Automated Temperature Controlled Solar Dryer for Ascorbic Acid Retention in Fruits

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Abstract— *This paper proposes to analyze a solar drying model with an Arduino controller for controlled temperature drying to ensure efficient drying. The biggest limitation of the traditional sun drying method is that the temperature is not properly controlled. An automatic temperature-controlled drying process produces high-quality drying of fruits. The goal of this project is to produce an affordable, easy-to-use solar dryer with automatic temperature control capability for home and industrial use. It provides a continuous monitoring function and eliminates the need for regular temperature testing. In this created miniature model, the drying efficiency of automatic temperature-controlled solar drying is 6% higher than that of conventional solar drying, and temperature drying removes 8.33% more moisture from the product for lemon peel. The dried final product of the miniature model has 20% more ascorbic acid than the sun-dried product.*

Keywords— Automatic Temperature controller, Solar dryer, LM35 sensor, Arduino UNO, Ascorbic acid retention.

I. INTRODUCTION

The world is racing toward automation everything we have done manually is now become automated. The conventional techniques for food safety and quality analysis (vitamin) are very tedious and time-consuming and require trained personnel. Therefore, there is a need to develop quick sensitive, and reliable techniques for quickly monitoring food quality and safety. This can be overcome by using the sensor and automation in the food processing industry. This research focuses on building and implementing automated temperature-controlled solar dryers at affordable prices with the help of microprocessors, sensors, cooling fans, transistors, etc. Controlling the temperature of food is extremely important in ensuring that food is safe to eat and must ensure that food is always cooked, cooled, chilled, or reheated properly to minimize the risk of harmful levels of bacteria in the foods.

The system for controlling temperature automatically is achieved by using an Arduino UNO-based microcontroller system. The test result is displayed with the help of the LCD. The program is written in Arduino IDE. The Arduino UNO board sends the temperature measurement input to the cooling fan, which is ON/OFF automatically based on the input values of temperature. To sense the temperature, an LM35 temperature sensor is used. Using an Arduino UNO board circuit, the temperature was Controlled automatically in a solar dryer. Initially, a small solar dryer model was developed which controls the inside temperature of the solar miniature model using an Arduino UNO board circuit. In this model temperature is controlled by a cooling system with the help of Arduino UNO board so that the product drying inside the solar miniature model, doesn't lose their nutrient or less amount of nutrients are lost. The scope of our project is to eliminate the need for continuous and manual monitoring of temperature, control the temperature of solar dryers, and prevent the destruction of vitamins in fruits during drying.

Ashara et al. (2015) suggested, that the design and implementation of microcontroller-based temperature control using an electric fan automatically switches the speed according to the change inner temperature of the box. The system contains an LM35 temperature sensor, 89C51 microcontroller, fan interface circuit, and the box. Khine (2015) suggested that the room temperature control system using a peripheral interface controller (PIC) is to provide the concepts of PIC and to develop the factories, buildings, and rooms by using temperature measurement and control systems. Sihombing et al. (2018) developed automatic control of the temperature of an oyster mushroom system, using an Arduino UNO microcontroller. The sensors are placed around the root of the oyster mushroom and will transmit the detection result every time to the Arduino microcontroller. Mangwala et al. (2018) studied the design and simulation of an automatic room heater control system. This system allows the user to set a desired temperature which is then compared to the room temperature measured by a temperature sensor.

Roy et al. (2019) revealed that the microcontroller forms the processing part, which firstly senses the temperature and the controller then compares the data with the set temperature. If the current temperature is less than the set temperature, the fan will be turned OFF the fan's speed will change according to the temperature. Aneja et al. (2019) cover the study of PLC, microcontrollers, and sensors which will be beneficial to readers in understanding the difference between the application of PLC and microcontrollers in controlling temperature. Thakre et al. (2017) examined the design and implementation of an automated temperature control system using a PIC microcontroller to control the temperature of the system. This project mainly includes the temperature control of the heater, temperature control of the surroundings in winter, and voltage control i.e., it works as a stabilizer & also as a dryer in rainy seasons. Siddika et al. (2018) evaluated that Arduino UNO forms the processing part. Firstly detect the human with the use of a PIR sensor and sense the temperature with the use of LM35 (Temperature sensor). Arduino UNO senses the temperature and controls the speed with the set temperature, which is set by the user. Tun (2018) studied the microcontroller-based temperature control system controls the temperature of any device according to its requirement for any industrial application. At the heart of the circuit is the PIC16F887. A microcontroller that controls all its functions.

II. MATERIALS AND METHODS

2.1 Arduino coding/programming and Simulation

In this work, Arduino code was developed in the Arduino IDE using a simple if-else statement to adjust the temperature of the solar drying cabinet. The temperature is controlled by a 12V cooling fan. The temperature reading is shown on a liquid crystal display, and the temperature is measured using an LM35 sensor. The temperature sensor LM35 is configured for two different temperatures and measures the temperature within the solar dryer. Arduino code was built for a variety of variables such as temperature range, fan speed, and LCD display. The Arduino UNO board delivers temperature measurement input to the cooling fan, which operates automatically based on the supplied temperature readings.

Tinkercad is an online set of Autodesk software tool that allows total beginners to make 3D models. This CAD software is based on constructive solid geometry (CSG), which enables users to generate complicated models by merging simpler components. It is entirely web-based, making it open to anybody with an internet connection. It has a search box to locate the necessary components (breadboard, LED, resistor, etc.) and set them in the worksheet or work area. All necessary components are searched for and placed before being interfaced and connected to each other in order for the coding to function properly. These components are arranged on a huge breadboard and then the connections are made.

2.2 Interfacing the LM35 and Cooling Fan with Arduino

LM35 is a temperature sensor that outputs an analog signal which is proportional to the instantaneous temperature. The output voltage can easily be interpreted to obtain a temperature reading in Celsius. It has 3 pins such Vs, Vout and GND. The Vs of the sensor is connected to the 5V supply from the breadboard. The GND is connected to the GND supply from the breadboard. The Vout is connected to the analog pin A1 as shown in Figure 1.

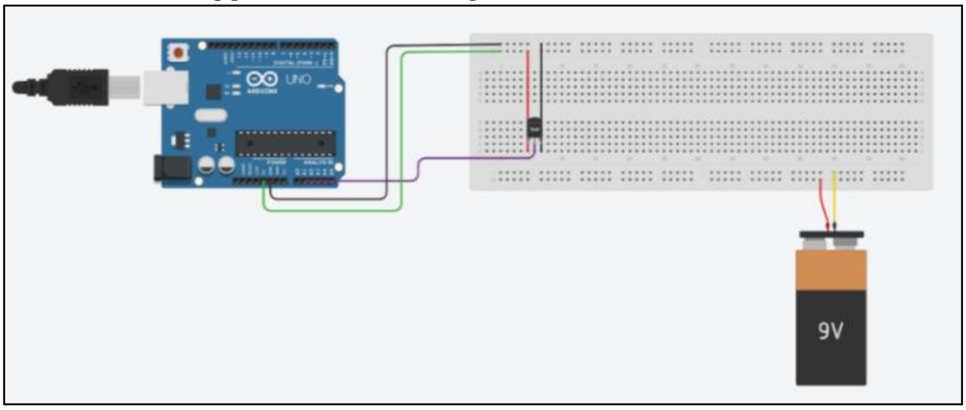

FIGURE 1: LM35- Arduino Circuit Connection

The 12V dc cooling fan is used in the dryer to reduce the temperature when it reaches maximum temperature value. The Arduino board does not have default 12V supply. It only has 3.3V and 5V in default. In order to overcome this limitation, a 12V AC power adapter is connected to the barrel jack of the Arduino UNO board. In this way the 12V input supply for giving output to 12V cooling fan through the Vin pin from Arduino UNO. The negative terminal of the 12V cooling fan is connected to the Emitter of 2N222A transistor and the positive terminal is connected to the Vin supply from the breadboard. The positive and negative terminal of the polarized capacitor are connected to the emitter and base of the 2N222A transistor. The collector of the transistor is connected to the GND of breadboard. The base is connected to the output pin 9 of the Arduino. Figure 2 shows the interfacing connections between Arduino and cooling fan.

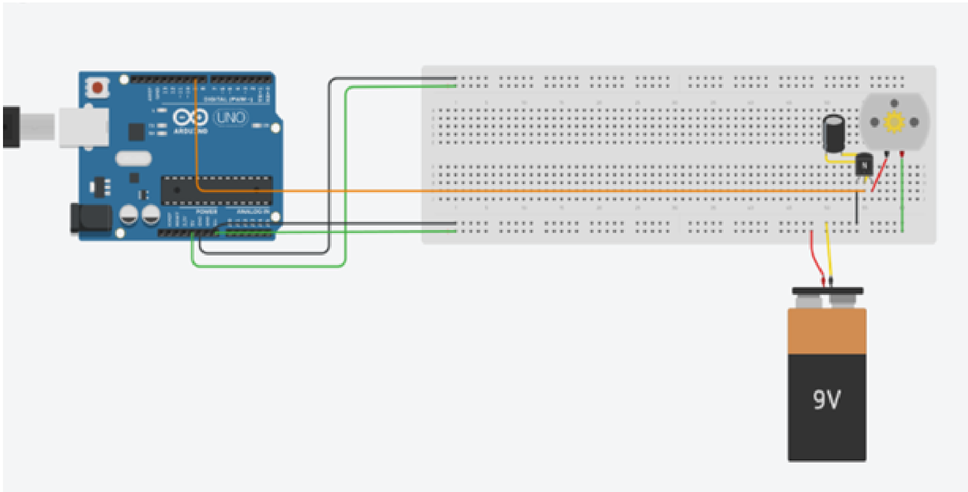

FIGURE 2: Interfacing Cooling Fan with Arduino

2.3 Fabrication of Solar dryer with temperature controller

The mini prototype is made up of 15 liter capacity oil tin which is of corrosion resistance and have high melting point. The top surface of the tin can was cut open to fit the glass material and a small square shape hole is made in the right side of the tin for fit a cooling fan using sheet cutter. Then a 12V a cooling fan, Arduino UNO board, bread board with connecting wires was attached A glass of thickness 4 mm and SS mesh attached for sun light absorption and placing a food material inside the tin material. A wooden support was fitted inside the tin can using nails to form a supporting frame for hold above the product and the SS mesh is fixed to the wooden support by the drilling the screw into them. The layer of black paint gives a black body radiation to produce more heat to circulate into the cabinet. Each time the draws the heat of the cabinet, fresh air is incoming into it. This will continuously subject the product to hot air. The cabinet consists of a tin compartment of rectangular shape with a dimension of 32.4*23.2 cm. The top of this compartment is a flat glass panel as shown Figure 3. The temperature checking of solar dryer was done after the fabrication to find how much amount of temperature would rise inside the dryer cabinet and found that the temperature was raised up to 52ºC at peak sun light.

FIGURE 3: Fabrication of Automatic Temperature controlled solar dryer

III. RESULTS AND DISCUSSION

3.1 Analysis of ascorbic acid retention in lemon peel

Lemon belongs to citrus fruits, it is used as a functional food, and has a high vitamin C content. Recent innovative research determined that the peel of a lemon has a rich amount of vitamin C, used for the production of flavored salt. This innovative work requires lemon peel in powder form. The peel must be dried in controlled conditions. Vitamin C is a heat-sensitive nutrient that degrades at the temperature of 70 °C. In some circumstances, vitamin C degrades at 50 °C in a hot air oven and under sun drying at 55 °C. The best way to retain the vitamin C is to dry under medium temperature for a long time. To overcome such difficulty, the product (lemon peel) must be dried under the sun but under a controlled condition. Since the temperature rises with time till noon (2 PM) under sun drying and falls gradually, it is not suitable to dry the product even in a solar dryer. The product is dried in an automated temperature-controlled dryer under a pre-set temperature value of 48 °C. Simultaneously lemon peel was also dried direct sun drying process. To compare the nutrient retention from both processes, the product is dried for a total of 5 hours.

3.2 Volumetric analysis test for ascorbic acid in the lemon peel

The dried samples were ground and titrated against the dye (2,6-dichlorophenol indophenol). In brief vitamin C, present in the given test sample reduces 2,6-dichlorophenol indophenol (DCIP), a blue-colored dye to pale pink or colorless leuco form in an acidic medium. The appearance of pink color indicates the end point of the titration. In this reaction, vitamin C acts as a reducing agent and gets converted to dehydroascorbic acid (oxidized).

The Lemon peels are completely dried and attain a crispy form within 5 hours (the drying rate is shown in Table 1) and they are subjected to ascorbic acid analysis. The contents of Vitamin C are analyzed by the ascorbic acid test of the volumetric method.

TABLE 1
DRYING RATE OF LEMON PEEL

Time	Sun drying method (g)	Temperature control drying method (g)
11.00 AM	78.80	75.03
13.00 PM	44.34	27.47
15.00 PM	24.56	19.75
16.00 PM	21.35	19.57

The amount of ascorbic acid in the lemon peel was found by using below formula:

$$\text{Amount of ascorbic acid} = \frac{0.5\text{mg}}{V1ml} \times \frac{\text{V2}}{5\text{ ml}} \times \frac{100\text{ml}}{\text{Weight of sample}} \times 10$$

TABLE 2
AMOUNT OF ASCORBIC ACID RETAINED AFTER DRYING IN LEMON PEEL

Nutrient	Amount of nutrients retained after drying	
	Automated temperature-controlled dryer	Sun drying
Ascorbic acid	59.25 mg/100g	47.4 mg/100g

When compared to solar drying automated temperature-controlled drying gives a high amount of ascorbic acid retention in a lemon peel. In normal sun drying lemon peel will achieve a high amount of heat causing nutrient loss. However, in automated temperature-controlled solar drying, due to controlled temperature, the nutrients were retained, which is 20 % more than sun drying. The controlled temperature in solar drying prevents the destruction of heat-liability vitamins i.e., ascorbic acid. Based on the temperature limit, the type of the product to be dried.

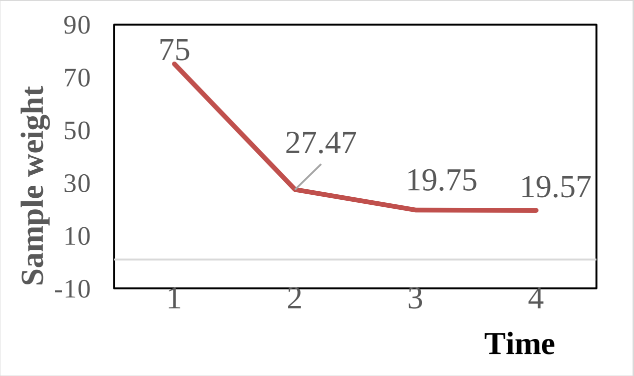

FIGURE 4: Time-temperature relation in sun drying

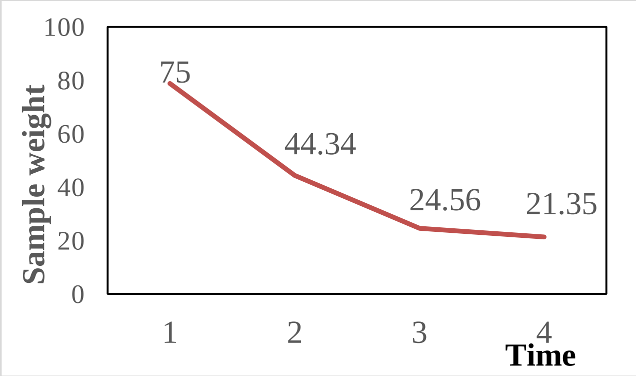

FIGURE 5: Time-temperature relation in temperature-controlled dryer

The graph shown in Figure 4 and Figure 5 describes the drying time- sample weight relationship. It shows that the weight of the product decreases gradually with an increase in time.

The graph shows the drying time-temperature relation between normal sun drying and temperature-controlled drying. From Figure 4 and Figure 5, it is evident that the drying rate is faster in temperature-controlled dryers as compared to normal sun drying.

FIGURE 6: Lemon Peel before and after Automated temperature-controlled drying

IV. CONCLUSION

In this miniature model, the temperature is controlled using a cooling fan, so that can be used to dry a heat-sensitive product without/with minimum nutritional destruction. This seems to be a robust way of handling only temperature control on an automatic basis. In this research, the citrus fruit peel is dried in an automated temperature-controlled method compared to sun drying and other electrical dryers. It is noted that the drying efficiency of the automatic temperature-controlled drying is 6% greater than the normal temperature drying. Because of the controlled temperature in solar drying which prevents the destruction of heat-liability vitamins i.e., ascorbic acid. The nutrients retained in automatic temperature-controlled solar drying are 20% more than in sun drying.

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