Automatically Controlled Solar Tunnel Dryer using Arduino for Sapota

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ABSTRACT:- Sun drying of agricultural products is the traditional method employed in most of the developing countries. Sun drying is used to denote the exposure of a commodity to direct solar radiation and the convective power of the natural wind. Solar drying can be considered as an advancement of natural sun drying and it is a more efficient technique of utilizing solar energy due to its renewable, environmentally friendly technology. Nowadays drying agricultural products have great attention and there are various methods of drying fruits, vegetables such as dehydration, canning etc. due to this the quality of such product is degraded so solar dryer is used to avoid wastage, increase the productivity of agriculture, also the production in terms of quality and quantity. This project describes a controlled environment which is suitable for small scale agricultural products drying process within a closed chamber, using Arduino. To start with, the sun rays are used to internally heat the fruit to remove the water content within the agricultural products. Then to maintain the humidity below a specified level, exhaust the humid air out of the chamber. Arduino is used to control the functions of heating, controlling the speed of exhaust fan and giving time indication & maintain constant temperature throughout the chamber. The graphs of time versus drying process obtained show that the automatic drying unit designed has worked as per the expectation by consuming less time compared to conventional drying process.

Keywords : Arduino, Sensor, Foldable Solar Dryer, LCD Display.

INTRODUCTION

Drying is an excellent way to preserve food and solar food drying is an appropriate food preservation technology for a sustainable world. The high moisture content in fresh agricultural product (produce) is the basic cause for spoilage. If water is removed, then the shelf life of produce increases. Traditional open sun drying methods often yield poor quality, since the produce is not protected against dust, rain and wind, or even against insects, birds, rodents and domestic animals while drying. The solution of all these problems is the use of solar dryer instead of open sun drying.

Solar dryers are the devices that use free solar energy to dry agro products. The studies indicate that cost of drying with solar energy is only one-third as compared to the cost using a dryer based on conventional fuels. Adequate drying helps to preserve the flavor, texture, and color of the food, which leads to a better quality product.

In India, sapota is cultivated over an area of 156.1 thousand hectares with annual production of 13.08 lacs MT [6]. Sapota is widely cultivated in Gujarat, West Bengal, Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu. It is highly perishable fruit with moisture content of 70-80% which can be reduced down to 10% by drying in order to increase the shelf life [3]. Mostly used methods for drying agricultural products like Sapota are canning, osmotic dehydration, microwave drying, oven drying, vacuum drying etc., due to this the quality of such product is degraded so solar dryer is used to avoid wastage, increase the productivity of agriculture, also the production in terms of quality and quantity. Different food types require different temperature for drying conditions in order to maintain their quality. In solar tunnel dryer we cannot control various drying parameters like temperature, relative humidity etc., due to that quality and quantity of product degraded. To overcome this problem we can use automatically controlled solar tunnel dryer. The temperature inside the solar tunnel dryer can be controlled by using microcontrollers like 8051, PIC, ARM, Arduino etc These solar dryers allow for controlled drying by managing the drying parameters such as moisture content, air temperature, humidity, and air flow rate.

METHODOLOGY

The design used for agro products drying chamber needs the temperature to be controlled throughout the drying process by using solar energy. Variable temperature conditions during drying are harmful for agro products. Over drying causes discoloration and reduction in quality. On the other hand, under drying causes fungal infection and bacterial action. Thus main objectives are to design the solar tunnel dryer and to design a controlling circuit to control various drying parameters inside it.

1) Solar Tunnel Dryer:

The material used for construction of folding type small size passive solar tunnel dryer is given in the following table 1:

Table 1: Material required for solar tunnel dryer

Sr. No.	Item	Specification/ Quantity
1.	GI Bar	8.92 m
2.	GI Sheet	26 gauge
3.	PVC Pipe	5.49 m
4.	UV stabilized polythene sheet, thickness 200 microns	5 × 5 m^2
5.	Insulation(Plywood)	2
6.	Binder Clips	28

The schematic design of solar tunnel dryer is shown in fig 1:

All dimensions in mm

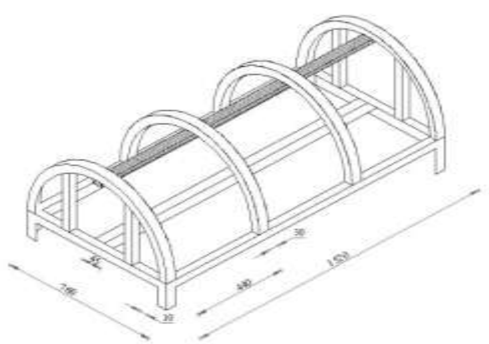

Fig. 1: Schematic diagram of solar tunnel dryer

2) Solar tunnel dryer with controlling circuit:

Solar tunnel dryers parameters are tested and controlled using Arduino as shown below

BLOCK DIAGRAM

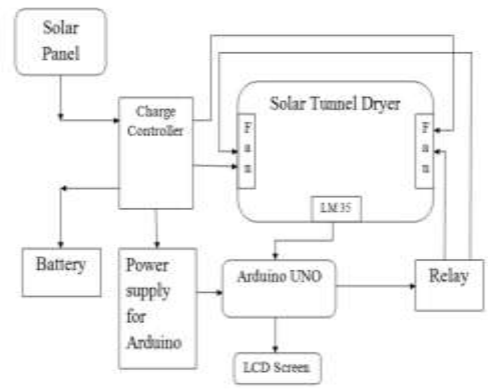

Fig. 2: Block diagram of solar tunnel dryer

CIRCUITRY

1. Arduino Uno

Table 2: Specifications of Arduino Uno

Operating Voltage	5V
Input Voltage	7-12V
Digital I/O	Pins 14
Analog Input	6 Pins
Length	68.6 mm
Width	53.4 mm
Weight	25 g

2. Temperature Sensor LM 35

Table 3: Specifications of temperature sensor LM35

Supply Voltage	+35 V to -0.2 V
Output Voltage	+6 V to -1 V
Temperature Range	-55 °C to 150 °C

3. Relay

Table 4: Specifications of relay

Operating Voltage	5 V DC
Nominal Current	70 mA
Quantity	2

4. Liquid Crystal Display

Table 5: Specifications of liquid crystal display

Operating Voltage	5 V DC
Module Dimension	60 mm x 36 mm x 15 mm

Viewing Area Size	64.5 mm x 16 mm
Displays	2 lines x 16 characters

5. Exhaust Fan

Table 6: Specifications of exhaust fan

Operating Voltage	5 V
Dimension	100mm×100mm×10mm

6. Solar Panel

Table 7: Specifications of solar panel

Rated power	10 Watt
Open circuit voltage (Voc)	21.5 Volt
Short circuit current (Isc)	0.65 Ampere
Voltage at maximum power (Vmp)	17.7 Volt
Current at maximum power (Imp)	0.57 Ampere
Maximum system voltage	600 Volt

7. Battery

Table 8: Specifications of battery

Voltage	12 Volt
Capacity	7 Ah
Type	Sealed Lead Acid Battery
Rechargeable	Yes

8. Charge Controller

Table 9: Specifications of charge controller

Voltage	12 Volt
Max. PV charging Current	5 Ampere
Max. load	5 Ampere

Fig. 3: Actual view of circuit diagram

The measurements of the parameters were taken after every half hour.

Table :10 Parameters measured and instruments used

Parameter	Instrument
Temperature	Digital Thermometer
Relative Humidity	Hygrometer
Air Velocity	Digital Anemometer
Solar Radiations	Pyranometer

Flow chart of sapota drying is given below :

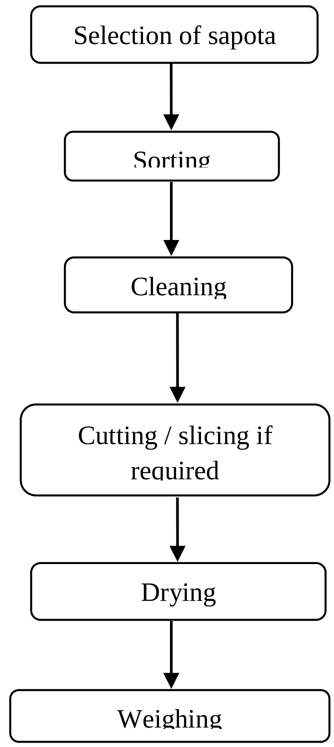

Fig. 4: Process of drying sapota

Flow chart of controlling solar tunnel dryer is given below:

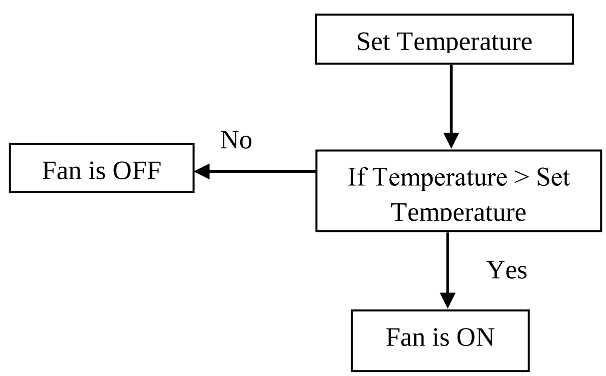

Fig. 5: Process of controlling solar tunnel dryer

The effect of drying air temperature that is 50ºC on drying kinetics of Sapota slices was investigated using solar tunnel dryer.

Determination of Moisture Content:

$$\text{Moisture content \% (wb)} = \frac{W_2 - W_3}{W_2 - W_1} X\ 100$$

Where,

W_1= Weight of empty box, g.

W_2= Weight of sample before drying, g.

W_3= Weight of sample after drying, g.

RESULT AND DISCUSSION

Evaluation of Solar Tunnel Dryer for No Load Condition

Evaluation and testing of the solar tunnel dryer was carried out under no load conditions.

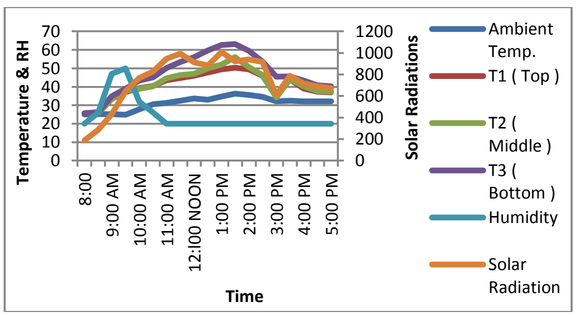

Fig. 6: Variation of Temperature, Humidity and Solar Radiation with Time at No Load Condition

It was observed that the minimum inside temperature was 25.7⁰C at 8:00 am and also observed that the minimum and maximum dryer humidity was 20 % and 32% from 08:00 am to 5:00 pm respectively. The minimum and maximum base temperature is 25.7⁰C at 08:00 am and 63.2⁰C at 1:30 pm respectively. The minimum solar radiation was observed at 08:00 am and maximum at 1:00 pm were 189 and 1008 W/m² respectively.

Fig. 6 shows that, minimum and maximum temperature of dryer, ambient temp, humidity, solar radiation. It was observed that the minimum and maximum ambient temperature of air was observed at 8:00 am and 01:30 pm that is 25.0⁰C and 36.2⁰C respectively.

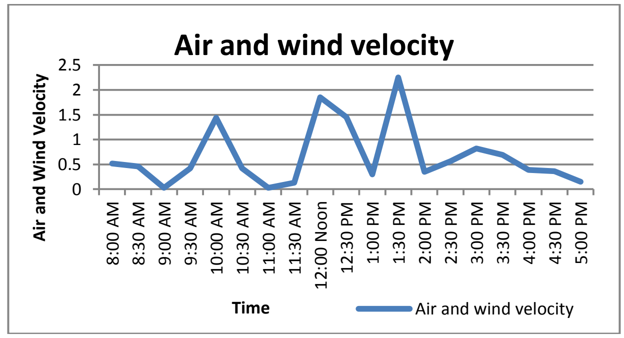

Fig. 7: Variation of Air Flow Velocity with Time at No load condition

Fig. 7 shows that the variation of air flow velocity of wind velocity with respect to time. The minimum & maximum air flow velocity was observed at 09:00 am and 01:30 pm, 0.03 m/s and 2.25 m/s respectively.

Evaluation of Solar Tunnel Dryer for Sapota

Evaluation and testing of the solar tunnel dryer was carried out under load conditions for drying of sapota slices.

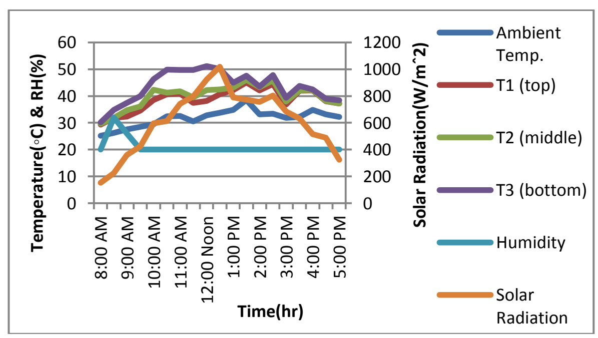

Fig. 8: Variation of Temperature, Humidity and Solar Radiation with Time at 1st Day

On the first day of drying it was observed that the minimum inside temperature was 27.8⁰C at 8:00 am. It also observed that the minimum and maximum dryer humidity was 20 % and 32 % from 08:00 am to 5:00 pm respectively.

The minimum and maximum base temperature is 29.2⁰C at 08:00 am and 52.64⁰C at 12:00 noon. The minimum solar radiation was observed at 08:00 am and maximum at 12:00 noon were 169 and 995 W/m² respectively.

Fig. 8 shows that, minimum and maximum temperature of dryer, ambient temp, humidity, solar radiation. It was observed that the minimum and

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maximum ambient temperature of air was observed at 8:00 am and 01:30 pm that is 25.2^{0}C and 34.1^{0}C respectively.

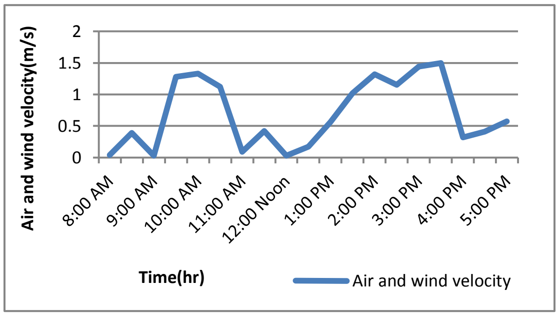

Fig. 9: Variation of Air Flow Velocity with Time at 1st day

Fig. 9 shows that the variation of air flow velocity of wind velocity with respect to time. The minimum and maximum air flow velocity was observed at 09:00 am and 03:00 pm i.e. 0.03 m/s and 1.44 m/s respectively.

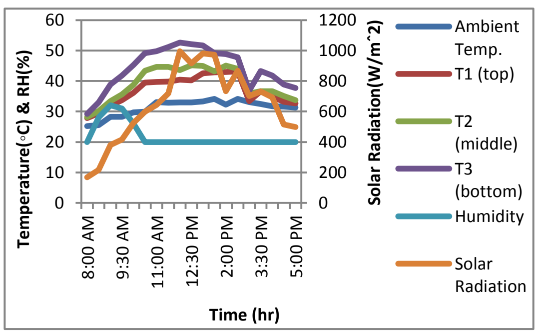

Fig. 10: Variation of Temperature, Humidity and Solar Radiation with Time at 2nd Day

On the second day of drying it was observed that the minimum inside temperature was 29.4^{0}C at 8:00 am and also observed that the minimum and maximum dryer humidity was 20 % and 32 % from 08:00 am to 5:00 pm respectively. The minimum and maximum base temperature is 30.2^{0}C at 08:00 am and 51.17^{0}C at 12:00 noon. The minimum solar radiation was observed at 08:00 am and maximum at 12:30 noon were 153 W/m^2 and 1019 W/m^2 respectively.

Fig. 10 shows the minimum and maximum temperature of dryer, ambient temp, humidity, solar radiation. It was observed that the minimum and maximum ambient temperature of air was observed at 8:00 am and 1:30 pm i.e. 25.2^{0}C and 38.5^{0}C respectively.

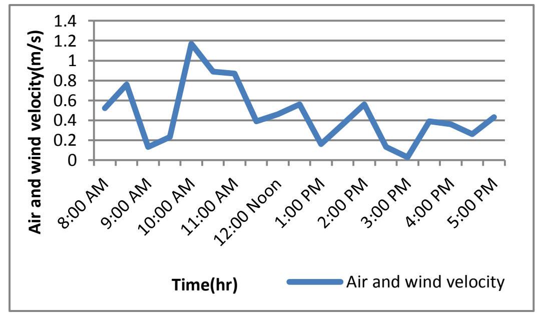

Fig. 11 Variation of Air Flow Velocity with Time at 2nd Day

Fig. 11 shows that the variation of air flow velocity of wind velocity with respect to time. The minimum and maximum air flow velocity was observed at 03:00 pm and 10:00 am i.e. 0.03 m/s and 1.17 m/s respectively.

Fig. 12: Sapota slices before drying

Fig. 13: Sapota slices after drying

Determination of Moisture Content

Table 11: Initial moisture content

Weight of empty box (W_1) g	Weight of empty box + Weight of sample before oven drying (W_2) g	Weight of empty box + Weight of sample after oven drying (W_3) g	Moisture content % (wet basis)
59.3	64.16	60.6	73.25

Table 12: Moisture content after 1st Day

Weight of empty box (W_1) g	Weight of empty box + Weight of sample before oven drying (W_2) g	Weight of empty box + Weight of sample after oven drying (W_3) g	Moisture content % (wet basis)
59.3	63.52	62.39	26.72

Table 13: Moisture content after 2nd Day

Weight of empty box (W_1) g	Weight of empty box + Weight of sample before oven drying (W_2) g	Weight of empty box + Weight of sample after oven drying (W_3) g	Moisture content % (wet basis)
59.3	63.69	63.24	10.22

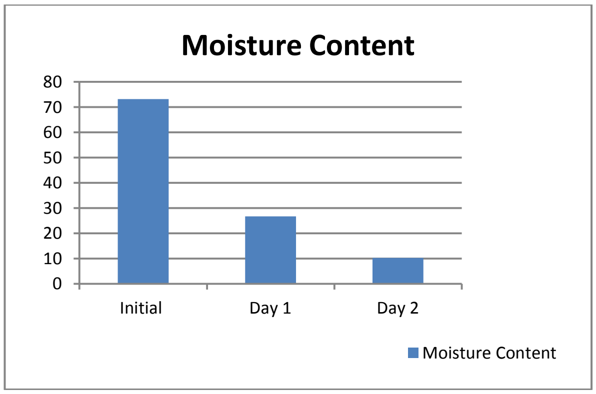

Fig. 14: Removal of moisture from sapota per day

From the fig. 14 it is observed that sapota require 2 days for drying. The drying rate is high. It is found that the initial moisture content of Sapota Slices was 73.25% which was reduced to 26.72 % on first day and on next day it was reduced to 10.22%.

CONCLUSIONS

Using the concept of basic solar conduction dryer and implementing the automation and design enhancement, the efficiency of the system and quality of agro products has been increased. By utilizing large amount of solar heat to maintain the quality of the food products is also achieved. From the experiment performed, the dryer accomplishes the temperature control at desired temperature.

The overall reading observed that the maximum inside temperature was 52^0C and corresponding average ambient temperature was 32.52^0C. It was also observed that the average solar radiation was 787.52 W/m^2, average humidity was 20% and average the air flow velocity was 0.89 m/s. The initial moisture content of sapota slices was 73.25% which was reduced to 26.72% on first day and on next day it was reduced to 10.22%.

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