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IOT Based Solar Dehydration System For Chilli Drying

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Abstract: Solar dehydration is an innovative technology that combines renewable energy sources with thermal storage to improve drying efficiency and product quality. This research focuses on developing an Internet of Things (IoT) -based solar dryer for drying chili peppers. The IoT technology enables users to remotely monitor system parameters on mobile phones using an IoT application. The study investigates the integration of solar dryers for agricultural products, specifically focusing on Dominican bananas. It demonstrates the effectiveness of solar-assisted drying systems in reducing moisture content and enhancing the quality of dried chilies by providing controlled and consistent drying conditions. The results highlight the economic and quality benefits of these dryers, although further research on scalability and environmental impact is needed. The system utilizes a DHT22 sensor, which communicates temperature and humidity data to a microcontroller unit (MCU) via a single-wire serial interface. The MCU, an ESP8266-based Node MCU, is programmed using the Arduino IDE to read sensor data and transmit it over Wi-Fi. By connecting the Node MCU to a local Wi-Fi network, it serves a web page displaying real-time temperature and humidity readings. Users can connect their mobile devices to the Wi-Fi network to monitor the system remotely. The solar dehydration system was tested for drying chili samples weighing 2 kg, 5 kg, and 10 kg. The drying times for these samples were 1 hour 15 minutes, 2 hours, and 3 hours 30 minutes, respectively. The system also calculated the humidity levels for each sample, which ranged from 38% to 47%. Additionally, the system monitored and recorded the intensity of solar radiation during the drying process.
Keywords: IOT, Monitoring, Node MCU, Temperature Sensor, Humidity.

1. INTRODUCTION

The study of solar dryers faces limitations due to frequent cloud cover during the day and evening, which hampers the drying process. Incorporating solar energy storage within the dryer facilitates drying during the evening. Computational Fluid Dynamics (CFD) analysis is performed on two-dimensional converging and diverging sections. Latent heat storage materials are beneficial for energy storage, as they can store more energy than sensible heat storage materials. Phase Change Materials (PCMs) are effective for storing solar energy. The findings indicate that the converging section provides accurate results, with consistent in let wind speed in both scenarios. However, the exit wind speed in the converging section is nearly twice the inlet speed, while it significantly decreases in the diverging section (C.V. Papade and M.A. Boda 2014). The article examines a cost-effective and environmentally friendly solar dryer for banana drying. It compares two airflow Configurations and drying methods, concluding that the bottom flowsetup is more efficient and that using wooden skewers enhances drying rates. Bananas dried at an airflow of 1m/s exhibited the best quality. The dryer offers energy savings and reduces post-harvest losses, making it a practical solution for small-scale farmers (Vinay Narayan Hegde,Viraj Shrikanth Hosur, Samyukthkumar K Rathod, Puneet A Harsoor and K Badari Narayana 2015). This research compares two solar dryers for drying black pepper: a mixed-mode (Case-I) and an indirect (Case-II) dryer, both integrated with a latent heat storage system. Case-I reduced drying time by 76% compared to open sundrying and was 20% more efficient than Case-II. Additionally, Case-I preserved more nutrients and antioxidants. The results emphasize the economic and quality advantages of these dryers, although further research on scalability and environmental impact is necessary (D.V.N. Lakshmi, P. Muthukumar and Prakash Kumar Nayak2021). This study evaluates two photovoltaic-thermal solar dryer systems: a double-pass solar dryer (DPSD) with a black matte-coated aluminum absorber and a nano-enhanced double- pass solar dryer (NDPSD) with a graphene-coated absorber. The NDPSD demonstrated higher thermal (73.36% vs. 57.23%) and exergy efficiency (27.77% vs. 16.64%) compared to the DPSD. The findings underscore the enhanced performance of nano-enhanced systems for solar drying applications (Murat Ozturk, Coskun Yuksel and Erdem Çiftçi 2024).

To increase the amount of recycled air, an orifice was added to the pipe's inlet. The effect of the orifice's diameter was studied, and its optimal value was determined. Ultimately, two dryer designs, one with fins and the other without, were proposed, determining the CFD result (Anand Chavan, Vivek Vitankar, Nikhil Shinde and Bhaskar Thorat 2021). IoT-driven seed drying systems employ sensors such as DHT-11 and LM-35, managed by microcontrollers like the Raspberry PiPico-W, to fine-tune drying conditions. This system sensure precise regulation of temperature and humidity, avoiding excessive drying. Farmers can easily oversee the process remotely via web interfaces, making it both cost-effective and energy-efficient, while enhancing seed preservation and boosting agricultural productivity (Shreyas Rajendra Tayade, Pallavi Sanjay Karale and Anjali Rajesh Garde 2024). She is engaged in developing various solar dehydration systems, with the primary aim of this experiment being to design a dehydration system that meets essential dehydration needs and is improved by modifying the design of the indirect forced solar dehydration system.

The purpose of constructing a dehydration unit is to preserve food and conserve energy through the moisture removal process of solar dehydration (Jyoti Singh.et.al.2015).This researcher evaluated the capacity of solar dryers for drying, reviewing research papers from 2000 to 2023, and provided a comprehensive review of solar dryers (direct, indirect, mixed, and hybrid), including their types and drying capacities, which range from 1 kg to 250 kg in the drying process(Halefom Kidane, Istvan Farkas and Janos Buzás 2024). The researcher conducted a numerical study on apple slices using TRNSYS software, reducing the fruit's humidity from86% to 11% inapproximately270 minutesat70°C. The maximum thermal capacity of the drying system was also determined (Amir Hossein Nikpey, Abolfazl Hajizadeh Aghdam, Sadegh Hamoud Shaltouki 2024). This article presents experimental results of growing spinach using forced convection, reducing the spinach's humidity from 93% to 2%. Forced convection reduced drying time from 3 to 4 hours, and 90% of the air was recycled (Nourelislamsi Abdallah, Radhia Ferhat, Miloud Lahbari and Djamel Fahloul 2019).The study examines an IoT-integrated solar dryer for drying potato slices, where thinner slices (3 mm) dried more quickly and efficiently. The Modified Page model accurately predicted drying kinetics, highlighting the advantages of thinner slices and IoT in enhancing solar drying efficiency (Makar and Naniwadekar,Santosh Walke, ManojMandake,RaviTapre, KalyanPatil and Sachin Komble 2025). The study explores the use of IoT technology in solar dryers for agricultural products, focusing on Dominican bananas. The system measures temperature and relative humidity, transmitting data via LoRa and Wi-Fi to Thing Speak for real- time monitoring. An auto regressive model (ARX) is employed to predict moisture content with high accuracy (R^2=0.99). The IoT-based system enabled efficient drying, reducing moisture content by up to 20.03% over 5 days, even during rainfall. This integration improves drying control, reduces waste, and supports sustainable food preservation through solar energy (B. López-Velasco, A. Ruíz-García, J. G. Cebada-Reyes, Member, IEEE, and C. A. Villaseñor-Perea 2025). The researchers developed an IoT-based solar banana drying system, utilizing IoT to calculate humidity and temperature, with the highest humidity recorded at1.14. They display the drying outlet temperature and compare humidity (Pandit.S. Patil, Dilip.R Pangavhane, Sanjay. P. Shekhawat, Dr. Dheeraj. S. Deshmukh and Dr. M.S Deshmukh 2022).

II. METHODOLOGY

DESIGN SYSTEM
INTRODUCTION

The solar dehydration system designed for drying chilies combines renewable energy technologies with thermal storage to boost drying efficiency and enhance product quality. Central to this system is a 335-watt solar panel that charges three batteries, supplying power to various components. Two 500-watt blowers circulate heated air through the drying chamber, which is equipped with six 150-watt infrared (IR) bulbs and four air heaters to maintain optimal drying temperatures. Additionally, the chamber contains four DC fans to ensure even air flow. A250kg tank of paraffin wax serves as the phase change material (PCM), absorbing and storing heat during the day and releasing it during cooler periods to maintain consistent drying conditions. An Internet of Things (IoT) kit, featuring DHT22 sensors and a Node MCU ESP8266 module, monitors and regulates the temperature and humidity within the chamber, ensuring precise drying parameters. This integrated system not only reduces energy consumption but also enhances the quality of dried chilies by providing controlled and consistent drying conditions. Solar Dehydration System for Drying Chilies Fig1 below illustrates the process, which begins with solar radiation entering a flat plate collector that absorbs and converts sunlight into heat. The heated air is then directed through a solar panel connected to a battery, storing electrical energy for future use. This energy powersa500-watt blower, with two blowers in operation, supplying heated air to the dehydration chamber. Inside the chamber, a Phase Change Material (PCM) tank containing 250 kg of paraffin wax acts as thermal storage. The PCM absorbs excess heat during the day, transitioning from solid to liquid, and releases this stored heat as steam during cooler periods, maintaining a consistent drying temperature. In the event of insufficient solar energy, an auxiliary 1000-watt air heater maintains the desired temperature within the dehydration chamber. Additionally, 150-watt infrared (IR) bulbs supplement the heating process, ensuring continuous drying both day and night. The system is equipped with an IoT-based monitoring setup using DHT22 sensors and a Node MCU ESP8266 module to track and control temperature and humidity levels. This data is processed using a Microcontroller Unit (MCU) to optimize drying conditions. The dried chilies are then expelled from the chamber through an exhaust chimney, releasing the moisture-laden air into the atmosphere. If you require a schematic diagram or further technical specifications of the materials used in this solar dehydration system, they are shown in Table no.1 and also follow process in Fig 1 below.

Tables1: Specification of Materials

S.No	Particular	Specification
1	Bolwer	500 watt
2	Solar Panels	335watt
3	Air Heater	1000watt
4	IR Bulb	150watt
5	Inveter	1500watt
6	Battery	12v
7	Temperture Sensor	-40□to100□
8	Node MCU	ESP8266

Table 1. There are showing specification and they using solar dehyration system. The system comprises several components, each serving a specific function to ensure optimal performance. The blower operates at 500 watts, providing necessary airflow. Energy is harnessed through a 335-watt solar panel, which charges a 12V battery, supplying power to the inverter rated at 1500 watts. This inverter supports devices like a 1000-watt air heater and a 150-watt infrared bulb. Temperature regulation is achieved via a sensor capable of measuring from-40°C to 100°C. The system's operations are managed by an ESP8266 Node MCU, facilitating remote control and monitoring. This configuration ensures efficient energy use and precise temperature control.

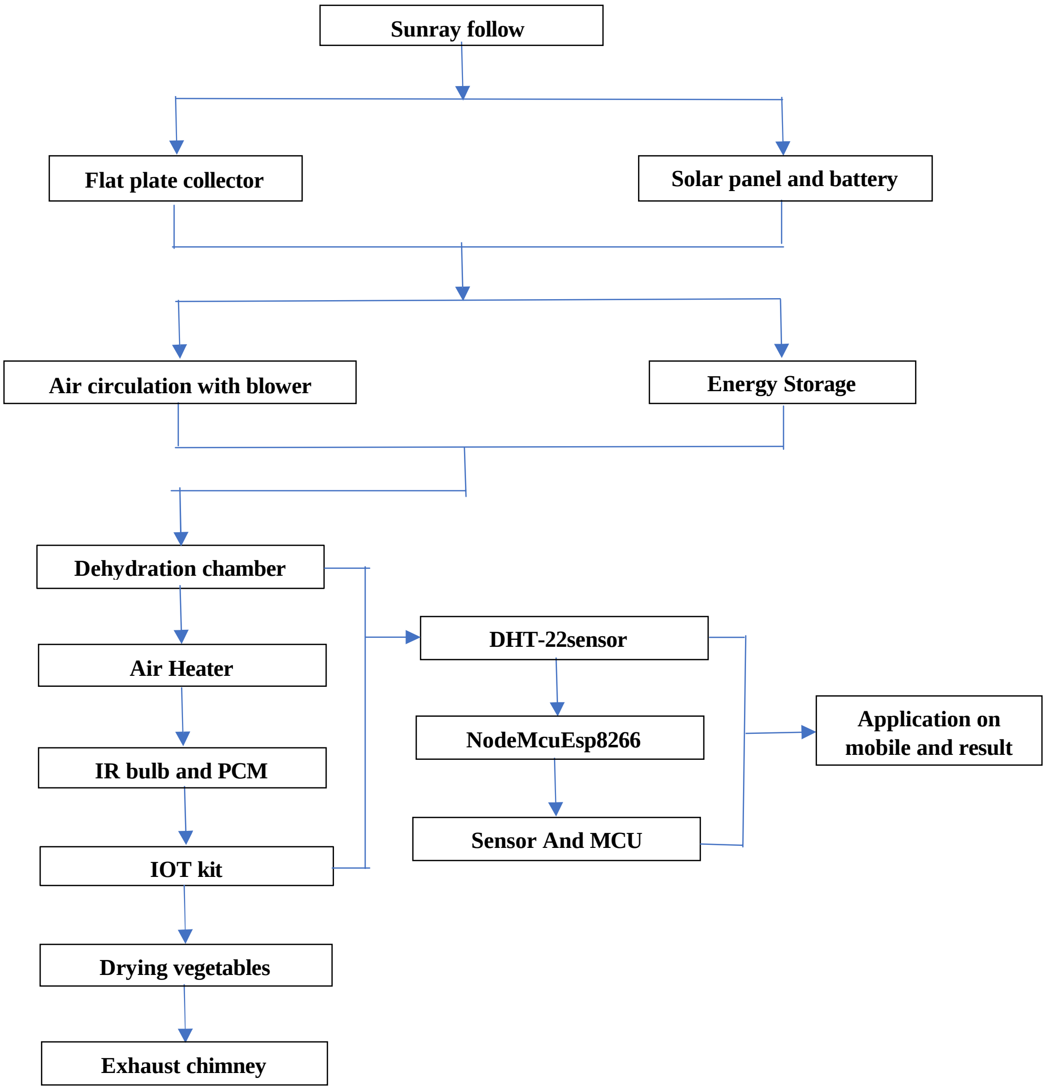


Fig.1 Solar dehydration system process

Monitoring with IOT Application

The term IoT stands for the Internet of Things, which refers to a network of physical objects equipped with sensors, software, and other technologies to facilitate data exchange with other devices and systems via the internet. The development of these objects has been driven by the integration of various technologies, including real-time analytics, machine learning, commodity sensors, and embedded systems. IoT devices have a wide range of applications, typically categorized into consumer, commercial, industrial, and infrastructure sectors.

Use of IOT in solar dehydration system

Fig2.show This application contains sensors and one microcomputer unit enabled with Wi-Fi connectivity. Sensor senses the temperature and humidity levels and send state do MCU (micro controller unit) this unit is programmed to take input from sensors and forward it to the user's device over the Wi-Fi connectivity. The internet of things (IOT) in a solar dehydration system allows the user to monitor and control or detect the temperature and humidity levels in chamber for better results. In dehydration system temperature and humidity varies throughout the day. So, by this application usercan monitor system parameters remotely in mobile phones with the help of IOT application.

Fig2. IOT Kit.

Working IOT Kit

The Internet of Things(IoT) describes a system of connected physical devices that collect and exchange information over the internet. Here's an overview of how it functions:

1. Sensors/Devices: IoT devices are outfitted with sensors that capture data from their surroundings, such as temperature, movement, humidity, and light.
2. Connectivity: This sensor information is sent to the internet using network connections like Wi-Fi, Bluetooth, Zigbee, or cellular networks.
3. Data Processing: A microcontroller or cloud server processes the data, allowing it to be analysed, decisions to be made, or actions to be triggered, such as turning on a fan if the temperature becomes too high.
4. User Interface: Users can observe and control these devices through applications or dashboards on their smart phones or computers.
5. Automation and Control: The system can automatically execute actions, such as sending notifications or switching devices on or off, based on the data and predetermined rules.

2. IOT INTEGRATION

DHT22 Sensor:

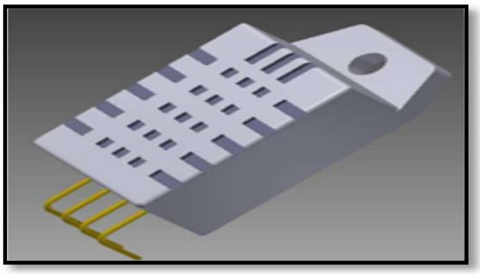


Fig 3. DHT22 Sensor

Fig3.depicts the DHT22, a budget-friendly digital sensor engineered for the measurement of temperature and humidity. It operates by integrating a capacitive humidity sensor with a thermistor to gauge the surrounding air, sending a digital signal through its data pin. The DHT 22 employs a single-wire serial interface for communication with the microprocessor unit. The sensor's data pin is responsible for data transmission and connects directly to the microprocessor. When powered on, the sensor remains in an unstable state for one second, during which no instructions should be sent. The communication between the MCU and the sensor takes 5 milliseconds. Fig 3.

Show cases the Node MCUESP 8266:

Fig 4. outlines the Node MCU as an economical, open-source IoT platform. In this context, MCU refers to the Microcontroller Unit, which acts as a development platform for both hardware and software, built on the System on a Chip known as Wi-Fi (SoC) ESP8266. The Node MCU ESP8266 development board is equipped with the ESP-12E module, which integrates the ESP8266 chip featuring a Tensilica Xtensa32-bit LX106RISC microprocessor. This microprocessor is compatible with RTOS and can function at frequencies between 80MHz and 160MHz. It offers 128KB of RAM and 4 MB of flash memory for storing data and programs. Its powerful processing capabilities, combined with built-in Wi-Fi, make it an excellent choice for IoT applications. The board can be powered using a micro-USB connection. The above Fig5. Shows connection of sensor and MCU. Connection is very simple and with little information any one can do connections of these two components.

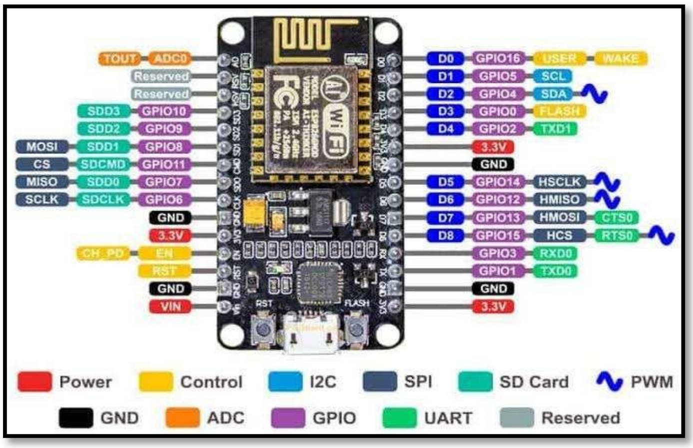


Fig4. NODE MCUESP8266

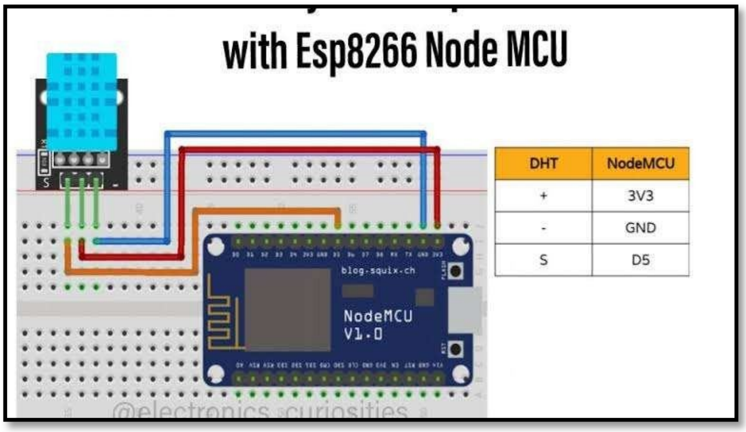


Fig5. Connection Diagram of Sensor and MCU Interfacing DHT22 Sensor with Node MCU ESP8266

It is laced on bread board it is has bunch of tiny holes it acts like a base to components; the pins are inserted in holes and wiring can be done of it. The DHT22 has 4 pins; VCC, Data, NC (not connected or no function), and GND. The GND of both components are needed to connected together. VCC can be either the 3.3V or 5V output, both on the ESP8266 or an external voltage. As DHT22 can operate at voltage of 3.3 to 6 volt, this can connect to Vin pin of ESP8266.The data pin of DHT22 is connected to GPIO pin 5 of ESP8266 in above showing Fig 5.

IOT Integration

The Node MCU can be programmed with the Arduino IDE to gather data from the DHT22 sensor and send it via Wi-Fi. By linking the Node MCU to a local Wi-Fi network, it can host a webpage that shows real-time temperature and humidity data. This setup allows for remote monitoring and management, making it ideal for uses like environmental monitoring in agricultural environments, such as a solar dehydration system for drying chilies. If you require help with the Arduinocode for this configuration or more information on incorporating it into your solar dehydration system.

3. RESULT AND DISSOCIATION

Introduction

They are observation result in 2kg, 5kg and 10kg drying chill with calculated in humidity are temperature with IOT kit. They are below showing result also drying time in 2kg, 5kg and 10kg. they are chilli moisture contain calculated they are only drying chilli. They are indirect solar dehydration system.

2kg Drying Result Chilli

Table 2. Observation Result 2kg Drying Chilli

Time	INTENSITY (w\m^2)	CH1 (^{o}C)	CH2 (^{o}C)	CH3(^{o}C)	Tin(^{o}C)	Tout (^{o}C)	Ta(^{o}C)	HUMIDITY (%)
10:00am	689.3	28	30	31	29	29	31	42
10:15am	720.3	29	27	27	31	31	31	43
10:30am	730.2	26	28	28	32	35	32	45
10:45am	739.2	28	75	31	50	55	32	47
11:00am	759.6	37	50	32	48	36	30	39

Table2. shows installed in solar radiation sat10:30am; at that the time initial weight 2KG and initial temperature of food sample 28^{o}C. It increased gradually; because of the solar radiations and maximum solar intensity observed 584.4 w\m^2, and wind speed 2.50m/sec. At this conditions weight of dried sample obtained 144gm, the moisture removed 85.6% from food sample in 1 hour 15 minutes.

5kg drying result chilli

Table 3. Observation Result 5kg Drying Chilli

Time	INTENSITY (w\m^2)	CH1(oC)	CH2 (oC)	CH3 (oC)	Tin(°C)	Tout(°C)	Ta(°C)	HUMIDITY (%)
01:00pm	429.2	32	55	45	58	41	32	38
01:15pm	398.2	33	52	44	32	42	31	39
01:30pm	382.5	36	54	45	34	35	31	38
02:00pm	380.2	34	68	43	30	37	30	39
02:15pm	376.2	35	71	44	38	38	30	41
02:30pm	368.3	37	59	42	34	38	29	41
03:00pm	347.6	36	57	34	35	32	28	39

Table 3 presents the solar radiation system setup at1:00 PM, where the starting weightwas5 kg and the initial moisture content stood at 85%. Over the course of two hours, 80% of the moisture was removed from the food sample. Table 6.34 provides insights into the performance of a solar-assisted chili drying system during the two-hour period from1:00PM to 3:00 PM. Throughout this time, solar intensity decreased from 429.2 W/m² to 347.6 W/m², reflecting the natural progression of the day. Temperatures within the drying chamber (CH1, CH2, CH3) varied, with CH2 reaching a peak of 71°C at 2:15 PM, while CH3 maintained comparatively lower temperatures. The inlet air temperature (Tin) remained stable, averaging around 34°C, whereas the outlet air temperature (Tout) varied between 35°C and 41°C, indicating effective moisture removal. The ambient air temperature (Ta) fell from 32°C to 28°C, and the relative humidity inside the chamber ranged from 38% to 41%, suggesting efficient drying conditions. These findings align with similar research, such as a study conducted at the Bangladesh Agricultural Research Institute, where solar dryers achieved drying efficiencies of 3.81% for red chili, with drying chamber temperatures ranging from 46°C to 60°C. This data underscores the effectiveness of solar- assisted drying systems in reducing moisture content and enhancing the quality of dried chilies. Refer to Table 3 above.

10kg drying result chilli

Table 4. provides an overview of the drying process for 10 kg of chili, as detailed below. The data reveals that as solar intensity rose from 578.5 W/m² at10:00 AM to 789.9 W/m² by noon, the temperatures within the drying chamber (CH1, CH2, CH3) also increased, peaking at 12:00 PM. This trend indicates that the drying system effectively captured solar energy. The inlet air temperature (Tin) remained fairly constant, while the outlet air temperature (Tout) fluctuated between 35°C and 42°C, demonstrating efficient moisture extraction from the chilies. The ambient air temperature (Ta) showed minor variations, and the relative humidity inside the chamber ranged from 38% to 42%, suggesting favourable drying conditions. These findings are in line with similar research, such as a study at the Bangladesh Agricultural Research Institute, where solar dryers achieved a drying efficiency of 3.81% for redchili, with chamber temperatures between 46°C and 60°C. Furthermore, a study on solar tunnel dryers reported a decrease in moisture content from 75% to 5% over 48 hours, underscoring the effectiveness of solar drying systems in improving the quality and shelf life of dried chilies. Table 4 is displayed below.

Table 4. Observation10kg Drying Chilli

Time	INTENSITY (w\m^2)	CH1(°C)	CH2 (°C)	CH3 (°C)	Tin(°C)	Tout (°C)	TaoC	HUMIDITY (%)
10:00am	578.5	29	51	32	31	37	30	42
10:30am	554.2	31	52	36	36	35	30	41
11:00am	612.2	35	56	38	33	39	31	39
11:30am	648.8	55	59	45	36	42	31	39
12:00pm	789.9	36	62	42	30	40	32	38
12:30pm	766.3	32	55	41	32	41	32	38
01:00pm	728.5	29	51	32	31	37	30	42
01:30pm	654.2	31	52	36	36	35	30	41

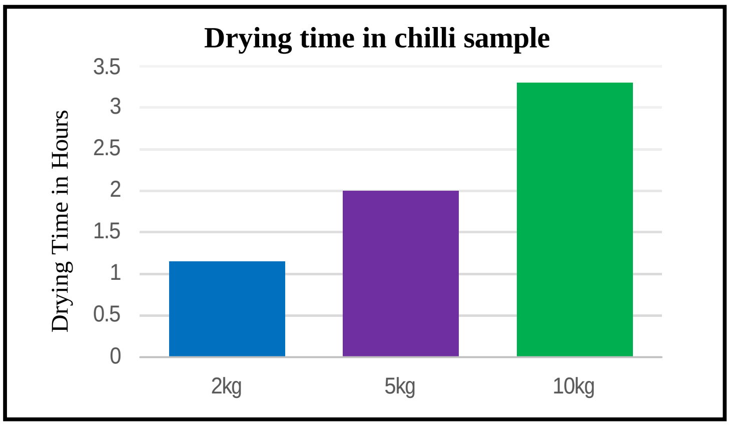
Table 6.41 shows system installed in solar radiations at 10:00 am at this moment initial weight was 10KG and initial moisture content was 85% the moisture removed 80% from the food sample in 3 hours 30 minutes.

Comparing 2kg, 5kg and 10kg Graph 1: Comparison of Drying Times for 2kg, 5kg, and 10kg of Chilli Using a Solar Dehydration System. The drying time for 2 kg of chillies is approximately 1 hour and 15 minutes. The system is equipped with an IoT kit that monitors humidity and temperature during the drying process. For 5kg of chillies, the drying time extends to 2 hours, while drying 10 kg of chillies takes about 3 hours and 30 minutes.

4. CONCLUSION

This research focuses on the development of an Internet of Things (IoT)-based solar dehydration system for drying chili peppers. The system employsaDHT22 sensor, which communicates temperature and humidity data to a microcontroller unit (MCU) via a single-wire serial interface. The MCU, an ESP8266-based Node MCU, is programmed using the Arduino IDE to read sensor data and transmit it over Wi-Fi.

By connecting the Node MCU to a local Wi-Fi network, it serves a web page display in a real-time temperature and humidity readings.



Graph1. Comparing 2kg, 5kg and 10kg Drying Chilli

The system is designed to dry chili samples weighing 1kg, 5 kg, and 10 kg. The drying times for these samples are as follows: 1 hour 15 minutes for 1 kg, 2 hours for 5 kg, and 3 hours 15 minutes for 10kg. These drying times are determined based on the weight of the chili samples and the efficiency of the solar dehydration system. 2kg, 5kg and 10kg humidity 38% to 47%.

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