farming but also contributes to sustainable resource management, aligning with the growing emphasis on environmentally friendly agricultural technologies.

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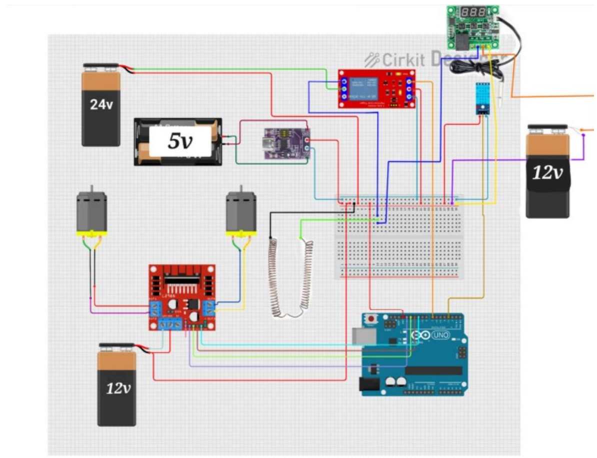

Fig 1: Basic Circuit Diagram of IOT-Based Areca Nut Dryer.

Steel Drying Chamber

Fig 2: Steel Drying Chamber

The steel drying chamber is the core of the system, providing a controlled environment for drying.

- Material: Stainless steel for durability and resistance to rust and corrosion.
- Features:
  - Thermal insulation to retain heat and reduce energy consumption.
  - Controlled ventilation for effective moisture release.
  - Multiple racks for increased capacity.
- Functionality: Ensures uniform heat distribution and protects areca nuts from environmental contaminants. It is the perfect option for this Internet of Things

Heaters

Strategically positioned on both sides of the chamber, heaters supply the required heat for drying.

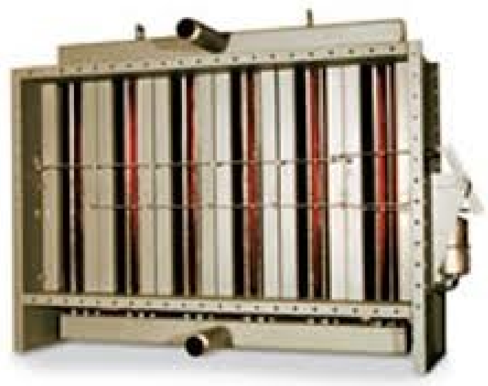

Fig 3: Heaters

- Type: Nichrome wire heaters, known for high efficiency and durability.
- Control: Regulated by an Arduino-based thermostat for precise temperature maintenance.
- Features:
  - Even heat distribution to prevent over-drying or under-drying.
  - Energy efficiency, with the ability to utilize natural sunlight via a motorized lifter.
- Safety Mechanisms: Includes relays and circuit breakers to prevent overheating.

Temperature Sensors

Fig 4: Temperature Sensors

The temperature sensors monitor real-time conditions within the chamber.

- Type: Digital sensors with high accuracy and fast response times.
- Purpose: Provide feedback to the Arduino Uno for regulating the heaters.
- Integration: Enables the system to maintain consistent drying conditions.

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Arduino Uno-Based Thermostat

Fig 5: Arduino Uno-Based Thermostat

The Arduino Uno serves as the control unit for the system.

- Functionality: Processes data from temperature sensors and adjusts heater operations.
- Programming: Utilizes Arduino IDE with pre-programmed logic for real-time control.
- Role in Automation: Ensures precise temperature regulation and reduces manual intervention.

Bluetooth Module

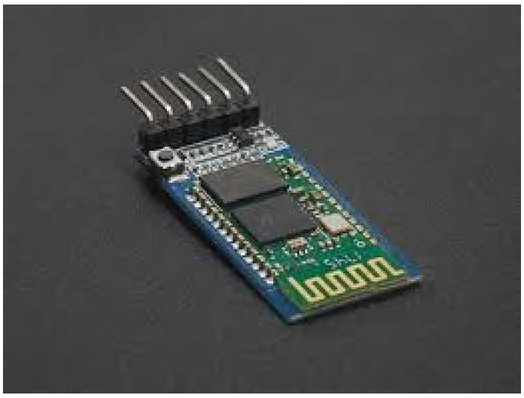

Fig 6: Bluetooth Module

The Bluetooth module enables wireless communication between the Arduino Uno and the mobile app.

- Technology: Bluetooth 4.0 for low power consumption and reliable connectivity.
- Purpose: Facilitates remote monitoring and control of the drying process.
- Integration: Works seamlessly with the mobile app to display real-time temperature data and allow user adjustments.

Motor with Scissor Lifter

The motor and scissor lifter add a mechanical dimension to the system, enabling sunlight-based drying.

Motor with Scissor Lifter

Fig 7: Motor with Scissor Lifter

- Purpose: Raises the base of the chamber to expose areca nuts to natural light when available.
- Control: Managed via the Arduino Uno and mobile app.
- Energy Efficiency: Reduces heater usage during sunny conditions.

Dart-Based Mobile Application

The mobile app serves as the user interface for the system.

Fig 8: Dart-Based Mobile Application

- Development: Built using the Dart programming language for smooth operation and compatibility.
- Features:
  - Real-time monitoring of temperature and heater status.
  - Remote control for temperature adjustments and motor operations.
- Benefits: Enhances user convenience and ensures optimal drying conditions.

METHODOLOGY:

Using Internet of Things technology, the Cloud-Based Food Dehydrator with Intelligent Profile Sele ctor aims to improve the flexibility and efficiency of the food dehydration process. System architecture design, sensor integration, data processing, and control mechanisms are some of the methodology's primary aspects.

The drying process begins with the preparation of fresh, high-quality areca nuts, ideally 6–7 months mature. These nuts undergo conventional processing methods to ensure they are suitable for the drying stages. The preparation involves several steps: dehusking, cutting into segments or discs, boiling to extract juice, and filtering to separate the concentrate. Following this, the nuts are subjected to a two-stage drying process. The first stage involves preliminary drying to reduce surface moisture, after which the nuts are mixed or coated with additional materials as required. Finally, a second-stage drying process ensures the nuts reach optimal dryness, making them ready for packing and marketing. This structured approach ensures consistent quality and maximizes product value.

Ripened Arecanut
↓
Dehusking
↓
Cutting into segments / discs
↓
Boiling Juice extraction
↓
Concentrate Filtered nuts
↓
Drying (First stage)
↓
Mixing / coating
↓
Drying / (second stage)
↓
Packing and marketing

Drying Method: IoT-Based Areca Nut Drye

System Design and Component Selection

The ESP32 microcontroller, temperature sensor, humidity sensor, relay module, and fan are among the vital parts of the system's architecture. Because of its integrated Wi-Fi, the ESP32 is chosen since it is perfect for Internet of Things applications and cloud connectivity. The dehydrator's internal environment is continuously monitored by the temperature and humidity sensors. High-power parts, such as the fan and heating element, are managed by the relay module, enabling automated switching based on sensor data.

By ensuring adequate circulation, the fan helps remove moisture from food. The exact control over the dehydration process is made possible by this combination of components. The ability to handle various food profiles while preserving the system's effectiveness and safety is the main focus of the design.

Sensor Integration and Data Collection

The dehydrator is equipped with temperature and humidity sensors to track current environmental conditions as the drying process progresses. The chamber is kept within the ideal temperature range for various food products thanks to the temperature sensor. The humidity sensor monitors moisture content at the same time, which is important for effective dehydration without sacrificing food quality. The ESP32 microcontroller receives continuous data from both sensors for processing. The system can dynamically change the fan speed and heating element thanks to this data. To preserve food texture and flavor while maximizing drying efficiency, real-time data collecting is crucial. Actionable insights are generated and saved in the cloud using precise sensor data.

Microcontroller Programming

Based on preset food dehydration patterns, the ESP32 microcontroller is configured to process sensor inputs and regulate the heating element and fan. The appropriate temperature and humidity levels for various food categories, such as fruits and vegetables, are specified in the profiles. After reading the sensor data, the ESP32 compares it to the specifications specified in the profile.

The ESP32 senses variances and sends a relay module command to switch on or off the heater or fan, modifying the environment as necessary. Additionally, MQTT communication protocols are used by the application to transmit data to the cloud for remote monitoring. By providing automated control, this programming minimizes the need for ongoing user intervention and preserves product consistency.

Cloud Integration via MQTT Protocol

Real-time data transfer and remote control are made possible using the MQTT protocol, which connects

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the system to the cloud. Data on temperature and humidity is sent via the ESP32 to a cloud server, where a MongoDB database stores the information. Users with an internet connection can watch the dehydration process from any location thanks to this real-time data transmission. Additionally, the MQTT protocol allows users to send remote commands to the ESP32, enabling them to change fan speed or temperature via a mobile or online interface.
Users can track previous data through cloud integration, which enables them to optimize dehydration procedures going forward. This configuration guarantees secure, scalable, and adaptable data transfer between the cloud and the dehydrator.

User Interface Development

The dehydrator can be easily monitored and controlled by users with the help of an intuitive web-based application. Through interactive gauge meters, the interface presents temperature, humidity, and system condition in real-time. Depending on the kind of food being dehydrated, users have the option to load pre-made food profiles or build new ones. Additionally, users can remotely change the fan and heater settings via the interface using preset profiles or real-time data.
Users can access performance logs and historical data using this platform, which will help them improve their dehydration procedures going forward. The user interface is made to be responsive and simple to use on a variety of devices.

Testing and Optimization:

After the system is configured, it is put through a thorough testing process using different foods, like fruits and vegetables. Setting dehydration profiles tailored to the particular food type is the first step in each test, after which the system's ability to maintain the ideal humidity and temperature is monitored. To improve the dehydration profiles and guarantee that the food is preserved while the procedure is energy-efficient, data from these experiments is examined. To maximize the efficiency of the system, variables such as moisture retention, temperature stability, and drying time are assessed. To ensure consistent and dependable dehydration results across a variety of food items, the ESP32's programming and sensor thresholds are adjusted based on feedback from these tests.

Performance Evaluation

To make sure the Cloud-Based Food Dehydrator with an Intelligent Profile Selector operates precisely and effectively, performance evaluation is crucial. It verifies the accuracy of humidity and temperature sensors, which are essential for preserving ideal drying conditions. You may increase the quality and consistency of the dehydration profiles by experimenting with different foods and testing the system with them. Additionally, it aids in evaluating energy efficiency by guaranteeing that the heater, fan, and sensors run without using excessive amounts of electricity.
By assessing the system's performance, any malfunctions like relay or sensor problems are found and fixed, increasing reliability. Additionally, it guarantees the responsiveness of the cloud interface, giving users real-time management and monitoring. In the end, performance evaluation raises user satisfaction and optimizes system performance.

LITERATURE SURVEY:

[1] S.KULANTHAISAMI et al. “Drying kinetics of areca nut using solar cum biomass drying system” This paper examines the drying kinetics of areca nut using an integrated solar and biomass drying system. The system combines solar energy and a biomass heater to maintain optimal drying temperatures, ensuring efficiency even during low sunlight conditions. A controlled airflow mechanism and temperature sensors are used to regulate the drying process, which helps in maintaining the quality of the areca nuts. The drying kinetics are analyzed by studying the moisture content reduction over time, establishing parameters like drying rate, equilibrium moisture content, and energy consumption. The hybrid system enhances drying efficiency, minimizes energy waste, and reduces reliance on conventional power sources, making it sustainable and cost-effective for areca nut farmers.

[2] Nithin Noronha et al. “A review on Electric dryer for areca nut” This paper reviews the design and operation of an electric dryer specifically developed for drying arecanuts. The dryer uses an electrically powered heating element to maintain consistent temperatures, ensuring uniform moisture removal from the arecanuts. The system includes a temperature control mechanism to optimize the drying process, preventing overheating and preserving the quality of the nuts. The study highlights the efficiency and convenience of using electric dryers compared to traditional sun-drying methods, emphasizing its applicability in regions with limited sunlight or high humidity. This approach offers a reliable, modern solution for arecanut farmers seeking improved drying methods.

[3] Esper et al., “Solar drying effective means of food preservation,” published in *Renewable Energy*. The system is controlled by a small computer that regulates drying parameters to ensure consistent quality. Powered by solar energy, this setup effectively dries fruits by maintaining a controlled environment where moisture is removed gradually. A blower aids in the final stages of drying, optimizing airflow to enhance drying efficiency while reducing dependency on conventional energy sources.

This solar-powered approach is both energy-efficient and sustainable, offering a valuable method for food preservation in remote and resource-limited areas.

[4] Masu et al. (2007) - "Performance of Solar Air Heater Coupled with Biomass Stove" This research evaluates the integration of a solar air heater with a biomass stove. The system shows significant temperature rises, making it suitable for drying arecanut and other agricultural products. The results indicate the potential for solar-biomass hybrid systems to provide cost-effective drying solutions

[5] Karapantsios T.D et al "Design and testing of a new solar dryer. Drying Technology" This paper introduces an innovative solar drying system for agricultural products that incorporates a heating element to enhance the drying process. The design is cost-effective and scalable, making it accessible for local communities. The solar dryer works by efficiently capturing and retaining solar energy, which is absorbed by the system to maintain consistent drying temperatures. This method ensures a sustainable and environmentally friendly solution for drying agricultural products, reducing reliance on conventional energy sources while increasing productivity and preserving food quality.

CONCLUSION:

The IoT-Based Arecanut Dryer represents a significant advancement in agricultural drying processes by incorporating IoT technology, renewable energy sources, and automation to address the limitations of traditional methods. This innovative system features a robust steel drying chamber outfitted with nichrome wire heating coils, a thermostat, and high-precision sensors for temperature and humidity monitoring. These components work together to ensure consistent drying conditions tailored to optimize the quality of arecanuts.

The system integrates solar energy to reduce dependency on conventional power sources, making it environmentally sustainable and cost-efficient. The drying chamber includes a scissor lifter mechanism that allows arecanuts to be exposed to sunlight during favorable weather conditions, providing an additional natural drying step. This hybrid approach minimizes energy consumption and maximizes drying efficiency. An Arduino Uno microcontroller, coupled with real-time data feedback, facilitates precise control of the drying process. Remote monitoring and control capabilities are provided through a Dart-based application, enhancing usability by allowing users to manage operations from their mobile devices. This eliminates the need for constant physical monitoring and provides real-time insights into the system's performance. Additionally, the app's intuitive interface displays environmental data and allows users to adjust drying parameters easily, ensuring optimal conditions throughout the process. The integration of renewable energy, IoT, and smart engineering solutions makes this system highly adaptable and scalable. Its modular design supports future enhancements, such as adding advanced sensors or machine learning algorithms, which can analyze historical data to further refine the drying process. This flexibility enables the dryer to cater to various crop types and drying requirements, extending its applicability beyond arecanuts to other agricultural products.

By addressing challenges like inconsistent drying, energy inefficiency, and weather dependency, this IoT-based solution empowers small-scale farmers and agricultural enterprises. It offers a reliable, sustainable, and technologically advanced method to preserve crop quality, reduce post-harvest losses, and improve profitability. This project serves as a model for future agricultural innovations, combining automation, renewable energy, and IoT to transform traditional practices into data-driven, efficient systems.This project combines automation, cloud computing, and Internet of Things technology to deliver a novel method for food dehydration.

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