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AI INTEGRATED MECHANICAL DRYING SYSTEM FOR POST HARVEST GROUNDNUT

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Abstract: This project presents the design and development of an AI Integrated Mechanical Drying System for Post Harvest Groundnut with Moisture Sensors, aimed at improving the efficiency, accuracy, and quality of the drying process. Traditional drying methods such as open sun drying and conventional hot-air drying are highly dependent on environmental conditions, require significant manual effort, and often result in uneven moisture removal, contamination, and quality degradation.To overcome these limitations, the proposed system integrates Artificial Intelligence (AI), Internet of Things (IoT), and sensor-based automation, with a special focus on moisture sensing technology for precise drying control. The system is built around an ESP32 microcontroller, which collects real-time data from temperature, humidity, load cell, and moisture sensors. The moisture sensor plays a crucial role by directly measuring the moisture content of groundnuts, while the load cell monitors weight reduction to estimate moisture loss.An AI-based control algorithm analyzes the collected data and predicts optimal drying conditions. Based on this analysis, the system automatically controls the heater and blower through relay modules to maintain proper temperature and airflow. The system also incorporates IoT connectivity, enabling remote monitoring and control through mobile applications such as Blynk, allowing users to track drying parameters and receive real-time updates.The integration of moisture sensors significantly enhances drying accuracy by ensuring that the groundnuts reach the desired safe moisture level without over-drying or under-drying. This improves product quality, shelf life, and reduces the risk of fungal contamination. Additionally, the system minimizes energy consumption and reduces human intervention, making it efficient, reliable, and suitable for both small-scale and commercial applications.

Keywords: Artificial intelligence (AI), Internet of Things (IoT), ESP32 microcontroller, mechanical drying system, groundnut drying, moisture monitoring, predictive control, energy efficiency, automation.

I. INTRODUCTION

Groundnut (*Arachis hypogaea*) is one of the most important oilseed crops widely cultivated across the world. It serves as a major source of edible oil, protein, and nutrients, playing a crucial role in both the agricultural economy and food industry. After harvesting, drying is a critical post-harvest operation required to reduce moisture content to safe storage levels and prevent fungal contamination, especially aflatoxin formation.Traditional drying methods, such as open sun drying, are commonly used due to their low cost and simplicity. However, these methods are highly dependent on weather conditions, require extensive manual labor, and often result in uneven drying. Exposure to dust, pests, and unexpected rainfall further degrades product quality. Similarly, conventional mechanical dryers, although faster, lack intelligent control systems, leading to excessive energy consumption, over-drying, or under-drying of groundnuts.To overcome these limitations, modern technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) have been introduced in agricultural processing systems. AI enables smart decision-making by analyzing real-time sensor data, while IoT facilitates remote monitoring and control of system parameters. Integrating these technologies into mechanical drying systems can significantly improve efficiency, consistency, and energy utilization.

This project proposes an AI-integrated mechanical drying system for post-harvest groundnuts, designed to automate and optimize the drying process. The system uses an ESP32 microcontroller connected with sensors such as temperature, humidity, and load cell to continuously monitor drying conditions. Based on this data, AI algorithms dynamically adjust parameters like airflow and heating to achieve uniform drying and maintain optimal moisture levels.In addition, the system incorporates IoT connectivity, allowing users to monitor and control the drying process remotely through a mobile or web interface. This intelligent approach reduces human intervention, minimizes post-harvest losses, improves product quality, and enhances overall operational efficiency.Thus, the proposed system represents a significant advancement in smart agriculture by combining automation, data-driven control, and energy-efficient drying techniques to support modern post-harvest management practices.

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II. OBJECTIVE

The main objective of this project is to design and develop an AI-integrated mechanical drying system for post-harvest groundnuts that ensures efficient, uniform, and controlled moisture reduction while maintaining product quality and reducing energy consumption. The system aims to utilize an ESP32 microcontroller integrated with temperature, humidity, and load cell sensors to continuously monitor real-time drying conditions. Based on the collected data, an AI-based control algorithm is implemented to predict drying time and automatically regulate heating and airflow for optimal performance. Additionally, the project focuses on incorporating IoT connectivity to enable remote monitoring and control through a mobile or web-based platform. The system also aims to minimize post-harvest losses, prevent fungal contamination, and reduce manual intervention by automating the entire drying process. Furthermore, data logging and analysis are included to improve system efficiency and accuracy in future drying cycles, making the system suitable for both small-scale and large-scale agricultural applications.

III. EXISTING SYSTEM

The existing methods used for drying post-harvest groundnuts primarily include traditional sun drying and conventional mechanical drying systems. Sun drying is the most widely practiced method due to its low cost and simplicity, where groundnuts are spread in open fields under sunlight to reduce moisture content. However, this method is highly dependent on weather conditions and is often affected by unexpected rain, dust, pests, and contamination. It also requires significant manual labor and results in non-uniform drying, which can lead to quality degradation and fungal growth.Conventional mechanical dryers, such as hot-air dryers, are used as an alternative to overcome weather dependency. These systems use heated air circulated by blowers to remove moisture from the groundnuts. Although they provide faster drying compared to sun drying, they are generally manually controlled and lack intelligent monitoring systems. As a result, they often consume high energy, produce uneven drying due to improper airflow distribution, and may cause over-drying or under-drying of the product.Furthermore, existing systems do not incorporate real-time sensing, data analysis, or automation features. There is limited ability to monitor key parameters such as temperature, humidity, and moisture content continuously. The absence of IoT connectivity and predictive control makes it difficult to optimize the drying process, leading to inefficiency, higher operational costs, and reduced product quality.

IV. PROPOSED SYSTEM

The proposed system is an AI Integrated Mechanical Drying System for Post Harvest Groundnut designed to provide accurate, automated, and energy-efficient drying. The system integrates Artificial Intelligence (AI), Internet of Things (IoT), and multiple sensors to ensure precise control over the drying process and improve product quality.

At the core of the system is an ESP32 microcontroller, which acts as the main control unit. It collects real-time data from sensors including a temperature sensor, humidity sensor, load cell (with HX711 module), and moisture sensors. The moisture sensors directly measure the moisture content of the groundnuts, while the load cell tracks weight reduction to estimate moisture loss during drying.

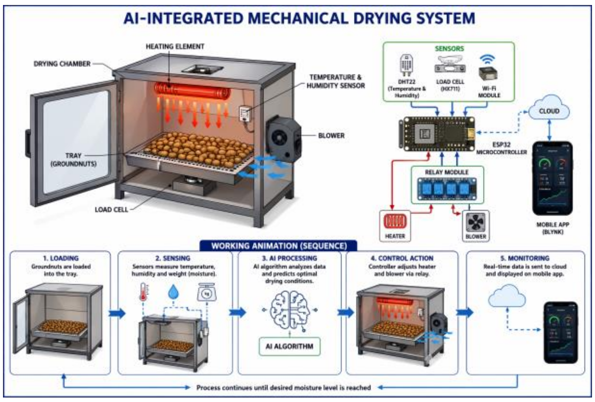

Fig 1 – PROPOSED SYSTEM

The system uses a heater and blower unit to generate and circulate hot air within the drying chamber. These components are controlled through a relay module, which allows the ESP32 to switch high-power devices ON and OFF. The embedded AI-based algorithm continuously analyzes sensor data and predicts the optimal drying conditions. Based on

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this analysis, it automatically adjusts the heating temperature and airflow to achieve uniform and efficient drying.In addition, the system incorporates IoT connectivity using Wi-Fi, enabling users to monitor and control the drying process remotely through a mobile or web application such as Blynk. Real-time parameters such as temperature, humidity, moisture level, and drying status can be viewed, and alerts are generated when the desired moisture level is reached.The inclusion of moisture sensors enhances the system's accuracy by ensuring that the drying process stops exactly when the groundnuts reach the safe moisture level (around 7–8%). This prevents over-drying and under-drying, improves product quality, and increases shelf life.Overall, the proposed system operates as an intelligent closed-loop control system that ensures uniform drying, reduced energy consumption, minimal human intervention, and improved efficiency, making it suitable for modern agricultural and industrial applications.

V. LITERATURE REVIEW

Over the past decade, drying technologies for agricultural products have significantly evolved from traditional methods to intelligent and automated systems. Studies have shown that conventional drying methods such as sun drying and basic hot-air drying are widely used but suffer from limitations including uneven drying, contamination, and dependence on weather conditions. Research by Xie et al. (2023) compared various drying techniques and concluded that advanced methods such as vacuum and infrared drying improve drying efficiency and maintain product quality more effectively than traditional approaches. Similarly, Ahmad and Mirani (2012) analyzed hot-air drying of groundnuts and emphasized the importance of controlled temperature and airflow in improving drying performance and reducing processing time.

Recent advancements focus on integrating modern technologies such as Artificial Intelligence (AI) and sensor-based monitoring systems. Nguyen Van Minh et al. (2025) demonstrated the application of machine learning models like multilayer perceptron (MLP) and radial basis function (RBF) networks to predict moisture removal in peanut drying, achieving higher accuracy and reduced drying time. Kumar et al. (2021) also showed that AI-based models can accurately estimate moisture content in agricultural products, reducing the need for manual measurement and improving process reliability. In addition, Lewis et al. (2018) developed a sensor-based automated drying system capable of monitoring real-time temperature, humidity, and moisture levels, which significantly improved drying consistency and reduced errors associated with manual control.

Solar drying techniques have also been explored as energy-efficient alternatives. Prajapati et al. (2022) investigated multi-layer solar drying of peanuts and found that drying efficiency is influenced by parameters such as airflow, temperature, and layer thickness. Another solar drying study (2014) demonstrated that indirect solar dryers reduce drying time and operational cost compared to open sun drying, while providing better product quality. Furthermore, Zhu et al. (2021) introduced infrared-assisted drying, which enhances drying rate and preserves nutritional properties, making it a promising alternative to conventional methods.

Theoretical studies such as Chen et al. (2020) provided insights into heat and mass transfer mechanisms during peanut drying, forming a strong foundation for the design of efficient drying systems. Onwude et al. (2016) reviewed various drying technologies and highlighted the limitations of traditional systems, including high energy consumption and lack of automation, reinforcing the need for intelligent solutions. More recent works by Wang et al. (2025) and Miraei Ashtiani et al. (2024) emphasized the growing role of AI in food drying processes, demonstrating how predictive algorithms and smart sensors can optimize drying conditions, improve energy efficiency, and ensure consistent product quality.

Overall, the literature indicates a clear transition from manual and conventional drying methods to smart, AI-integrated systems. While significant progress has been made, there remains a need for cost-effective, scalable, and fully automated drying solutions specifically designed for groundnuts. This gap is addressed by the proposed AI-integrated mechanical drying system, which combines sensor-based monitoring, predictive control, and IoT connectivity to achieve efficient and reliable drying performance.

VI. PROBLEM STATEMENT

Groundnut drying is a critical post-harvest process required to reduce moisture content to safe levels for storage and to prevent fungal contamination such as aflatoxin formation. However, existing drying methods, including traditional sun drying and conventional mechanical dryers, face several significant challenges. Sun drying is highly dependent on weather conditions, exposes the produce to dust, pests, and unexpected rainfall, and results in uneven moisture removal. On the other hand, conventional mechanical dryers lack intelligent control systems, leading to excessive energy consumption, inconsistent drying, and the risk of over-drying or under-drying.Additionally, most existing systems do not provide real-time monitoring of important parameters such as temperature, humidity, and moisture content. The absence

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of automation and predictive control increases manual intervention, reduces efficiency, and affects the overall quality of the final product.These limitations result in post-harvest losses, reduced shelf life, and lower market value of groundnuts.Therefore, there is a need for a smart, automated, and energy-efficient drying system that can monitor drying conditions in real time, ensure uniform moisture removal, minimize human intervention, and improve overall product quality.

VII. SYSTEM OVERVIEW

The proposed system is an AI-integrated mechanical drying system designed to provide efficient and controlled drying of post-harvest groundnuts. The system combines sensor-based monitoring, artificial intelligence, and IoT connectivity to automate the entire drying process and ensure optimal performance.At the core of the system is an ESP32 microcontroller, which acts as the central processing and control unit. It collects real-time data from various sensors, including a temperature sensor, humidity sensor, and load cell with HX711 module. The load cell continuously measures the weight of the groundnuts, enabling indirect estimation of moisture loss during the drying process.The system includes a heating element and blower unit that generate and circulate hot air inside the drying chamber. These components are controlled through a relay module, which acts as an interface between the microcontroller and high-power devices. Based on the sensor data, the embedded AI algorithm analyzes drying conditions and dynamically adjusts the heater and airflow to maintain uniform temperature and humidity levels.In addition, the system is integrated with IoT technology using Wi-Fi, allowing remote monitoring and control through a mobile or web application such as Blynk. Users can view real-time parameters, receive alerts, and manage the drying process from anywhere. The system also supports data logging, enabling performance analysis and continuous improvement of the drying process.Overall, the system operates as a closed-loop intelligent control system, where sensor feedback is continuously processed to optimize drying conditions. This ensures uniform drying, reduces energy consumption, minimizes human intervention, and improves the quality and shelf life of groundnuts.

VIII. FABRICATION OUTPUT

The fabricated AI-integrated mechanical drying system was successfully developed as a compact and functional prototype for post-harvest groundnut drying. The system consists of a closed drying chamber constructed using durable materials such as metal frame and transparent panels, allowing visual monitoring of the drying process while maintaining proper insulation. Inside the chamber, a perforated tray is provided to hold the groundnuts, ensuring uniform exposure to heated airflow.A blower and heating unit are installed to generate and circulate hot air evenly throughout the chamber. The airflow system is designed to prevent hotspots and ensure consistent drying across all groundnuts. A load cell is mounted beneath the tray to measure the weight of the groundnuts continuously, which helps in estimating moisture loss during the drying process. Temperature and humidity sensors are positioned inside the chamber to monitor environmental conditions in real time.

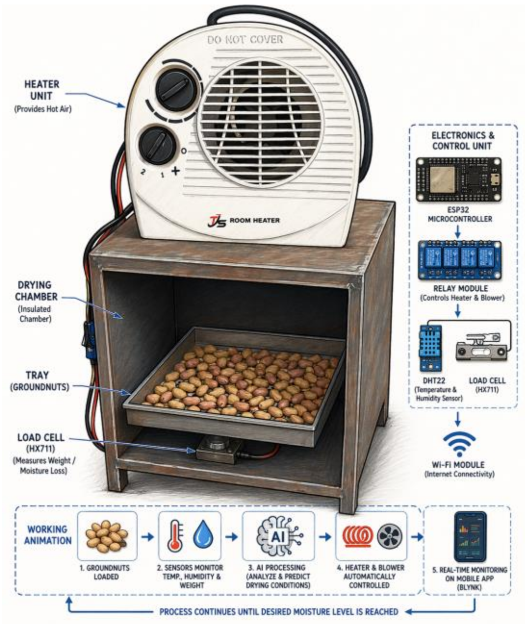

Fig 2 – Fabrication output

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The control system is built around an ESP32 microcontroller connected with a relay module to operate the heater and blower. The entire setup is powered using a regulated power supply, ensuring stable operation of all components. The IoT functionality is integrated using Wi-Fi, enabling remote monitoring and control through a mobile application.The fabricated model demonstrates efficient working by automatically adjusting drying conditions based on sensor inputs. It provides uniform drying, reduced energy consumption, and minimal manual intervention. The system is compact, cost-effective, and suitable for small-scale and semi-commercial applications, validating the feasibility of implementing AI and IoT in agricultural drying systems.

IX. CONCLUSION

The AI-integrated mechanical drying system developed for post-harvest groundnuts provides an effective and intelligent solution to overcome the limitations of traditional drying methods. Conventional techniques such as sun drying and basic mechanical drying often result in uneven moisture removal, high energy consumption, and dependence on environmental conditions. The proposed system successfully addresses these issues by incorporating Artificial Intelligence, IoT, and sensor-based automation to achieve controlled and efficient drying.The system continuously monitors key parameters such as temperature, humidity, and weight using sensors and processes this data through an ESP32 microcontroller. The AI-based control algorithm dynamically adjusts the heating and airflow conditions to ensure uniform drying while preventing over-drying or under-drying. Additionally, IoT integration enables remote monitoring, control, and data logging, enhancing usability and decision-making.The fabricated prototype demonstrates improved drying efficiency, reduced energy consumption, and better preservation of groundnut quality, including texture, flavor, and nutritional value. It also minimizes human intervention and post-harvest losses, making the system reliable and user-friendly.In conclusion, the proposed system represents a significant advancement in smart agricultural processing. It offers a cost-effective, scalable, and sustainable solution that can be adapted for both small-scale farmers and industrial applications. With further enhancements and field-level implementation, this technology has strong potential to modernize post-harvest management and improve overall productivity in the agricultural sector.

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