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Design and Fabrication of Hybrid Solar Dryer for Drying of Agricultural Food Products

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Abstract: ***Solar Drying Technology is used since years in different parts of the world. Depending upon the weather conditions there is variation in use of the solar dryers. For Example in countries/ regions where there are winter season throughout the year and there is no availability of sunlight solar dryers are not applicable. There are mainly two types of solar dryers i.e Direct and Indirect type Solar dryer. In this project we designed a Indirect type Solar dryer which works in Active mode (forced circulation) for the circulation of heated air which is used for the purpose of drying of food products. The main parts of the solar dryer are collector (Area where heat is collected through solar radiations) and chamber (Area where food products to be dried are stored). The main objective of this project was to design a solar dryer using hybrid technology which can help in continuous drying even when there is no availability of sunlight and for achieving this we used heating element which we controlled through a light sensor which helps to increase the efficiency of the drying process . The light sensor sense the brightness of the environment and operates heating element during the dark. Fans used for circulation works on a battery which stores charge from the solar panel. The temperature inside the drying chamber can be monitored on the lcd display paired with a temperature sensor which gives reading in Celsius. For the Automation of our project we used Arduino Uno R3 which contains a microcontroller to store the program by making use of Arduino software.***

Keywords: Indirect, Active, Hybrid, Automation.

I. INTRODUCTION

Solar dryers are devices that use solar energy to dry substances, especially food. Traditional drying methods use solar radiation to heat directly the products and to natural air currents. Hence, products drying using solar energy is a method that has been practiced for thousands of years. In traditional drying methods are also known as open sun drying, the products are spread on the ground or platform, where they are directly exposed to the sun and wind. despite of using the solar radiation that is freely available in an ambient environment, a little capital cost and less labour are required. However, this method produces low quality products and also results in considerable losses due to various influences such as an animal attack, insect infestation and rain. Historically, food and clothing was dried in the sun by using lines, or laying the items on rocks or on top of tents. In these systems the solar drying is assisted by the movement of the air that removes the more saturated air away from the items being dried.

One modern type of solar dryer has a black absorbing surface which collects the light and converts it to heat; the substance to be dried is placed directly on this surface. These driers may have enclosures, glass covers and/or vents to in order to increase efficiency. it is easier to protect the food, or other substance, from contamination whether wind-blown or by birds, insects, or animals. Also, direct sun can chemically alter some foods making them less appetizing.

A. Different Solar Drying Methods

Solar dryers can be classified by two types, active and passive mode. Passive dryers can be further divided into direct and indirect models. A direct solar dryer is a system in which the food is directly exposed to the solar radiations only in which the material to be dried are placed in a transparent enclosure of glass or plastic or with reflected radiations such as box dryer. Reflected radiations are used to increase the temperature in the box dryer. In an indirect solar dryer, solar radiation do not falls directly onto the product being dried, but pre-heater or collecter is used to raise the hot air temperature in the dryer chamber. Passive dryers can be called natural convection in which the fluid motion is generated by density differences in fluid occurring due to temperature gradients. They can be constructed easily with inexpensive and locally available materials. This is a simple and economical method to preserve food for a long period of time storage. Active dryers are required an external means such as fans or pumps. It is used for moving the heated air from the collector area to the drying chamber. The drying rate is higher compared with passive methods. However, for drying operation in mixed- mode solar dryer, the combination action process of solar radiation incident on the material to be dried and the air preheated in solar collector provide the heat required for the drying operation.

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II. LITERATURE REVIEW

1) (Imre, 2014), Direct, indirect and mixed dryers Direct solar dryers are characterized by the use of transparent covers to protect the crop from rain, dust and other sources of contamination,while indirect dryers use opaque chambers and solar collectors as a separate or inbuilt structure. Although, in both cases solar radiation is used as the principal source of heat, the direct heat gain differs due to the configuration of one or another. For example, while indirect dryers use the solar collector to increase the temperatures of the air inside the drying chamber, direct dryers rely on the absorption of solar radiation by the product.The latter method results in a poor product quality, primarily due to the poor hygienic conditions. During open-air sun drying, solar radiation is absorbed by the product surface , heat and moisture transfer take place by natural convection and diffusion, respectively. The whole process depends on the weather conditions, solar radiation, and natural air velocity (prevailing wind). This classifies it as an unsteady state process.

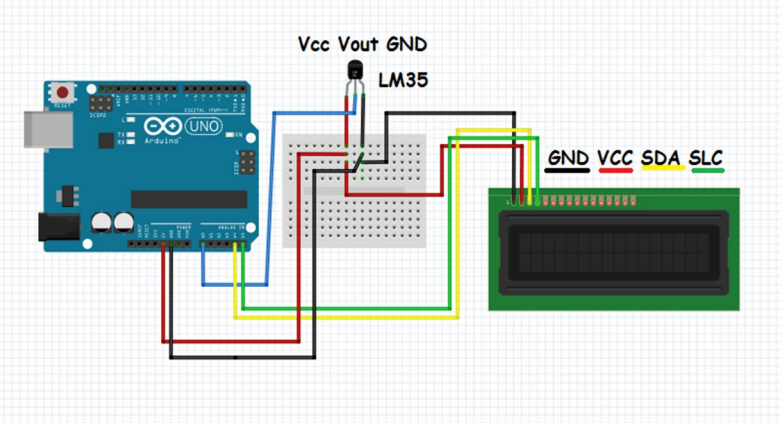
2) (Omolola et al., 2017)The intense labor involved in product handling and poor heat absorption, mixed with cross-contamination problems due to exposure in the open air, limit the drying process for open-air sun drying. Despite some of the disadvantages of this low temperature method, open-air sun drying does better in preserving some nutrients. However, some browning and bleaching occurs due to the product being directly exposed to the sun .Solar Drying Contrary to open-air sun drying, solar drying involves the use of an enclosed space to concentrate solar irradiation and temperature, and in many cases increased airflow in order to increase crop drying rates and prevent contamination by foreign materials. Thus, it reduces dust, insects, rodents, and contamination from the environment. Furthermore, solar drying uses different ways to concentrate heat, thus utilizing the solar radiation more effectively. Different types of solar dryers have been developed over time, involving several different thermal capture and heat transfer methods, and special configurations .These designs are still based on empirical 31 knowledge rather than fundamental physics and engineering theory. The lack of scientific background makes standardization a difficult task. This is reflected on the final quality of the product, and the possible markets it can be sold in. Besides the thermal capture of heat, forced airflow is used to achieve higher drying rates. These solar-energy forced air convection dryers are also classified into direct, indirect or mixed types of active dryers.

III. METHODOLOGY

Active Solar Dryers / Forced convection Dryer is designed to incorporate external means such as fan and pumps. For moving solar energy which is in the form of heated air from the collector area to the heating chamber. These external devices are used for Air circulation.The heated air is forced in to the drying chamber where it will increase the drying rate and decrease the drying time therefore increasing the thermal efficiency.This type of Dryer is suitable for large scale food processing industries. Automation is required for the better efficiency of solar dryers and continous production as per the requirement of the market which is achieved by making use of Arduino UNO & programming it using microcontroller board based on the ATmega328P . Different Electronic components are used for the automation of the dryers to operate and monitor different parameters and obtain desired drying rate in Less amount of time.

A. Circuit Diagram

1) Temperature Display Using Lm35 Sensor And I2c Lcd Display



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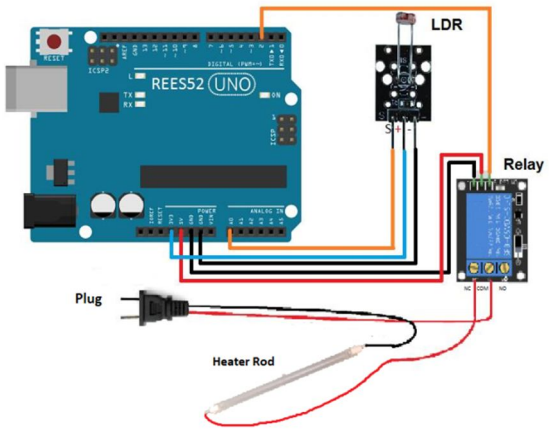
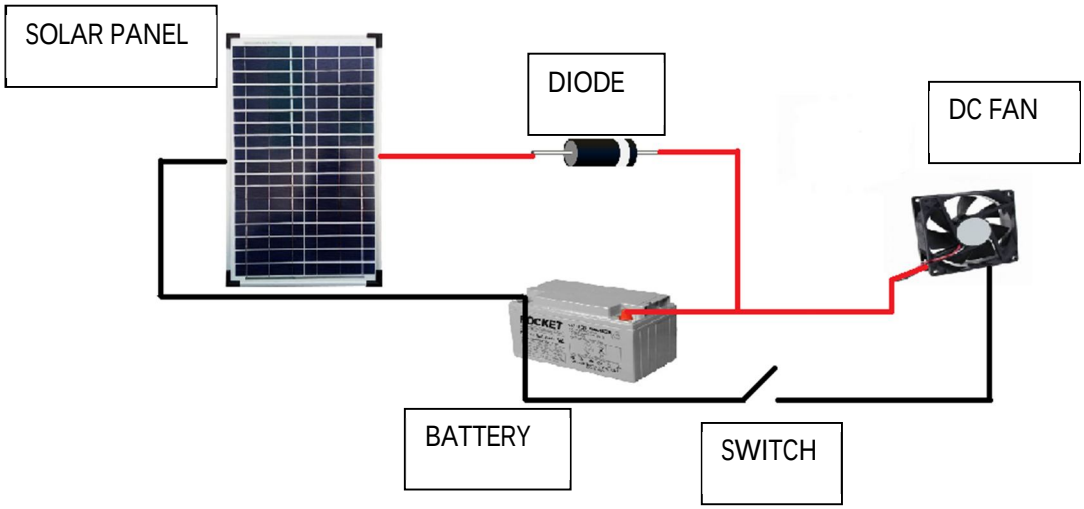
2) Heater Rod On/Off Using LDR And Single Channel Relay



3) Solar Panel Charge Battery And Fan Operated Using A Switch



B. Components And Their Function

1) Arduino UNO

Fig. Arduino Uno R3

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The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

2) Solar Panel

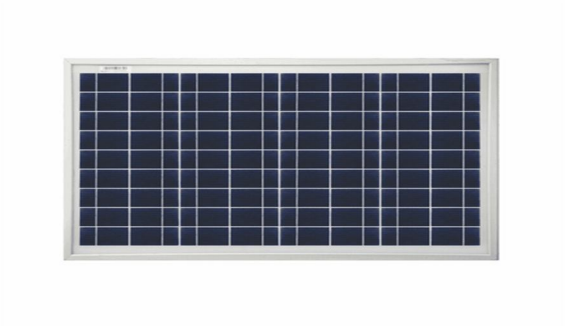

Fig. Solar panel

A solar panel, or photo-voltaic (PV) module, is an assembly of photo-voltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel, and a system of Panels is an Array. Arrays of a photovoltaic system supply solar electricity to electrical equipment. Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can be either the top layer or the back layer. Cells must be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells are connected electrically in series, one to another to the desired voltage, and then in parallel to increase amperage. The wattage of the module is the mathematical product of the voltage and the amperage of the module. The manufacture specifications on solar panels are obtained under standard condition which is not the real operating condition the solar panels are exposed to on the installation site.

a) Specifications

Max Rated power = 10 watts
Voltage at Max Power = 17.3 V
Current at Max power = 0.59 A
Open circuit Voltage = 21.8 V
Short Circuit current = 0.64 A
Dimensions = 13.8 x 11.8 x 0.98 inch

3) Relay Module (5v Single Channel)

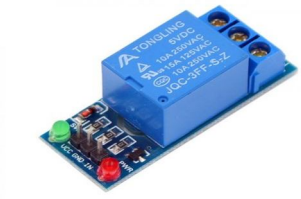

Fig. Relay Module

The Single Channel Relay Module is a convenient board which can be used to control high voltage, high current load such as motor, solenoid valves, and AC load. It is designed to interface with microcontroller such as Arduino, PIC and etc. The relays terminal (COM, NO and NC) is being brought out with screw terminal. It also comes with a LED to indicate the status of relay.

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a) *Specifications*

- Digital output controllable
- Compatible with any 5V microcontroller such as Arduino.
- Rated through-current: 10A (NO) 5A (NC)
- Control signal: TTL level
- Max. switching voltage 250VAC/30VDC
- Max. switching current 10A
- Size: 43mm x 17mm x 17mm

4) Battery

ES-7.0AH 12V

Fig. Battery

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy.[A *dry cell* uses a paste electrolyte, with only enough moisture to allow current to flow. In some designs, the ammonium chloride is replaced by zinc chloride.

a) Specifications

Nominal Voltage	**12V**
Nominal Capacity	25 degree Celsius
Short Circuit Current	350 A
Temperature Compensation	-20mV/degree Celsius
Design Life	3-5 years
Number of Cell	6
Discharge	20-60 degree Celsius
Maximum Charging Current	2.8A
Temperature Compensation	30mV/C
Length	151mm/5.94inch
Width	65mm/2.56 inch
Height	93.5mm3.68 inch
Weight	2.32 kg/5.12 lbs

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5) DC Fan (12v)

Fig. DC Fan

This Brushless DC Cooling Fans are operating at 12V with a dimension of 80x80mm. They are typically found in ATX Computer cases, servers, and other enclosed equipment but they can also be used in a variety of other projects requiring moderate airflow. The fan spins at ~2600 RPM and can move approximately 30CFM.

6) LDR (Light Dependent Resisitor)

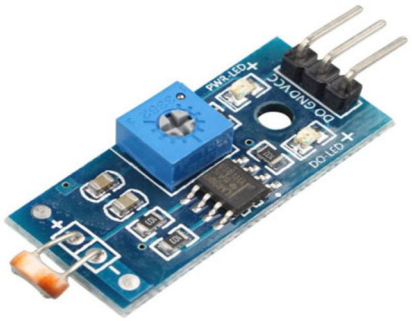

Fig. Light dependent resistor

Light dependent resistors, LDRs or photoresistors are often used in electronic circuit designs where it is necessary to detect the presence or the level of light. These electronic components can be described by a variety of names from light dependent resistor, LDR, photoresistor , or even photo cell, photocell or photo conductor. Although other electronic components such as photodiodes or photo-transistor can also be used, LDRs or photo-resistors are a particularly convenient to use in many electronic circuit designs. They provide large change in resistance for changes in light level.In view of their low cost, ease of manufacture, and their ease of use, LDRs have been used in a variety of different applications. At one time LDRs were used in photographic light meters, and even now they are still used in a variety of applications where it is necessary to detect light levels.

a) Specifications

- Operating Voltage: 3.3V to 5V DC.
- Operating Current: 15ma.
- Output Digital - 0V to 5V, Adjustable trigger level from preset.
- Output Analog - 0V to 5V based on light falling on the LDR.
- LEDs indicating output and power.
- PCB Size: 3.2cm x 1.4cm.
- LM393 based design.

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7) Switch

Fig. Switch

A switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit, interrupting the electric current or diverting it from one conductor to another. The most common type of switch is an electromechanical device consisting of one or more sets of movable electrical contacts connected to external circuits. When a pair of contacts is touching current can pass between them, while when the contacts are separated no current can flow. Switches are made in many different configurations; they may have multiple sets of contacts controlled by the same knob or actuator, and the contacts may operate simultaneously, sequentially, or alternately. A switch may be operated manually, for example, a light switch or a keyboard button, or may function as a sensing element to sense the position of a machine part, liquid level, pressure, or temperature, such as a thermostat. Many specialized forms exist, such as the toggle switch, rotary switch, mercury switch, push-button switch, reversing switch, relay, and circuit breaker. A common use is control of lighting, where multiple switches may be wired into one circuit to allow convenient control of light fixtures. Switches in high-powered circuits must have special construction to prevent destructive arcing when they are opened.

8) LM 35 Temperature Sensor

Fig. LM 35 Temp sensor

a) LM35 is a temperature measuring device having an analog output voltage proportional to the temperature.
b) It provides output voltage in Centigrade (Celsius). It does not require any external calibration circuitry.
c) The sensitivity of LM35 is 10 mV/degree Celsius . As temperature increases, output voltage also increases E.g. 250 mV means 25°C.
d) It is a 3-terminal sensor used to measure surrounding temperature ranging from -55 °C to 150 °C.
e) LM35 gives temperature output which is more precise than thermistor output.

9) Pin Description

a) VCC: Supply Voltage (4V – 30V)
b) Out: It gives analog output voltage which is proportional to the temperature (in degree Celsius).
c) GND: Ground

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10) Heater Rod

Fig. Heater rod

Heater rod is used a element for heating the chamber where the food product to be dried is placed on the drying tray . The heater rod operates on Ac voltage and gets heated due to the heating element present inside a glass coating . It consists of two terminals which are onnected to the ac plug one terminal is neutral and the other live. Different materials are used for the heating element in different types of the heating rod the glass tube have a risk of getting break and needs proper handling . For mounting it we require two supports inside the collector area.

a) Specification

- Weight : 250 g
- Dimensions (L x W x H) : 22 x 2 x 2 Centimeters
- Power Consumption : 400 WATTS
- Operating Voltage : 230

11) I2C LCD Display

Fig. I2C Lcd display

An LCD (Liquid Crystal Display) screen is an electronic display module and has a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols. This LCD has two registers, namely, Command and Data. Command register stores various commands given to the display. Data register stores data to be displayed. The process of controlling the display involves putting the data that form the image of what you want to display into the data registers, then putting instructions in the instruction register. In your Arduino project Liquid Crystal Library simplifies this for you so you don't need to know the low-level instructions. Contrast of the display can be adjusted by adjusting the potentiometer to be connected across VEE pin.

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IV. DESIGN AND CALCULATIONS

A. Design

1) 3D Design of Parts

Fig. 3D Model of Collector

Fig. 3D Model of Chamber

2) 3D Design Of Assembly

Fig. Assembly of the Model

B. Calculations

1) Moisture Removal

$$\text{Moisture Removal (\%)} = \frac{W2-W3}{W2-W1} * 100$$

Where,

W1= Weight of Drying tray (grams)
W2 = Weight of Drying tray + Weight of sample before Drying (grams)
W3 = Weight of Drying tray + Weight of sample After Drying

V. OBSERVATIONS

A. Volume of the Drying Chamber = 1860 m^3
B. Capacity of the Drying Chamber = 500- 1000g
C. Weight of Single tray = 778 grams
D. Time required to charge the 12v 7Ah Battery = 7 – 8 Hrs
E. Current consumption By a single Dc fan 12 v = 0.26 A
F. Overall consumption of current = 0.78 A
G. Max Running Time of fan on Battery = 7Ah / 0.78 = 8.9 Hrs

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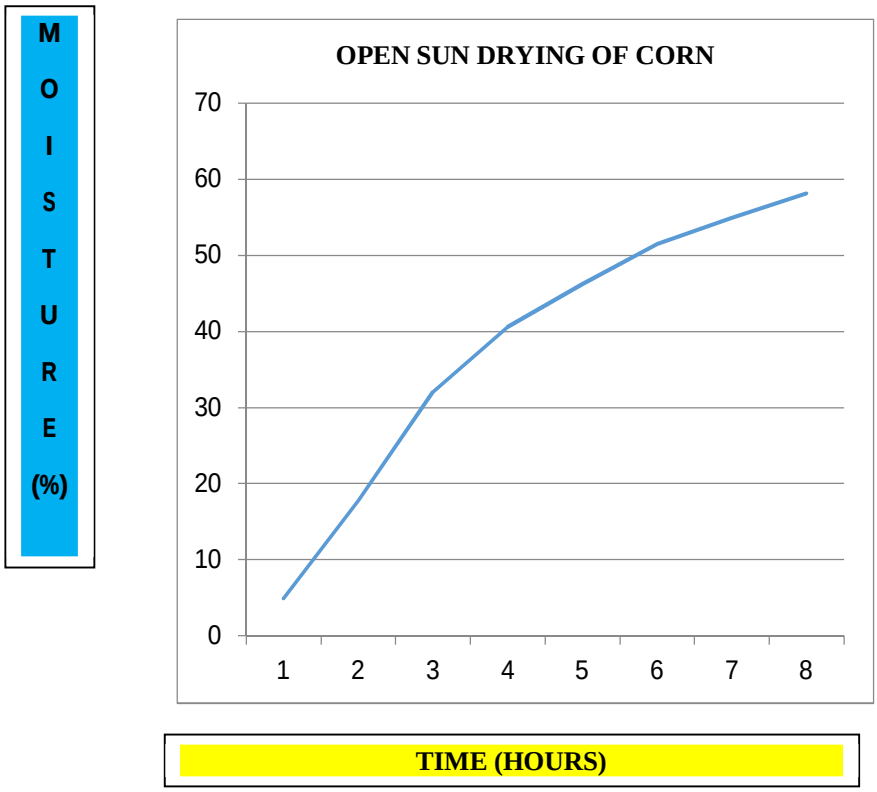
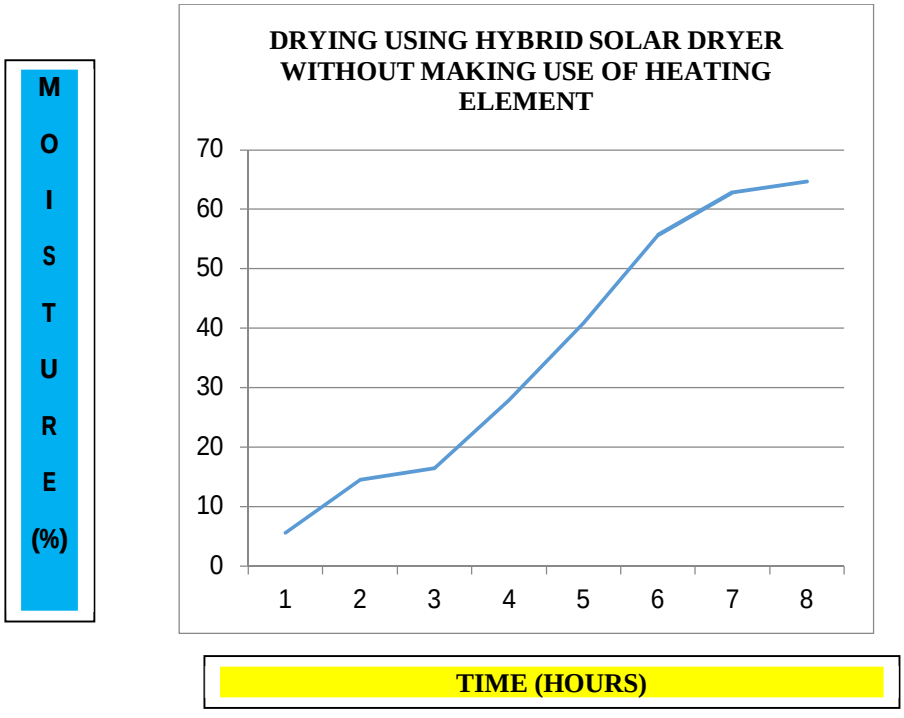
VI. RESULTS

(Time V/S Moisture Removal Graphical Representation For Drying Ofcorn)





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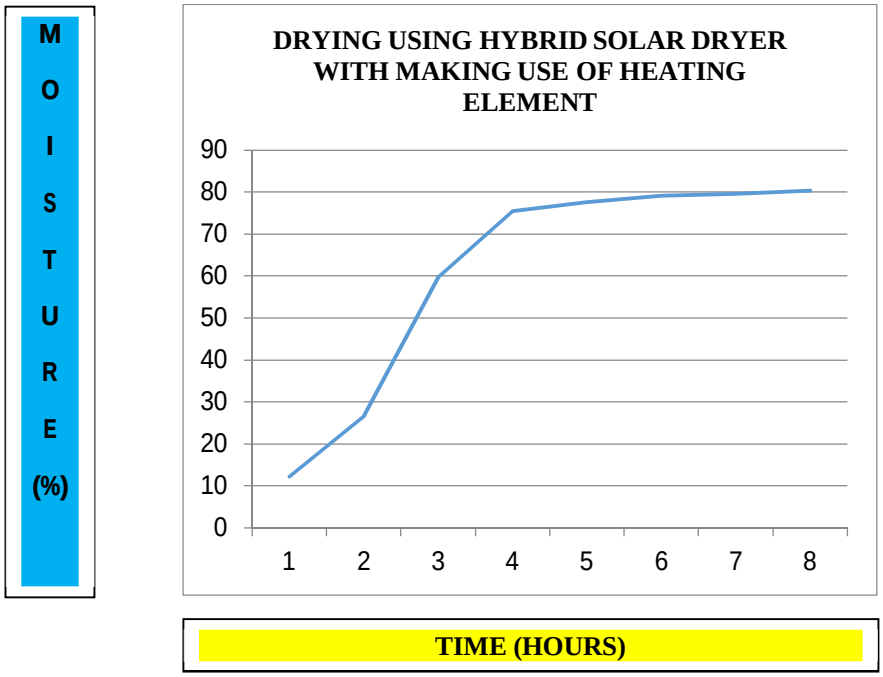
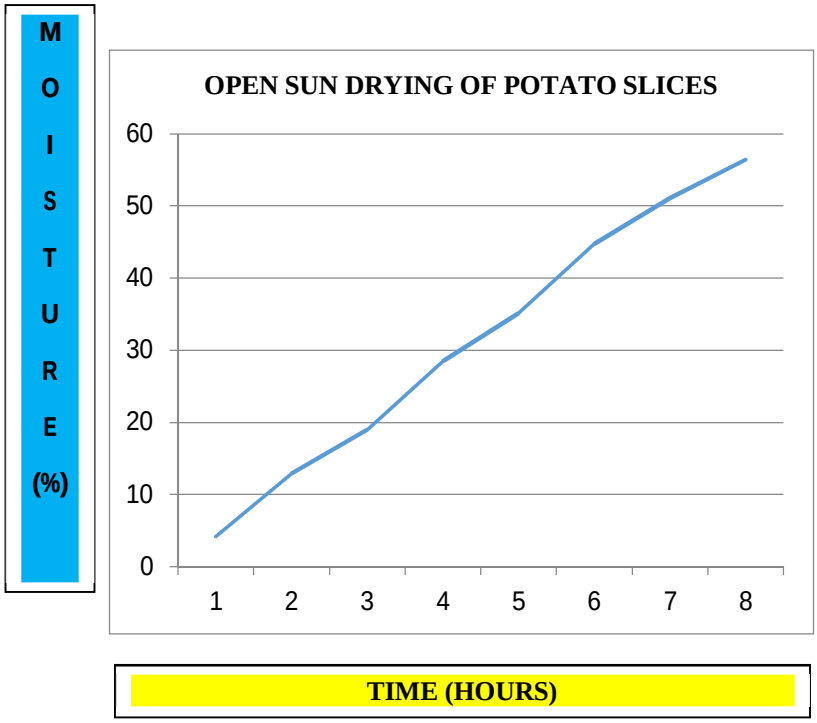


(Time V/S Moisture Removal Graphical Representation for Potato Slices)



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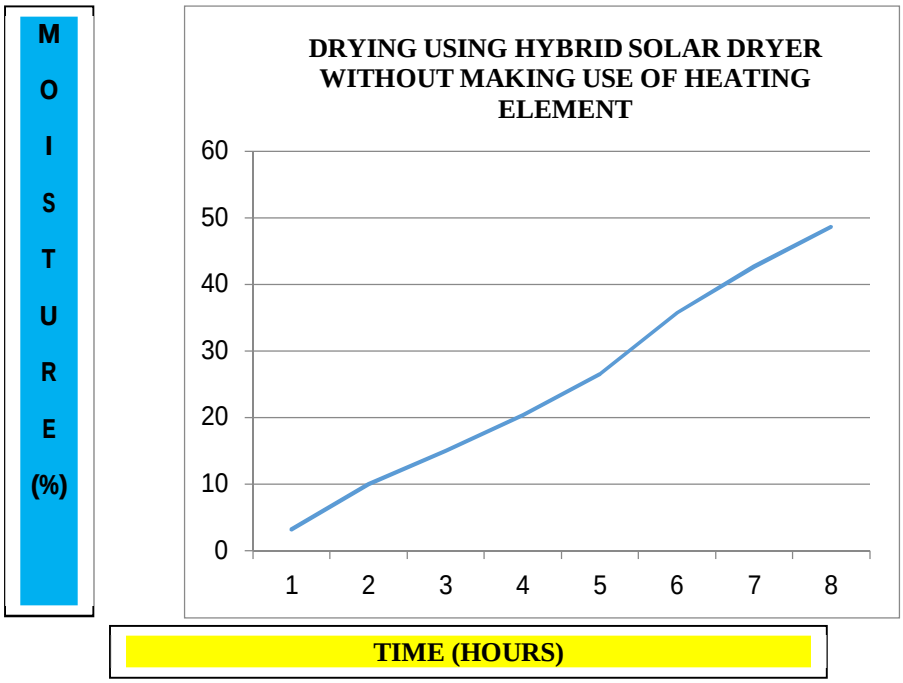

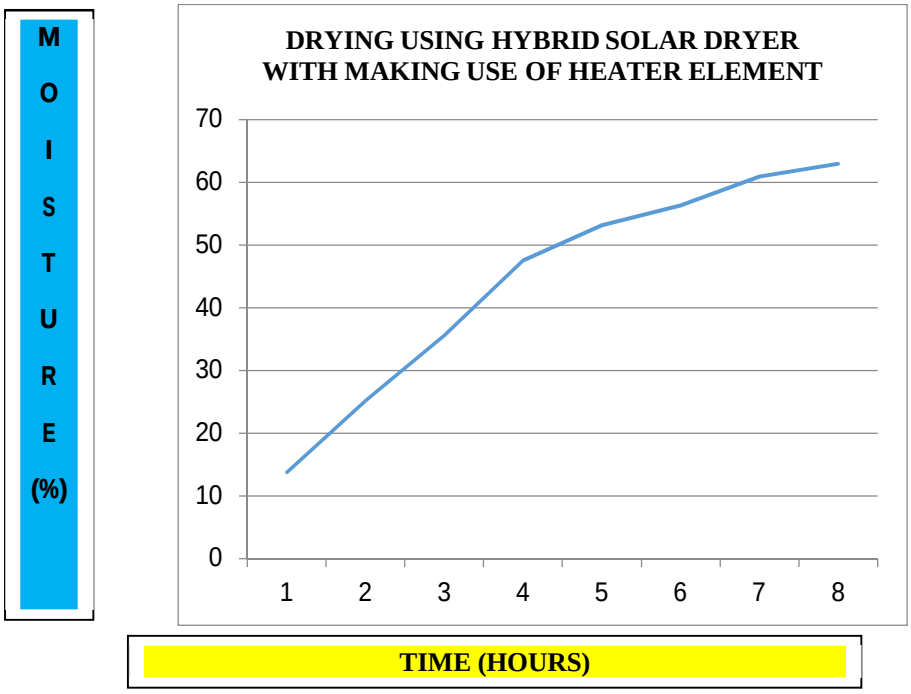

A. The amount of moisture removed in case of drying food products using the Hybrid soalr dryer is more compared to the open sun drying .
B. The fan can be operated whenever required with the help of switch.
C. The Time required is less for drying if we make use of heating element in the solar dryer rather than making use of solar rays .
D. The use of heating element makes it possible to achieve the process of drying even in absence of the solar radiations.
E. The maximum temperature inside the chamber achieved is 75 degree Celsius.
F. The process of drying is more efficient using a Hybrid soalr dryer in case of corn compared to the potato slices .
G. This project helped to increase drying efficiency by 6% in case of corn and 4% in case of potato slices.

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VII. CONCLUSION

This project helped us to learn about different technologies used in drying of different types of agricultural food products. The use of automation helped in achieving the continuous drying process which is a very important aspect in today's rapid lifestyle. The use of programming through Arduino board and different electrical components required study and in turn develop our interest in the field of electrical and software Engineering. This setup can be easily transported to the place of use as it has wheels installed to the frame and easy to install due to less parts .

VIII. FUTURE SCOPE

A. As we have designed a small Solar dryer for the study purpose having only 1kg capacity of drying at a time which can be increased by designing a dryer having larger dimensions.

B. Use of Big fans can increase the rate of air passing from the collector to the chamber area which will result in higher drying rates.

C. Use of More than single heating element will help in increasing the temperature inside the chamber within a short amount of time.

D. As we have used 10 watt solar panel which can be replaced by more wattage solar panel to charge the battery at a faster rate.

E. Different food products can be used and studied for the comparision.

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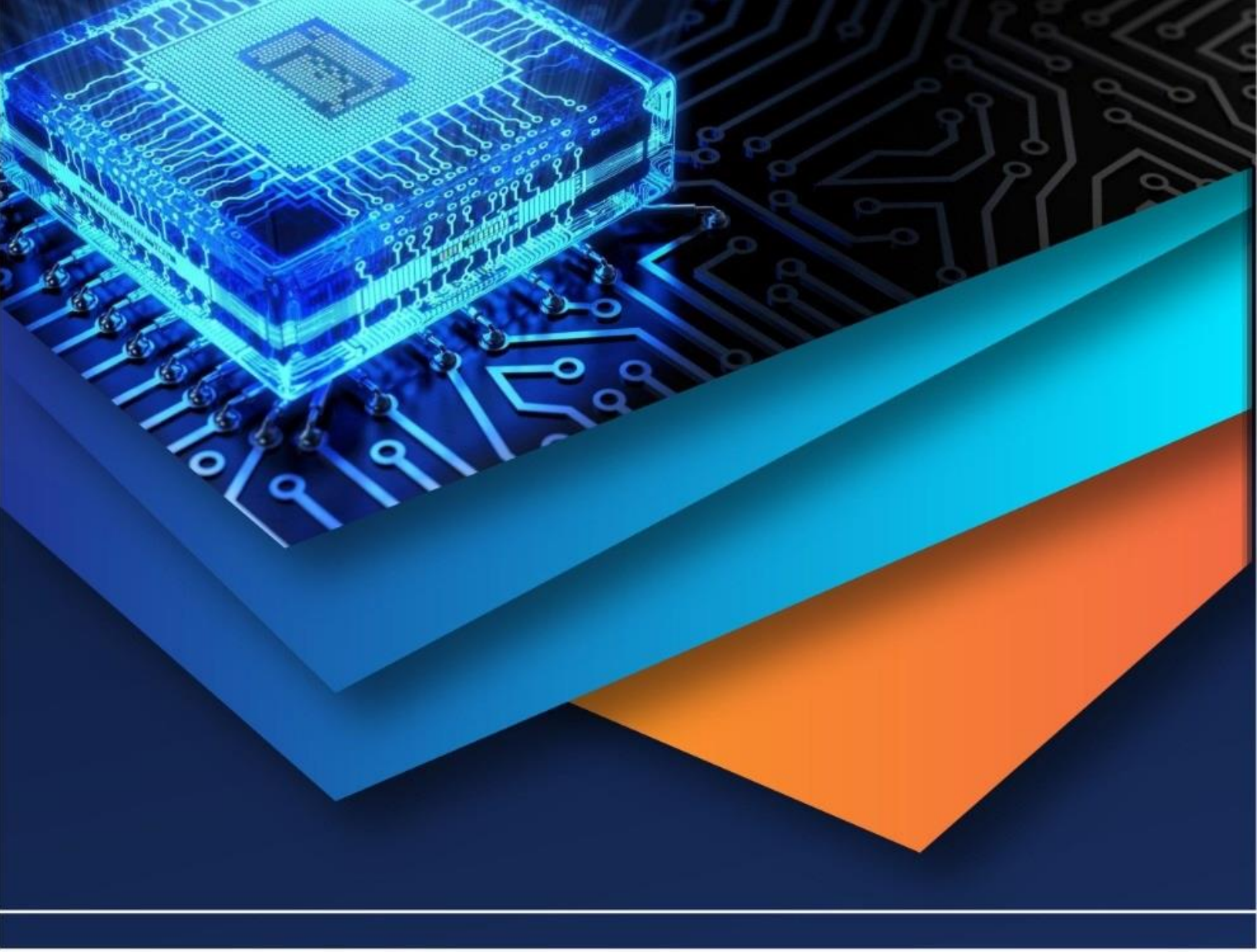

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