Journal of Technology Innovations and Energy ISSN: 2957-8809
https://doi.org/10.56556/jtie.v3i1.798

RESEARCH ARTICLE

Performance Assessment of Affordable Solar Dehydrator for Sustainable Energy

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Received: 20 February, 2024, Accepted: 04 March, 2024, Published: 18 March, 2024

Abstract
Dehydration has long been the preferred method of food preservation over all other techniques. In contrast to other techniques, dehydration uses heat to evaporate extra water from food. This can be simply obtained through solar energy. This work aims to apply appropriate engineering methods to use solar energy for food dehydration efficiently. This work prioritizes both food quality and cost equally. In addition, it features a backup system that operates at night to continuously dehydrate food items with drying times longer than 12 hours, in contrast to previous approaches that are either costly or result in lower-quality products. So, the solar collector is designed at an optimum angle of 27^{o} with an area of 0.5153 m^2 to collect useful heat from the sun that develops enough temperature difference to dehydrate some selected food. Experiment results show that the desired purpose is greatly achieved by comparing the dehydrated products with the conventional or commercially available products.

Keywords: Solar Energy; Solar Dehydrator; Food Preservation; Dehydration

Introduction

Solar energy has the greatest potential of all the sources of renewable energy (Ullah, Siddiqi et al. , Ullah and Sharif 2022, Mohammed, Alawee et al. 2024). If only a small amount of this energy is used, it will be one of the most important energy supplies, especially when other sources in the country have depleted (Sharif, Tipu et al. , Fernandes and Tavares 2024). The solar power where the sun hits the atmosphere is 1017 watts, whereas the solar power on the earth's surface is 1016 watts. The total worldwide power demand for all needs of civilization is 1013 watts (Sharif, Noon et al. , Shoukat, Noon et al. 2021, Akpan, Okon et al. 2023). Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is approximately 1 kW/m^2; attempts have been made to use this energy (Sharif, Siddiqi et al. , Sharif, Siddiqi et al. 2020).
No other energy can be as environmentally friendly as solar energy (Halidi, Ismail et al. 2023). Technical utilization of solar energy is of great importance to Pakistan since it lies in a temperature climate of the region of

the world where sunlight is abundant for a major part of the year (Majeed, Khan et al. 2023, Moula, peer Saheb et al. 2023, Fernandes and Tavares 2024). Due to the higher cost of fossil fuels and uncertainty regarding future cost and availability, the use of solar energy in food processing has probably increased and become more economical (Tipu, Arif et al. , Muhammad, Sharif et al. 2022) (Mohammed, Alawee et al. 2024). Properly constructed solar dehydrators improve product quality and reduce the risk of deteriorating, dry food more quickly, reduce humidity and repel mosquitoes, and protect food from birds, dust, and insects than when drying it in the open (Hyder, Khan et al. 2023). The dehydration process in foodstuffs is simply that of reducing the internal water content and, in certain instances, the intracellular water content of the food (Justo, Ribeiro et al. 2019, Cabrera-Escobar, Vera et al. 2024).

The reduction in water content results in reduced water activity with a consequent reduced growth of microorganisms. Solar dehydration uses the sunshine and consequent heat of the sun to induce evaporation and dry the food. An effective approach to dehydrating and preserving perishable goods such as fruits and vegetables is drying at low temperatures to preserve the food's natural texture. Slow drying can very easily be carried out by open sun drying, but it needs longer to reach the required moisture level. Rain, dust, insects, pollution and contamination from the surrounding environment may adversely affect the quality of the products (Chua and Chou 2003). Furthermore, products dried in open environments may need to meet the required standards. Thus, drying with a solar dehydrator shortens the drying time, meets hygienic standards, and retains the product's colour, texture and food value. Solar driers are of two types: direct and indirect. In a direct-type solar dehydrator, air is heated in a type chamber covered from the top with a glass or transparent polythene sheet (Belessiotis and Delyannis 2011). In the indirect dehydrator, air is first heated conventionally by solar energy in a separate heat collecting unit. This unit's hot and less humid air is circulated through the main drying chamber, where food is spread on perforated trays (Noon[1], Arif[1] et al. 2021, Ortiz-Rodríguez, Condorí et al. 2022). While exhausting through this unit, the hot, dry air stream removes the product's moisture. A steady state of evaporation is achieved when the heat required for evaporation and the heat losses equal the total heat absorbed.

When assessing the performance in the direct solar dehydrator, the colour of the dried end product is different than that was at the beginning of indirect ones. This may be caused by solar radiation, which produces heat within the bulk of the product upon penetration through its porous skin and changes its colour. It is also observed that the surface of the dried product gets withered, which reduces the appealing look necessary for its marketing, whereas, in the indirect type solar dehydrator, the colour and texture of the dried product remain unchanged.

The main objective of the current work is to design and develop a solar dehydrator system that utilizes solar energy for efficient food dehydration within less time than traditional methods. Also, to evaluate the effectiveness of the solar dehydrator in preserving the quality and nutritional content of various food products.

Material and Method

Design Consideration

Several aspects influence the design of a solar dehydrator. These include fair drying time, functionality, dependability, ease of use, insect resistance, and portability. Appropriate amounts of the following are necessary for high-quality food dehydration. Heat makes the air warmer, making it easier to absorb moisture. Additionally, the rate at which food evaporates rises with warmth. Hence, drying can happen more quickly at higher temperatures when there is more heat. Peshawar experiences temperatures reaching 42°C during the height of summer. The air temperature can be raised by 10 to 25°C with a decent sun dehydrator. The solar dehydrator's performance is gauged by its ΔT. With fans, the drying temperature can be changed. Dry, hot air is more capable of absorbing water than wet, saturated air due to airflow. A level of airflow that permits air heating should be maintained. By doing this, moisture absorption into the air is guaranteed. The air will not warm up sufficiently to dry the food if the flow is excessive. Insufficient flow rate causes the air to become overly damp, which prevents the food from absorbing additional moisture.

To Increase the amount of solar energy captured, we have tilted the collector at an angle. The tilt amount depends on the time of year at which the collector will be operating, i.e., the solar collector intended for winter will have a steep angle to capture more. To make our solar collector operate year-round, we set the tilt angle at a compromise between optimal summer and winter angles. Lower tilt angles will collect more energy in the summer, and higher angles will collect more energy in the winter. The tilt angle for maximum solar gain depends upon the latitude of the location at which the solar collector is placed; after studying the sun-path charts and taking an average tilt angle for our solar collector to be 27 C^{o} to ensure year-round operation of our solar dehydrator. Sun Path charts tell you where the sun will be in the sky anytime throughout the year. Sun's path is the same for all locations along the same latitude. To improve the performance of our solar dehydrator, we are using double walls, and in between the walls, there is packing material for insulation. So the internal heat will not be lost to the surroundings. Also, to keep as much heat as possible in the collector, use ordinary glass with a thickness of 6 mm and a gauge of five as glazing so that trapped solar energy will not go outside. To control the internal temperature, a ventilation system is needed, using one exhaust placed at the top of the side to pass the moisture to the outside environment and maintain humidity inside the cabinet.

The main drawback of solar food dehydration is that we can't predict the sun's shine. Also, some food has a longer drying period, so in that case, we are using a DC heater (2-5 watt) system as a backup source for heating. Now, food is dehydrated, having a longer drying period than 12 hours continuously. With this, the quality of our food also improves, and food can dry in any weather. To supply the heaters with a DC supply, we use a 12V battery with an energy-storing capacity of 48AH and 20Hr backup time, which can easily operate 3-4 DC heaters. These heaters can heat up to 120 C^{o}. The solar dehydrators are placed outside, so they must endure the elements without falling apart or harming the food. Thus, rain should drain off without entering the dehydrator and getting the food wet. Materials that can withstand rain and sun for many years should be selected. Proper design can keep food away from many animals and bugs. All vent openings must be screened to keep out flies and yellow jackets. The screen that the food rests on in the dryer must be made from a mesh that allows plenty of airflow. The screen should be made from an inert (non-reactive), food-safe material that can withstand dryer temperatures as high as 930 C^{o} (2000^{o}F). Good screens should not stick to food and will be easy to clean. Furthermore, the material should not stretch or sag when heated and loaded with food. In this study, galvanized stainless steel meshes are used as food screens.

Food drying can be messy; juicy fruit and tomatoes may drip onto the bottom. Concentrated fruit sugars from grapes may drip like honey. Therefore, it must be able to access and clean your dryer. So, the design must be such that it can easily hose out and scrub inside when needed. The outside glass must be cleaned regularly. Dirt, dust, and pollen will block precious solar rays from getting on the dehydrator.

Design parameters

Design parameters are specific variables or factors that influence the design and performance of a system, product, or process. These parameters are typically defined during the design phase. Design parameter selection is important before actual manufacturing or 3D modeling. Cabinet dimensions of the Solar Dehydrator are as shown in table 1 and solar collector dimension and glazing dimension are as shown in table 2 and 3 respectively.

Table 1: Cabinet Dimensions

	Length (mm)	Width (mm)	Height (mm)
Cabinet Rectangular Duct	325.12	-	63.50
Cabinet	495.30	355.60	990.60
Exhaust Fan Hole	152.40		139.70
Cabinet Frame	518.16	406.40	609.60

Table 2: Solar Collector Dimensions

	Length (mm)	Width (mm)	Height (mm)
Solar Collector	1155.70	495.30	180.34
Solar Collector Plate	1193.80	431.80	5 (Thickness)
Blower	12.70	-	15.24

Table 3: Glazing Dimensions

	Length (mm)	Width (mm)	Height (mm)
Ordinary Glass	1219.20	457.20	6

Design and Fabrication

The conceptual model is developed with modeling assistance by the analysis and calculations and can be used to pre-test the project’s outcomes. The design parameters design each component of the solar dehydrator, and the appropriate materials are for each part. The elements are then put together into a single assembly. The assembly consists of an Outer Frame, Collector Plate, Solar Collector, Cabinet, Food Racks, Blowers, Solar Panel, and Trolley Wheel. The outer frame supports the solar collector and cabinet. The exterior frame was designed with Solidworks. The front plane is first used to create the 2D sketch, then 28 extruded with angle iron (2x2x 0.125), square tube (2x2x 0.25), and pipe. And then coated with stainless steel with a black color. The model is subsequently rendered in the end. The collector plate is the most important part of the solar dehydrator assembly. Collector plates absorb solar energy (solar radiation) and convert them to heat. The collector plate is the flat-plate type with a curved area at a specific angle to increase the area for solar energy absorption. The overall width of the collector plate is 431.80 mm, and the length is 1193.80 mm.

The thickness of the plate is 5 mm. Mild steel is used, and the final image is rendered to provide a realistic view. The solar collector captures the sun's radiant energy and converts it into useful heat. It is an enclosure which surrounds the air to be heated. Solar energy is collected via glazing that allows the radiant energy to enter the collector but doesn't allow heated air to leave. As the radiant energy enters the collector, it strikes the steel plate inside and is absorbed and converted into heat. The black material sheet is the more efficient surface for solar energy absorption because the metal will distribute and transfer the heat evenly throughout the collector, called the absorber plate. The overall length of the solar collector is 1231.90 mm, and the width is 495.30 mm.

It is a closed cabinet or enclosure to facilitate food drying using solar energy. It provides a controlled environment for the drying process, protecting the food from external elements while harnessing the sun's power. Initially, the sketch is created in the front plane, and then the boss extrudes and cuts extrudes to make space inside the cabinet (Sharif, Hussain et al. 2023). It has a space for food racks to withhold 3-4 Kg of food for dehydration in a single turn. The length of the cabinet is 495.30 mm, the width is 355.60 mm, and the height is 990.60 mm. The realistic view is also achieved by applying render. Food racks are meshing-type racks that are used for loading food for dehydration. In this case, we used three racks that easily load 3-4 kg of foodstuff. Blowers transfer heat from the collector to the cabinet through the duct. The airflow should be kept at a level allowing the air to be heated. Two blowers are used in this case, with 7.4 watts each with a flow rate of 42.48 m3/hr, approximately equal to 1 m/s, the best airflow to transfer heated air to the cabinet. To provide a backup source for the dehydration of the food at night or in cloudy weather, we used a 20W solar panel, which will charge the battery and provide a backup source for the dehydration. Trolley wheels are used to give support to the whole solar dehydrator and can easily transfer /move/rotate from one site to another. They are used for easy mobility and transportation of solar dehydrators. They are made of rubber and metal; a specific trolley wheel was used to support the weight of the solar dehydrator. After developing every component, we assembled all of them in Solidworks as shown in Figure 1.

Figure 1: Assembly of Solar Dehydrator Design

The fabrication of the solar dehydrator is carried out using the actual design considerations—wood, steel sheets, mild steel, glass, etc. The outer frame, which serves as the primary support for the cabinet and solar collector, was constructed as the initial stage of our manufacture. The grinder cut the rectangular angle aluminium rods 18 gauge into necessary lengths and forms, then welded them together using shielded metal arc welding by design (Habib, Sharif et al. 2022). The frame is then colored black. The solar collector is made of wood; the wood is cut to the actual dimensions using a woodcutter for the solar collector. Then it was combined with screws and silicon where necessary. Packing material was used as insulation in all walls of the solar collector and covered with steel sheets. Then, a solar collector plate was placed inside, and an ordinary glass was fitted above. Our solar collector is designed at an optimum tilt angle of 27º for around the year.

High transmission (low iron) tempered glass is used on solar collectors (Habib, Sharif et al. 2021). The advantages of glass include long life, good transmittance, high-temperature capability, and strength. Two low air flow rate blowers (approximately one m/s) were used to flow air from the solar collector through a duct to the cabinet. The cabinet is also made of wood. The specified dimensions are cut using a woodcutter. A hole was made at the top left side of the cabinet for the ventilation system, and an exhaust fan was fitted to remove humid air from the cabinet. The cabinet is insulated from the inside using packing material and then covered with a steel sheet (Hussain, Sharif et al.). Steel sheets have two purposes: one to cover the insulation, and the second to prevent the wood from moisture inside the cabinet. A rectangular duct transferred air flow from the solar collector to the cabinet. Inside the cabinet, food racks (3 quantities) were fitted to load different foods for dehydration (Sharif 2022).The fruits and vegetables will be placed on the food racks. These are made from galvanized steel with wooden frames. The galvanized steel is used for these food racks to eliminate the process of rusting. These food racks have the capacity of 3-4 kg of foodstuff to dehydrate at a time. We utilized forced convection or dehydration through forced drift in normal operating conditions. The exhaust fan will automatically switch ON when the humidity inside the cabinet increases from the required limit. The fan's voltage is 12 volts, and its speed is 33 CFM.

Doors are located on the back side of the cabinet. It is used for loading and unloading the food racks in the cabinet. The dimensions of the layers and insulation are reduced to minimize the door's weight. The door is tightened with nuts and bolts to prevent heat leakage from the cabinet. The solar panel is fitted above the cabinet on the frame. It converts solar energy to electrical energy, which charges the 40AH battery. The panel used in this project is 20 Watts and easily available from the market.

Trolley wheels are used to move or rotate the solar dehydrator easily (Sharif, Khan et al. 2023, Tipu, Noon et al. 2023). All the parts constructed are assembled according to the design. First, the cabinet and solar collector are assembled and placed on the outer frame (supporting frame). The solar collector outlet enters the cabinet through the rectangular duct created in the cabinet. The door is fitted to the cabinet through a nut and bolt system to prevent heat from leaking through the hinge. The blowers are fitted to the bottom side of the solar collector. The solar panel is placed above the solar dehydrator cabinet to convert solar energy to electrical energy, which charges the battery. The wheels are welded to the legs of the outer frame to allow the whole solar dehydrator to move easily as shown in figure 2.

Figure 2: Solar Dehydrator Assembly

The drying principle is based on a continuous hot air supply to the fruits and vegetables. If heat is not provided continuously, then food quality will be affected. There is no need for a backup source for fruits and vegetables whose drying time is less than 10-12 hours. However, a backup source must be provided for fruits/vegetables whose drying time is over 12 hours.

In this project, we used four quantities of DC heaters as a heating source, to which the DC is supplied from the battery. The battery is charged from the solar panel in the daytime and then used to give current to the heaters at night. Hence, continuous heat is provided to the fruits/vegetables, which have a drying time greater than 12 hours.

We have used Arduino-based automation in our solar dehydrator. Temperature, humidity, and energy management are controlled in our solar dehydrator to enhance efficiency and accuracy in the drying process. When the solar collector temperature reaches 50℃, the blowers will start because it is cold air when the air enters the solar collector. It gets hot due to the convection process when it passes the solar collector plate. The air gets warmed and then passes to the cabinet to remove moisture content from food. The blowers are turned off when the collector temperature gets below 50℃. Similarly, the exhaust fan will turn on when the humidity inside the cabinet is above 10 or 20 %. It can be adjusted from the code in Arduino IDE. The heaters will turn on when the temperature is below 50℃. When it increases above 50℃, the heaters turn off. We can turn off the heaters completely on a sunny day. In this way, a controlled and continuous dehydration process takes place.

Experimentation

The experiments were performed on dehydrating some selected food items- Tomatoes, grapes, and apricots – within a constant temperature range inside a solar dehydrator. The collector's efficiency and useful energy available at different times of the day were also calculated to find the effectiveness of the solar collector.

Dehydration of Tomatoes

First, samples are prepared from fresh tomatoes (available in the market) and washed by cutting them into wise shapes about 10 mm. After the preparation of samples, a pre-treatment process called blanching is performed. In blanching, samples of tomato are dipped in boiling water for 30-60 seconds. The process is repeated, and samples are removed and washed with tap water. Before loading the samples into the dehydrator, it is necessary that the water absorbed by the sample during boiling is removed by placing the sample in an open atmosphere. The temperature inside the collector, cabinet, and outside at 1-hour intervals of time is noted from the temperature sensor called DHT-22, which is a Temperature Humidity sensor. As tomatoes take 7 hours to dehydrate, seven readings (including the initial reading) are taken, as shown in Table 4.

Dehydration of Apricot

First, a specific quantity of Apricots (1kg) is cut into two halves to remove the pit or stone it so that the maximum internal area of the fruit is exposed to heat. Then, a pre-treatment process called sulfuring is performed to retain the color and taste. A solution is prepared by putting two teaspoons of Potassium Meta Bisulphate in one gallon (3.78 Liter) of water. Then, Apricot samples are dipped into that solution for about 10 minutes and placed in an open atmosphere. Once the pre-treatment process is performed, the fruit is loaded into the dehydrator. Complete dehydration takes 20-24 hours; therefore, a backup source is needed. The readings and calculations are shown in the tables 5.

Table 4: Tomato Readings

Time	Cabinet Temperature	Outside Temperature
10:00 am	49	39.2
11:00 am	55	43.4
12:00 pm	58	45.5
01:00 pm	61	45.2
02:00 pm	57	42.4
03:00 pm	53	39.7
04:00 pm	51	38.1

Table 5: Apricot Readings

Time	Cabinet Temperature	Outside Temperature
10:00 am	42.1	33.3
11:00 am	47.4	37.8
12:00 pm	50.8	39.4
01:00 pm	62.3	42.1
02:00 pm	65.5	43.9
03:00 pm	61.2	41
04:00 pm	56.8	38.7
05:00 pm	54.3	36.6
06:00 pm	51.7	34.7
07:00 pm	52.5	33.4
08:00 pm	50.1	33.1

Dehydration of Grapes

First of all, specific quantity of Grapes (1kg) and then carefully separate individual grapes from the bunch by gently pulling them off the stem. Then pre-treatment process called sulfuring is performed to retain the color and taste. A solution is prepared by putting two tea spoons of Caustic Soda in one gallon (3.78 Liter) of water. Then Grape samples are dipped into that solution for about 30 minutes, so the outer layer of the grapes get soften and then placed in open atmosphere. Once the pre-treatment process is performed fruit is loaded into the dehydrator. Complete dehydration takes 24-30 hours; therefore, backup source is needed. The readings and calculations are as shown in tables 6.

Table 6: Grapes Readings

Time	Cabinet Temperature	Outside Temperature
10:00 am	48.9	39.6
11:00 am	55.3	44.2
12:00 pm	63.5	44
01:00 pm	62.1	43.5
02:00 pm	57	42.6
03:00 pm	54.4	40
04:00 pm	52.7	38.7
05:00 pm	53.8	36.6
06:00 pm	52.3	37.8
07:00 pm	50.6	36.8
08:00 pm	53.5	35.4

After performing different experiments at location UET Peshawar, Jalozai Campus., the readings were taken for every experiment, for 1-hour interval, to dehydrate the Tomato, Onion, Apricot, Mango, Banana, and Grapes.

Result and Discussion

Dehydration of Tomato

The solar dehydrator was placed at roof of Jinnah Hostel UET Jalozai. Tomato was loaded on racks for dehydration. It took about 7 hours to completely dehydrate the tomato with high quality, taste and color was retained. The readings were noted at 1-hour interval of time. The calculations are as follows in table 7.

The graph between solar collector efficiency and time for tomato as given figure 4. The solar collector efficiency at first increases as sun intensity increase and is at highest at Noon (12 pm) and then decreases with time.The graph between cabinet/outside temperature vs time, at respective time is as given in figure 3. This graph shows the relationship between the cabinet temperatures, outside temperature with time at 1-hour interval. The temperature increases at first and then decreases with time.

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Table 7: Calculations for Tomato

Time	Total Incident radiation I (w/m^2)	Temperature Difference $T_i - T_0(\text{in}^\circ C)$	Collector Heat Removal factor F_R	Useful Heat Q_U (w/m^2)	Efficiency of Collector η	$G = \frac{T_i - T_0}{I}$
10:00 am	820.94	9.8	0.87	434.819	0.53	0.0119
11:00 am	845.79	11.6	0.87	431.25	0.62	0.0137
12:00 pm	892.34	12.5	0.87	350.00	0.76	0.0140
01:00 pm	884.34	15	0.87	296.79	0.71	0.0169
02:00 pm	729.24	12.8	0.87	250.53	0.68	0.0175
03:00 pm	619.23	13.3	0.87	229.52	0.61	0.0214
04:00 pm	12.9	12.9	0.87	206.75	0.49	0.0267

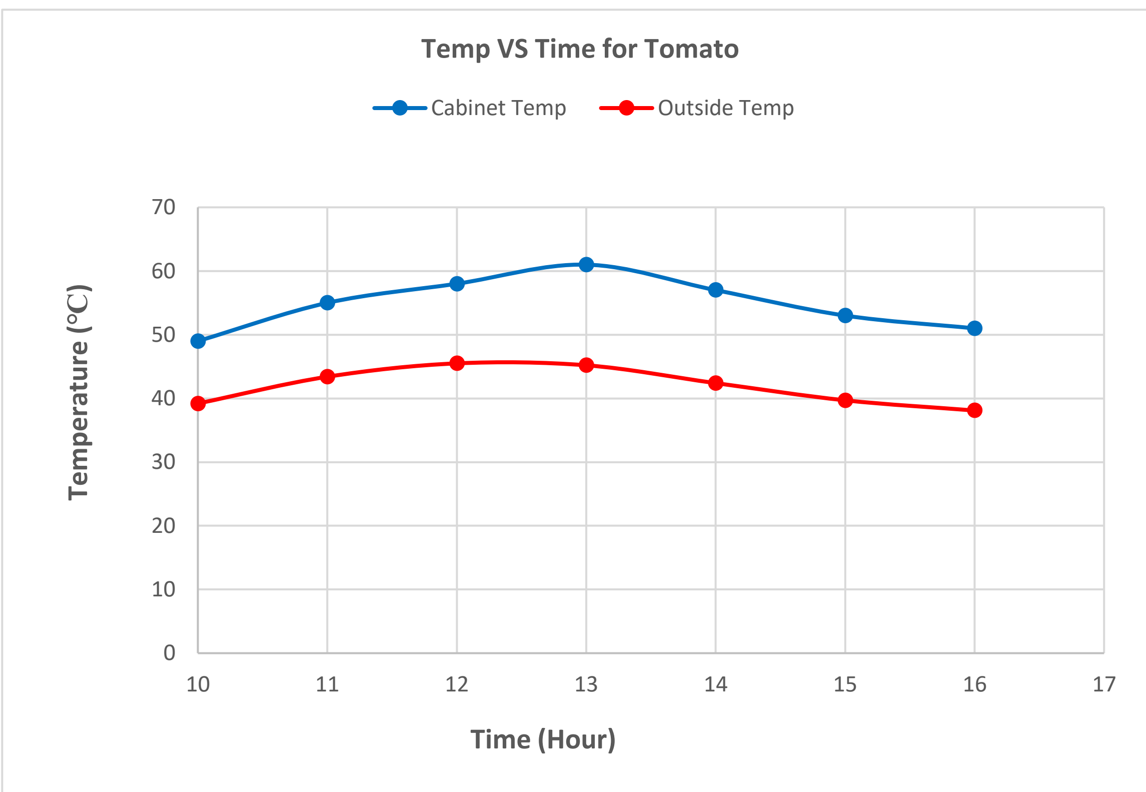

Figure 3: Cabinet/Outside Temp Vs Time Graph

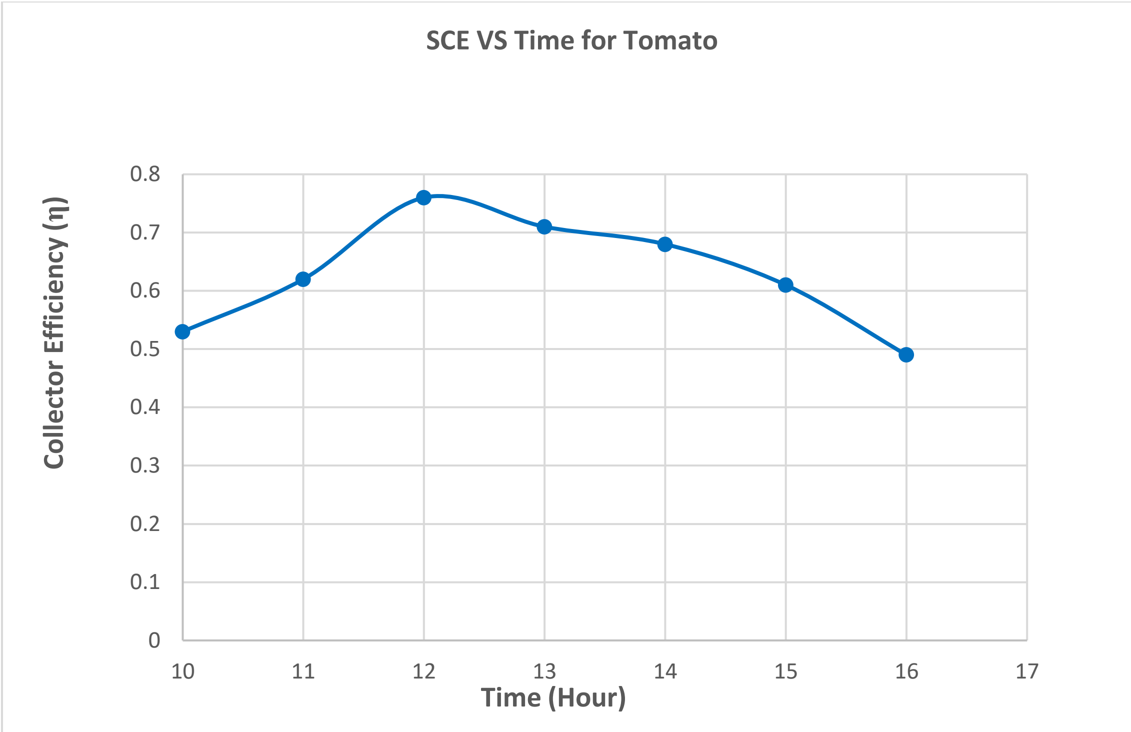

Figure 4: Solar Collector Efficiency VS Time

The graph shows the relationship between cabinet humidity and time as given in figure 5. The cabinet humidity is decreasing down continually as time passes.

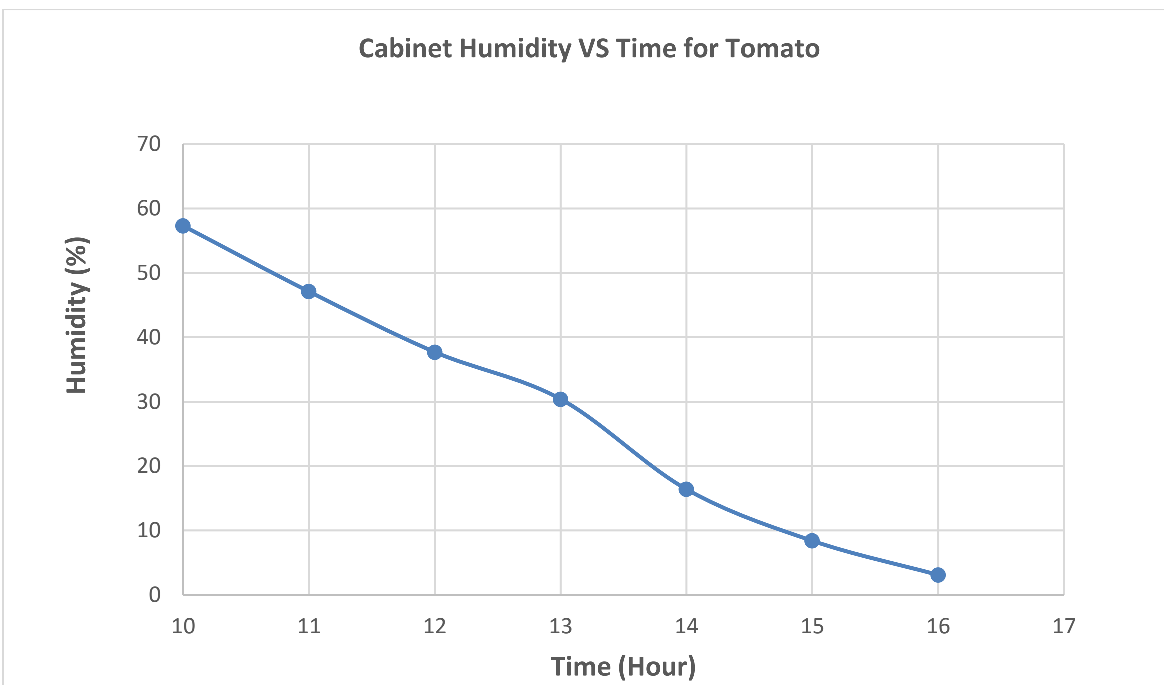

Figure 5: Cabinet Humidity Vs Time

Dehydration of Apricot

Apricot was loaded on racks for dehydration after proper pre-treatment. It took about 20 hours to completely dehydrate the Apricot with high quality, taste and color was retained. The readings were noted at 1-hour interval of time. As dehydration time is greater than 12 hours, we used backup source for continues dehydration. The calculations are as follow in table 8.

Table 8: Calculations for Apricot

Time	Total Incident radiation $I\,(w/m^2)$	Temperature Difference $T_i - T_0$(in°C)	Collector Heat Removal factor F_R	Useful Heat Q_U (w/m^2)	Efficiency of Collector η	$G = \frac{T_i - T_0}{I}$
10:00 am	816.6	9.8	0.87	680	0.53	0.0119
11:00 am	888.45	11.6	0.87	431.25	0.62	0.0137
12:00 pm	880	12.5	0.87	350.00	0.76	0.0140
01:00 pm	884.34	15	0.87	296.79	0.71	0.0169
02:00 pm	729.24	12.8	0.87	250.53	0.68	0.0175
03:00 pm	619.23	13.3	0.87	229.52	0.61	0.0214
04:00 pm	12.9	12.9	0.87	206.75	0.49	0.0267

The graph between cabinet/outside temperature vs time, at respective time is as given in figure 6. This graph shows the relationship between the cabinet temperatures, outside temperature with time at 1-hour interval. The temperature increases at first and then decreases with time.

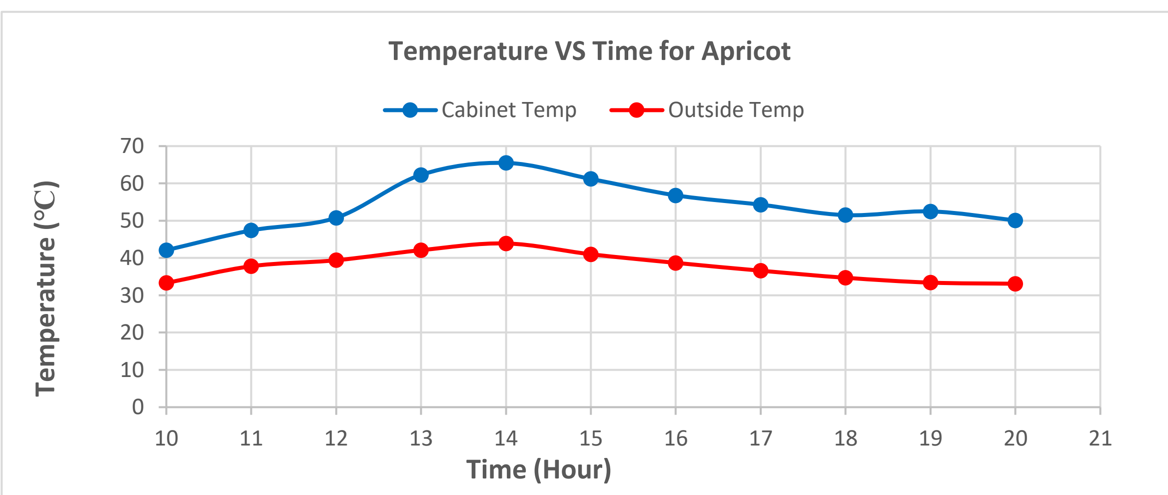

Figure 6: Cabinet/Outside Temp Vs Time

The graph between solar collector efficiency and time for apricot as given in figure 7. The solar collector efficiency at first increases as sun intensity increase and is at highest at Noon (12 pm) and then decreases with time.

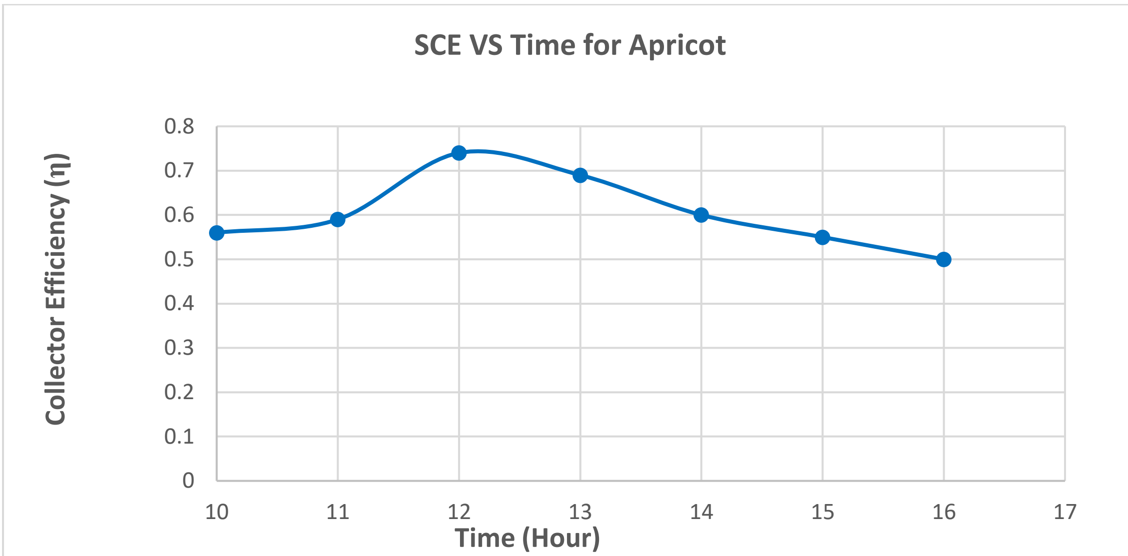

Figure 7: Solar Collector Efficiency VS Time

The graph shows the relationship between cabinet humidity and time as given in figure 8. The cabinet humidity is decreasing down continually as time passes.

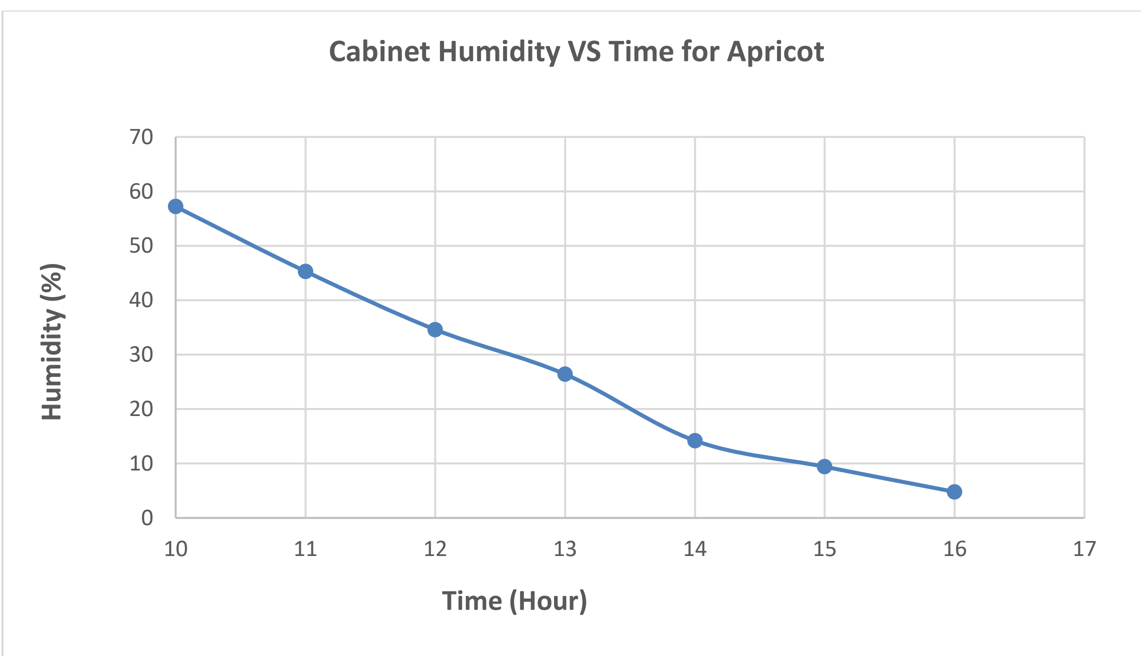

Figure 8: Cabinet Humidity Vs Time

Dehydration of Grapes

Grapes was loaded on racks for dehydration after proper pre-treatment. It took about 28 hours to completely dehydrate the grapes. The high quality, taste and color was retained. The readings were noted at 1-hour interval of time. As dehydration time is greater than 12 hours, we used backup source for continues dehydration. The calculations are as follows in table 9.

Table 9: Calculations for Grapes

Time	Total Incident radiation I (w/m^2)	Temperature Difference $T_i - T_0 (in^\circ C)$	Collector Heat Removal factor F_R	Useful Heat Q_U (w/m^2)	Efficiency of Collector η	$G = \frac{T_i - T_0}{I}$
10:00 am	834.2	9.3	0.87	478.2	0.53	0.0111
11:00 am	855.3	11.1	0.87	467.4	0.62	0.0129
12:00 pm	900.4	14.5	0.87	367.5	0.76	0.0161
01:00 pm	870.3	14.9	0.87	300.7	0.71	0.0171
02:00 pm	729.24	12.8	0.87	250.53	0.68	0.0175
03:00 pm	619.23	13.3	0.87	229.52	0.61	0.0214
04:00 pm	12.9	12.9	0.87	206.75	0.49	0.0267

The graph between cabinet/outside temperature vs time, at respective time is as given in figure 9. This graph shows the relationship between the cabinet temperatures, outside temperature with time at 1-hour interval. The temperature increases at first and then decreases with time.

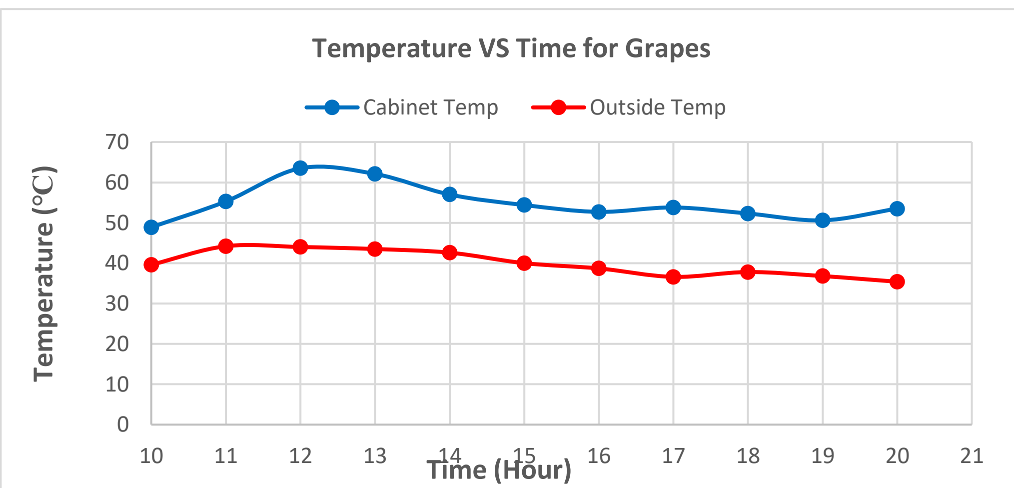

Figure Error! No text of specified style in document.**:** Cabinet/Outside Temp Vs Time

The graph between solar collector efficiency and time for grapes as given in figure 10. The solar collector efficiency at first increases as sun intensity increase and is at highest at Noon (12 pm) and then decreases with time.

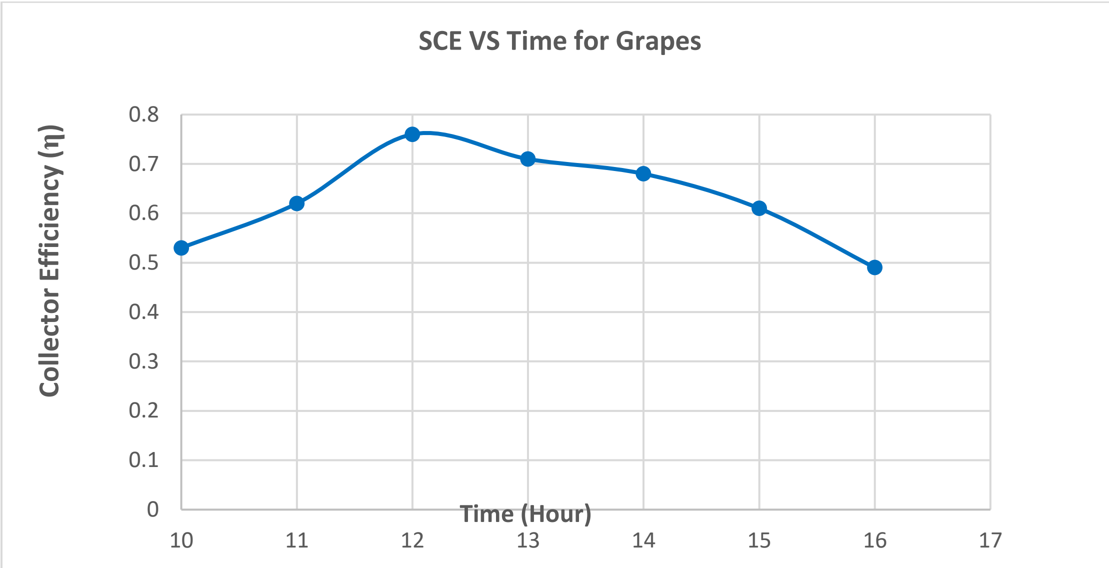

Figure 10: Collector Efficiency Vs Time

The graph shows the relationship between cabinet humidity and time as given in figure 11. The cabinet humidity is decreasing down continually as time passes.

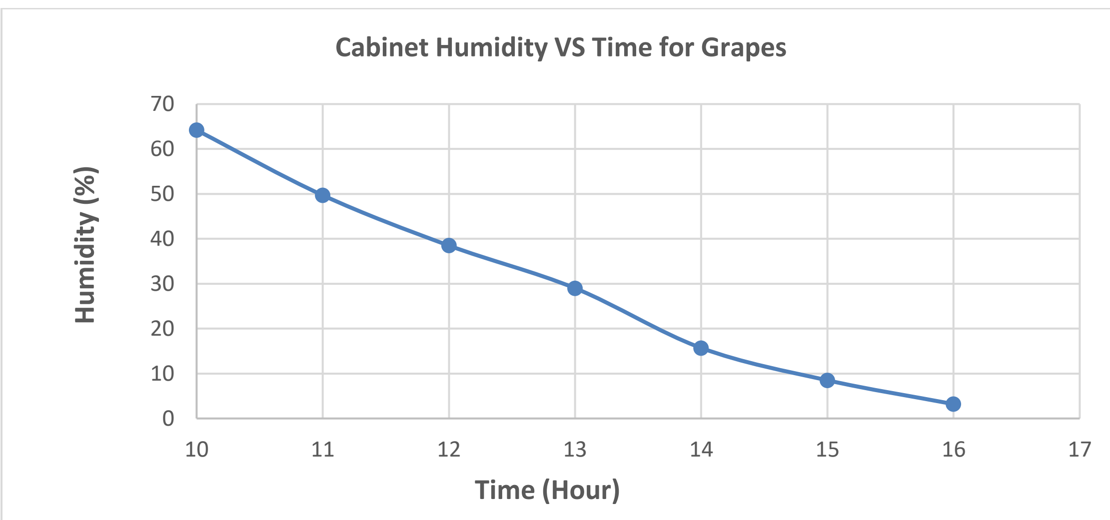

Figure 11: Cabinet Humidity Vs Time

Conclusion

The solar dehydrator was used to dehydrate different fruits and vegetables. Different experiments were performed and data was recorded and analyzed, and relationship between different parameters was found. From the observations it is concluded that:

The cabinet temperature rises at the start and we have seen the maximum temperature at noon (12pm) to 1 pm mostly. Then the temperature starts decreasing as solar radiation decreases with time.
The temperature range is 60-70℃ which is normal range of temperature for this case as the food stuff that are dehydrated lies in the range as mentioned.
The collector efficiency is maximum at 12 noon and then decreasing with time. The collector efficiency depends upon the useful heat, area of the collector and the incident radiation (I).
The cabinet humidity is maximum as we load the fruits/vegetables due to the fresh food stuff. The cabinet humidity decreases as time passes and become very less. In this case we unloaded the fruits/vegetables when humidity comes to the range of 2-5%.
In addition to analytical data, this solar dehydrator has a number of significant advantages over the traditional method of dehydrating the food stuff in order to prevent and store them for long period of time. The traditional method of drying food stuff is unhygienic, unsafe, time taking, and expensive and can only work at day time when there is sun. The solar dehydrator can be used day and night without any disruption if there is proper backup source for the dehydration of fruits/vegetables. Also, it can dehydrate fruits/vegetables whose drying time is greater than 12 hours as this is the sun time for 1 whole day.
Solar dehydrator does not require any type of fuel. It is environment friendly, pollution free and totally works on solar energy.
The solar dehydrator is finest alternative for the conventional method, particularly very advantageous for rural areas, and developing nation. Thanks to the worldwide efforts to limit the carbon dioxide emissions and the increased focus on renewable energy. No fuel is required for the solar dehydrator to operate. It is very beneficial for the farmers and small business men to dehydrate different fruits/vegetables to preserve them for long period of time.

Acknowledgment: I am happy to share the university of Engineering and Technology Peshawar Pakistan who support us on every step of paper

Funding: University of Engineering and Technology Peshawar Pakistan

Conflict of Interest: We have no COI anywhere in world on this paper

Authors contribution: Shamsher khan: worked on Result and conclusion of this paper and overall paper contribution, Tanveeruz Zaman. Worked on the literature Review of the Research papers,
Sana ullah : worrked on experimental task of this paper, Kifayatullah: work on material selection of this research, Mubashir Iqbal : work on Graphic and table performance, Arsalan Taj : work on the introduction of this paper

Data availability: On demand data is available for further research review

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