Solar Air Process Heating Systems for Drying of Agricultural Products

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Abstract – *Solar drying is one of the oldest and easiest ways of drying known to us. The purpose of this work is to design, develop and evaluate the indirect performance solar dryer prototype in a passive mode for drying of agriculture products like fruit & vegetables. Drying is one of the oldest ways to use solar energy where products such as vegetables, fruits, fish and meat to come in direct contact with the sun. This method has many disadvantages such as spoilage products caused by rain, wind, dust, insect infections, animal attacks and fungi. Foods must dry fast, but will harden out due to drying speed before the moisture has a chance to evaporate inside and it will affect the quality of dry products due to over-drying. Design of an indirect solar dryer system minimize these losses. The whole designing of 3-D indirect solar dryer has been done with the help of Google SketchUp. In this review, we also attached a moisture collector for the smooth extraction of any remnant moisture. This design of indirect mode prototype is employed in a graphical method, after finding out the parameters such as temperature, moisture contents and weight loss. This type of solar dryers has good performance and provide better products.*

Keywords: **– Solar Dryer, Design Concept, Modelling Methodology, Analytic Study, Future Availability, Renewable Energy, Environmental Friendliness.**

1. INTRODUCTION

Many agricultural products have a high moisture content which, due to biochemical reactions, makes them vulnerable to microbial and other spoilage. Therefore, to minimize the moisture content of the products, drying or dehydration activities must be carried out as preventive steps. One of the key problems faced by developing countries is the preservation of agricultural products. Over a long time, the rising nutritional requirements of the ever-expanding populace of these nations will deteriorate these issues.

Major amounts of products are being ruined in many developing nations because of unstable infrastructure &, improper processing facilities. It should be noted that around 70 percent of foods are being spoiled, due to traditional drying methods, especially in rural places. Drying these products will help solve these issues, while also making a major contribution to improving the income and supply situation of the population.

Drying is an important method of food preservation that is often carried out at farm level immediately after harvest or, in particular. The thermal drying of vegetables, fruits and meat allows for longer storage periods and easier transport. The food is placed in boxes with a transparent lid with direct sun dryers. In addition, because of the greenhouse effect, the temperature in the dryer is lifted and the air circulation is regulated by vents. In indirect sun dryers, food is not exposed to direct sunlight as fresh air is heated separately from the food chamber. For drying foods that lose nutritional value when exposed to direct sunlight, this approach is preferable. In contrast to current drying processes, solar drying can only be effective when it shows tangible benefits. Solar dryers avoid degradation of goods by pollen, insects, etc. as opposed to the conventional method of drying outdoors in an open area, thereby guaranteeing consistency. They help small-scale farmers to convert their harvest into products that can be processed and exchanged, which can be sold off-season at higher prices. The constant temperature and ventilation allow the drying process to be stable, resulting in increased product quality and higher prices. Investment costs for solar dryers, however, differ considerably depending on the scale of the solar dryer, the locally available components and the environmental factors, such as slope and side exposure, and the rainy seasons.

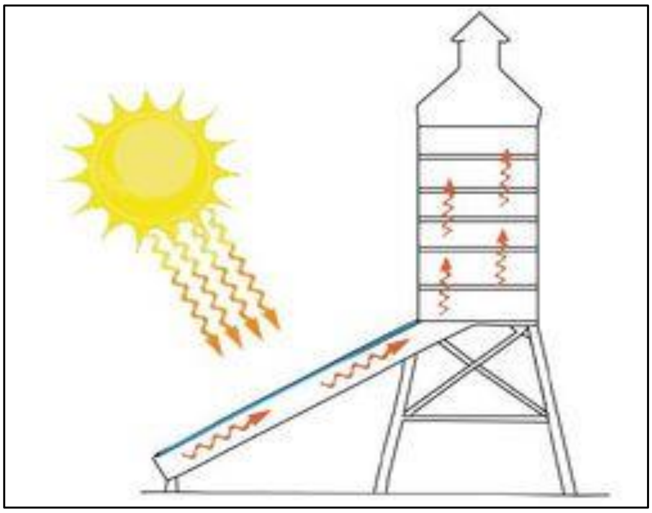


Fig -1: Schematic view of a solar dryer

Source: Energy Pedia

Drying successfully relies on:

- Enough heat, without cooking the food, to draw out moisture;
- Dry air to absorb the moisture released; and
- Sufficient air ventilation to take moisture down.

The drying of agricultural goods for improved preservation, long-term storage and export is a big part of the food processing industry. A big chunk of the drying is still achieved in India by drying the product out in the light. This not only takes a lot of time (usually in days) but is often very unhygienic because of possible environmental damage. It is possible to use a solar dryer for fruits (apples, apricots, grapes, pineapples and bananas, melons, plums, beets, mangoes, dates, figs), vegetables (cabbage, broccoli, peppers, basil, onions, squash, tomatoes, asparagus, celery, potatoes, peas, carrots, cassava, peppers, yams, red cedar, mahogany) corn, maize, rise, cassava, cocoa, fish, meat, mushrooms, spices (dried chili peppers, garlic) tea, coffee, cacao, tobacco, cashew and macadamia, milk, hay, copra (kernel of the coconut), for clothing also like, wool, kindling and as well as for treating timber.

The use of solar dryers is a more productive way; they increase the rate of removal of moisture, thereby accelerating the drying process while reducing the chances of contamination. The use of the industrial solar dryer thus decreases the drying time and helps you to increase the amount of output.

However, it's best to opt for gas fired dryers for high production capacity, as solar dryers need a lot of space. The drying time is significantly reduced by this gas-fired dryer and thus allows high output rates. These are not standard dryers and must be custom designed according to the requirement, which is typically based on the moisture content to be dried in the product, the necessary rate of moisture removal, total output per day, etc. With the preservation of original colour and taste, solar dryer eliminates excess moisture from the product as well as maintains the product clean of any environmental influences, dust, dirt, animal or bird droppings. [1]

1.1. Solar Dryer Can Be of Two Types

1. Direct Gain Dryer
2. Indirect Gain Dryer

In their way of using solar energy, the two are distinct from each other. In direct solar drying systems (fig.2), the products are directly affected by solar radiation. The goods are heated directly by sunlight and moisture is released by the outlet into the air (usually a chimney). Whereas the indirect drying system (fig.3) use solar radiation to heat air inside the heater chamber, which is then moved to the dryer chamber where the hot air passes through the products, removing their moisture content along the way and leaves through the chimney at the top of the drying chamber.

An indirect solar dryer system has two main components, i.e., solar air heater and dryer cabinet. The air heater is a box like a structure with a glass cover at the top to allow solar gain to enter (usually wooden or metal). Inside the heater, an absorber plate is located that absorbs heat from solar energy and transmits it to the surrounding air, heating it. In general, the absorber plate is a black sheet of painted metal that may have fins or may be corrugated to improve the absorber's surface area. The heated air is moved to the dryer cabinet, which is again a cabinet with perforated trays (wire meshes) and a chimney at the top to allow the air to escape to the outside as a framework made of wood or metal. [2]

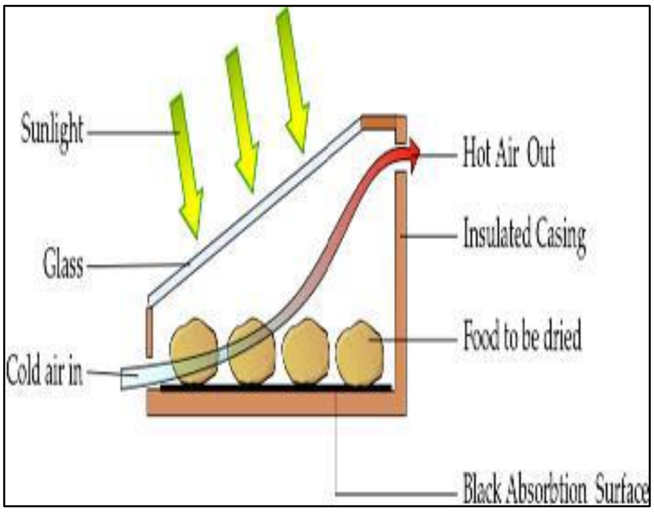


Fig -2: Direct Dryer
Source: Wikipedia

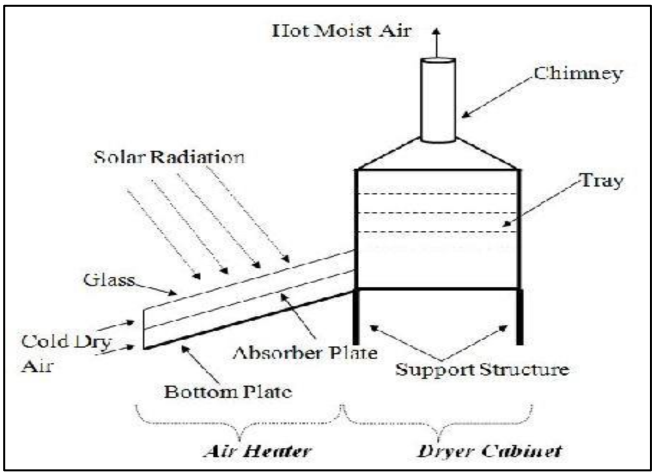


Fig -3: Indirect Dryer
Source: Wikipedia

1.2. Quality Changes During Drying

The act of applying heat to dry material does not simply remove moisture. But dry can affect product quality. These effects differ only from those Commonly encountered events that will be described here.

1. Browning: - It is the dissolution of material during drying, which can either be caused by Physical processes or chemical reactions. It depends on the combustion effect Time and temperature on the moisture of drying material.
2. Case Hardening: - it is characterized by the surface drying of the material and being relatively impermeable. For the further flow of moisture, but with some interior remaining at high humidity material. But with the drying of most vegetables and fruits, the matter does not harden.
3. Rehydration: - It is not that dehydration is a complete reversal of the dehydration process. As in the case of the production of a similarly rehydrated product, rehydration is basically not so important because the dried product is used by adding it to a soup or stove directly near the cook.

1.3. Classification of Industrial Dryers

A wide assortment of dryer plans has advanced throughout the years in terms of working the drying unit. The different method has been suggested as the best way to define them but before seriously considering the methods of classification, it is necessary to define, but Broad principles,

I. How thermal vital prerequisites are provided.
II. How to operate the dryer

In the first place, the heat must be transferred to the wet material for drying operation. heat can be applied in at least one of the accompanying ways.

(a) Convection whereby the heat medium where air or combustion product is in direct contact with wet material.
(b) Conduction, where heat exposure occurs indirectly through contact with the wet material.
(c) Radiation, where heat is transmitted directly and completely to a hot body, a material wet by heat radiation. [3]

1.4. The Following is a Comparison of Each Type Industrial Drying with Illustrations of Typical Application

1) *Conduction VS Convection Dryers*

A distinction can easily be made between conduction and convection drying. Relatively large solid gas separating equipment is often required for convection dryers (e.g., flash and spray dryers). With the increase in inlet temperature of the drying gas, the thermal efficiency of convection dryers also increases. While within conduction dryers, there is no such effect. The heat energy of the drying medium in convection drying is transmitted by convection to wet materials which have direct contact with hot airflow. As a drying medium, the hot air is both a heat carrier and a wet carrier in convection drying. In conduction drying, the heat energy is conveyed in terms of conduction to wet materials. Wet products do not have direct contact with heating media.

2) *Radiation VS Convection Dryers*

In the case of radiation drying, heat energy is produced by the emission of infrared radiation sources in the form of electromagnetic waves projected for water evaporation on the material surface. This process is often called infrared drying, and it is possible to use electricity and coal as the source of infrared radiation. Radiation drying is much quicker and requires less energy than convection drying, since it only heats the surfaces to be dried. However, it is only possible to dry up surfaces exposed to radiation and this restricts the possible form of the object Another downside is that it does not heat various colors, pigments and surface structures to the same degree. Convection drying does not have these limitations on goods, but it is important to heat a large thermal mass. Typically, drying happens in two separate ways. Usually, radiation drying is carried out with fair energy savings and 50 percent-80 percent of the energy is used for evaporation. The energy usage of convection drying is always low and it is pretty common to use just 10%-20% of the energy for evaporation. [3,4]

2. PROBLEM IDENTIFICATION

The solar air dryer is an old concept, but in the modern world, there are many different parameters considered during its construction. Advantages as well as disadvantages such as friction loss, vibration, expansion of acrylic.

Friction losses on glass, cross-section and reducing leakage due to heat and airflow it can't be identified that air in small parts. After considering all the factors, we have taken the decision to make solar dryers for agricultural products, which is less expensive, is more efficient for poor people or farmers.

3. DESIGN AND METHODOLOGY

3.1. Introduction to Google Sketchup Software

SketchUp is a 3D modelling computer program application created by Trimble Inc. A wide scope of drawing applications, for example, engineering, interior design, landscape design, civil and mechanical designing, film and video game design. [5]

How Google SketchUp is different from other 3D designing software: -

- SketchUp is much easier to used and master.
- SketchUp has a good and simple learning curve. you need to only start and create the modelling is a simple object to see.
- The user interface is easier to navigate and it's also a friendly interface.
- SketchUp is a 3-dimensional modelling software where you can draw and edit any 2D and 3D model with tools. push and pull are a tool that is used to convert any flat surface to create into 3D shapes.
- SketchUp has a warehouse option which is used to already created model available for anyone access it.

3.2. Design Considerations & Assumptions

Table -1: Parameters for Solar Dryer

S.No.	Parameters	Description
1.	Location	28°42'41.3"N 77°15'44.8"E
2.	Drying Period	December
3.	Solar Irradiation for December	15.3MJ/m2/hr
4.	Food Product	Agriculture Products (Potato & Carrots)
5.	Mode of Heating	Indirect
6.	No. of Glazing	1
7.	Glazing Material	Glass
8.	Loading Provision	Door at the Sideway of the Cabinet
9.	Air Outlet Provision	Air Conduct Passage through the Upper Most Section of the Back
10.	Number of Trays	4
11.	Air Circulation Mode	Natural Convection
12.	Drying Capacity	10 kg
13.	Thickness of Plantain Fillets	3 mm
14.	Construction Materials	Wood, Glass, Aluminium Sheet
15.	Insulation Used	Glass Wool
16.	Thickness of Aluminium Sheet	3 mm
17.	Thickness of Glass	5 mm

3.3. Design

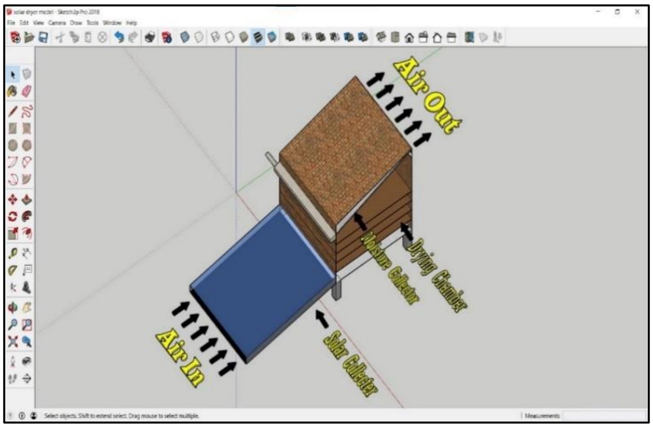


Fig -4: Isometric Model of Solar Dryer

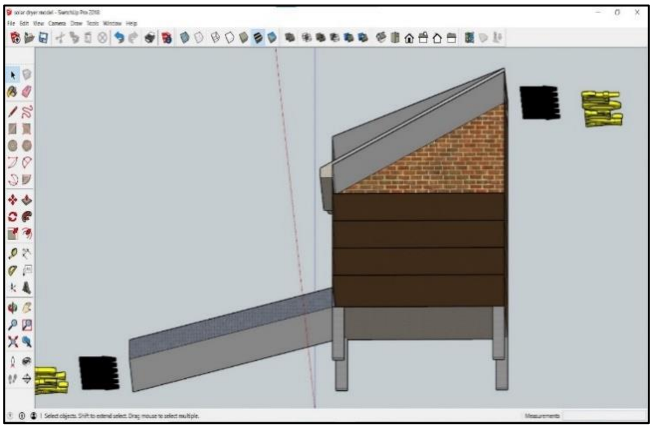


Fig -5: Top View of Model of Solar Dryer

The solar collector of a solar air heater has a box that is made of plywood on the bottom, where it acts as fiber glass on its top and body. Solar dryer is work on simple concept. then basic principles of solar dryer are:

- Converting light into heat energy: The plywood is painted black on one side. This helps in increasing the capability of plywood for converting light into heat.
- Trapping heat: It is of great importance to separate the air inside and outside of the dryer. For this, we used solid fiberglass as a cover. Once the light converts into heat, the glass fiber traps the heat inside in the dryer.
- Interaction of heat and product: There are two methods of the dryer, forced convection dryer and natural convection dryer, both of dryer transfer the heat in food. in this project, natural convection

method is using whereas there is a passive type of solar dryer.

- Moisture collector: We added a new concept of removing of evaporated moisture from the drying chamber with the help of attached incline aluminium sheet. [6]

4. COST ESTIMATION

Table -2: Bill of Materials [7,8,9]

Part Name	Quantity	Unit Cost	Total Cost (Rs.)
Aluminium Sheet	1	1225	1225
Angle Iron	4 (each 45 cm)	3/ cm	540
Wire Gauge	4	120	480
Plywood	135.225 sq. ft.	46.63/ sq. ft.	6305
Blank Paint	1 (500ml)	149	149
Fiber Glass	11.725 sq. ft.	25/ sq. ft.	300
Miscellaneous			500
TOTAL			**9499**

5. EXPERIMENTAL SETUP

5.1. Design Implementation

The ambient temperature of the solar dryer during the direction was determined in writing. After physical experiments with the help of a calibrated thermometer, in which in this real-time project, we offer modern design, compact construction and large display of an indirect solar dryer to conserve useful food Products. Thus, this solar dryer ultimately shows sufficient capacity to ensure rapid clean up to a safe moisture level safely and even more clearly. Improved quality of practical dried product.

Fig -6: Front View of the Indirect Solar Dryer Prototype

Fig -7: Top View of the Indirect Solar Dryer Prototype

5.2. Observations

The individual fact of moisture is wiped out during drying in the month of December 2020, both outside and inside the assembly, as shown below. During the drying period, room temperature is 21OC and compared percentage removal of moisture in preserved food with the help of the solar dryer. the atmospheric air (which is present in the surrounding) following table shows based on observational data. We also took various products for experimental calculation. Average the efficiency of the dryer in a day which was satisfactorily 15% with the rate of removal of moisture of various samples like potato, carrot was found to be 64%, 58% respectively. All practical offenses were on the underlying support of a day completely sunny. [10]

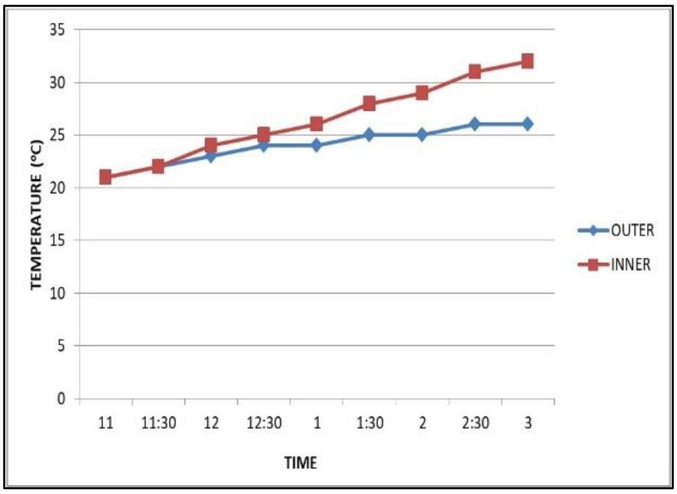
The coming after data is given below:

Table -3: Day-wise Temperature and Weight Measurement

DAY	Date	Time	Outer Temp.	Inner Temp.	Weight at Morning		Weight at Evening	
					Potato	Carrot	Potato	Carrot
1	06-12-2020	11:00 am	21° C	21° C	500 g	500 g		
		11:30 am	22° C	22° C				
		12:00 pm	23° C	24° C				
		12:30 pm	24° C	25° C				
		01:00 pm	24° C	26° C				
		01:30 pm	25° C	28° C				
		02:00 pm	25° C	29° C				
		02:30 pm	26° C	31° C				
		03:00 pm	26° C	32° C			219 g	173 g
2	07-12-2020	11:00 am	21° C	21° C	219 g	173 g		
		11:30 am	21° C	23° C				
		12:00 pm	23° C	25° C				
		12:30 pm	24° C	26° C				
		01:00 pm	24° C	27° C				
		01:30 pm	25° C	28° C				
		02:00 pm	26° C	29° C				
		02:30 pm	26° C	30° C				
		03:00 pm	26° C	30° C			136 g	118 g

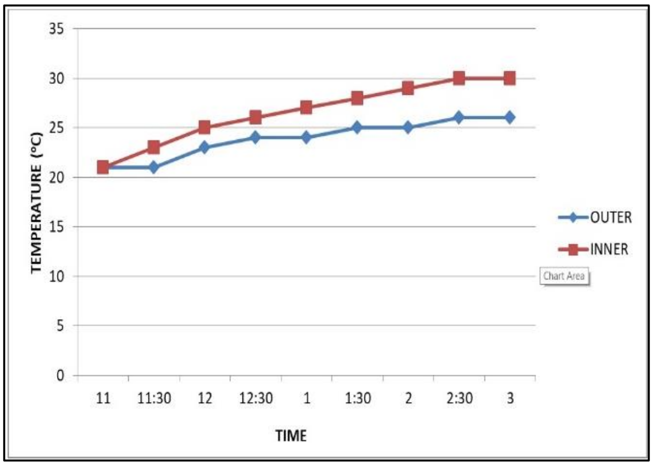
- **Graphical Representation of Temperature Vs. Time of Drying Potatoes and Carrots:**

DAY 1



Graph 1: Day 1, Temp Vs. Time graph of Potatoes and Carrots

DAY 2



Graph 2: Day 2, Temp Vs. Time graph of Potatoes and Carrots

- **Original Appearance of The Potatoes and Carrots Before and After 4 hours of Drying in a Shiny Day:**

Fig -8: Potatoes and Carrots Before Drying

Fig -9: Potatoes and Carrots After Drying

6. CALCULATION

6.1. Potatoes

Moisture content of potato before drying = 80%,
Weight before processing = 500g,
Weight after processing = 136g,
Amount of moisture content = $500 \times \frac{80}{100} = 400$g
Amount of moisture removed = $500 - 136 = 364$g
Moisture remains after drying = $400 - 364 = 36$g
Moisture content after dried = $\frac{36}{136} \times 100 = 26.47\%$

6.2. Carrots

Moisture content of carrot before drying = 88%,
Weight before processing = 500g,
Weight after processing = 118g,
Amount of moisture content = $500 \times \frac{88}{100} = 440$g
Amount of moisture removed = $500 - 118 = 382$g
Moisture remains after drying = $440 - 382 = 58$g
Moisture content after dried = $\frac{58}{118} \times 100 = 49.15\%$

7. RESULTS AND DISCUSSION

The general trend in the temperature profiles obtained indicates a rise from 11:00 to 15:00 and a decrease thereafter (Graph 1 and 2). It was noted that the temperature of the solar collector was always higher than the heating chamber. For the cabinet, maximum temperatures of 32oC and 30oC from day 1 and day 2 respectively were recorded. On day 1, the amount of water content removed from the product was higher than day 2. Also, the amount of moisture content removed within the products was observed to be proportional to the temperature of the heating chamber, hence the maximum removal occurred when the chamber temperature was between the third and fourth hours. The amount of moisture content extracted from potatoes is 281g & 83g for day 1 & day 2. For carrots, on day 1 it is around 327g & on day 2 it is 55g. For the span of 8 hours the percentage of moisture extracted for potatoes is 26.47 percent and 49.15 percent for carrots. [11]

8. CONCLUSION

Solar dryer works operated on solar energy. As in nation Out of 365 days in India, 300 days of sunlight a very valuable thing of solar energy. The government is encouraging toward the use of renewable energy as a solar panel, solar pump, solar heater, solar light, etc. and the government provides subsidies with the condition. Therefore, it is a good chance to take advantage of their Plans. We don't need anything from the cost of solar power, just a solar panel is needed; Sunlight is free and is also a non-ending source of energy.

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