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SOLAR DRYER WITH RECIRCULATING EXHAUST AIR

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ABSTRACT

The work presented is based on the work of a dryer, the main purpose of this experiment is to design a dryer that meets the basic requirements of a dryer which is modified by modifying the design of indirect forced solar dryer. Energy conservation and food preservation through the process of removing moisture in a solar dryer is the concept behind the manufacture of the dryer. The dryers designed in this experiment use solar energy as well as electrical energy, hence the name 'Hybrid Solar Dryer'. In this hybrid solar dryer a recirculating duct is connected from the motor fan assembly to the drawing chamber so that the hot air which is first hot air passes through the rectangular duct and finally into the divergent duct. Drying chambers but some heat is lost in them but this air is re-used by the circulatory system to heat the food in the dry chamber. Working on this dryer reduces drying time, increases drying rate, and increases moisture removal compared to indirect solar dryers.+.

I. INTRODUCTION

Drying is a complex process that involves simultaneous heat and mass transfer. The amount of energy required to dry a particular product depends on many factors, such as initial humidity, final humidity, dry air temperature, relative humidity and speed

The dryers are broadly classified as:

High temperature solar dryers and low temperature solar dryers based on their operating temperature range

1. Air movement mode. 2.Insulation exposure, 3.Air flow direction,4.Dryer system, 5.Solar contribution, 6.Type of dried fruits

A. On the basis of air flow:

1. Direct Solar Drying, 2.Indirect Solar Drying, 3.Mixed Mode Solar Drying.

WHY SOLAR DRYER

- More than 20% of the total fruit and vegetable production is wasted in India at various post-harvest stages.
- To improve the shelf life of these food products, their moisture content should be reduced so that microorganisms cannot grow.
- It saves shipping and transportation costs as it reduces both volume and weight.

A. DRYING PRINCIPLE:

In the process of drying, heat is required to evaporate the moisture in the drying material and air flow is required to evaporate the moisture.

"The drying process involves two basic mechanisms:

1. Moisture transfer from the inside of the dried substance.
2. Evaporation of moisture from the surface into the surrounding air.

The rate is determined by observing the following parameters:

1. Moisture content.
2. Temperature of the material to be dried.
3. Air temperature, humidity and velocity in contact with the substance.

B. PHYSICS OF DRYING:

Everyone knows what drying is, but not everyone understands the physical process of drying and not understanding this process can lead to the destruction of entire crops during the process of drying, healing and storing.

Drying an object (onion, potato or other product) is a process in which the following parameters play a decisive role:

1. air temperature. 2. Relative humidity 3.air pressure 4.dew point 5.drying product temperature. 6.The

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amount of air passing through the product.

The first 4 parameters are strictly related to the 'Laws of Physics'.

DEW POINT plays a determining role in all these processes.

What is Dew Point?

The dew point is the temperature at which water in an air sample condenses into liquid water at constant barometric pressure at the same rate as it evaporates.

These four parameters are relatively represented by "MOLLIER DIAGRAM".

C. Moisture content:

Humidity in fresh foods ranges from 20% to 90%. Foods require different levels of dryness for safe storage. For example: The moisture content of rice should be reduced from 24% to 14% of total weight. Therefore, 100 kg of water has to be removed to dry 1,000 kg of rice. Humidity should be reduced by 20% for fruits, 10% for vegetables and 10-15% for cereals for safe storage. If the food is properly dried, it will not show moisture when cut.

Fig: Solar collectors

Fig: solar dryer cabinet

1. solar collector as shown in fig. metal frame size is 40×60×6 inches. By using grinder remove excess material and sharp corner edges. for heat insulator 18mm plywood covering on collector casing each side and only top side fitted Toughened glass on which sun rays go inside through the glass The glass can handle temperature up to 250°C. Black painted aluminium sheet of 27gauge thickness and sheet is fastened to the heating chamber. This section consists of motor Fan arrangement to regulate air flow and a tapered duct attached in front of it.

Solar Collector

Solar Dryer Cabinet

Fig: Tray Arrangement And Door System

Drying Chamber

polycarbonate sheet is used as a cover of the dryer with metal support. because it has transmitted (about 0.5),thus creating a good greenhouse effect in the dryer .in addition, the polycarbonate sheet has a light weight and easy to bend and easy to reducing the construction cost. It consisted of three trays, each with size of 39 x 16 inch, for the produce to be dried. The trays were made from perforated stainless steel. Stainless steel was chosen to avoid rusting due to high initial moisture content of the produce. At one side of the chamber, 4 ×40 inch area hole was made. This hole was used to pass hot air side of the tray in the chamber. At the back of the drying chamber, a door will provide a means for loading and removing the material to be dried.

Fig: Loading try with potato slice

SILICA BREATHER :- the purpose of silica gel breather is to absorb the moisture in the air .silica gel breather are fitted with blue silica gel (indicating type) which has the moisture absorption capacity an signals the saturation degree by changing its colour.

Fig: Regulate valve for recirculation exhaust hot air with breather for remove moisture

HOT-AIR RECIRCULATION:

Now the hot air is recirculated into the motor fan arrangement, For recirculation of hot air 100mm pvc circular duct arrangement is used. In the recirculation moisture remove by silica breather as shown in fig, hygrometer is placed both side of breather to measure before and after humidity and temperature. After that dry hot air duct connected to solar collector bottom side as shown in fig.

Trial 1

Before breather	After breather
Humidity:- 35%	Humidity:- 30%
Temperature:-29.9℃	Temperature:-36℃

Recirculation difference temp and humidity

Trial 2

Before breather	After breather
Humidity:- 41%	Humidity:- 29%
Temperature:-38.1℃	Temperature:-43.7℃

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Recirculation difference temp and humidity

Inlet fresh air temp

Solar collector air temp

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Dryer temp

Trial 3

Before breather	After breather
Humidity:- 32%	Humidity:- 28%
Temperature:-40.6℃	Temperature:-42.9℃

Recirculation difference temp and humidity

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Before Drying

Solar dryer with recirculation duct arrangement

Intermediate Drying **After Drying**

- As we describe earlier our basic purpose is to achieve70 to 80ºc temperature at the inlet of the drying chamber and reduce moisture upto minor level.

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- After assembling both the chamber, we fit the blower in the inlet of the heating chamber.

The required reading are taken as follows :

Without blower :

Ambient temperature = 35ºc

Outlet temperature of heating chamber = 70ºc

With blower : [25/04/2013]

TIME OF DAY	AMBIENT TEMP. [ºC]	INLET TEMP. OF DRYING CHAMBER [ºC]	INTERMEDIATE TEMP. IN THE DRYING CHAMBER [ºC]	EXIT TEMP. [ºC]
10:00 A.M	35	75	68	60
11:00 A.M	38	80	73	63
12:00 A.M	40	84	75	66
1:00 P.M	39	80	72	64
2:00 P.M	39	78	70	63
3:00 P.M	38	76	68	63
4:00 P.M	35	70	62	55

With blower : [26/04/2013]

TIME OF DAY	AMBIENT TEMP. [ºC]	INLET TEMP. OF DRYING CHAMBER [ºC]	INTERMEDIATE TEMP. IN THE DRYING CHAMBER [ºC]	EXIT TEMP. [ºC]
10:00 A.M	35	75	65	54
11:00 A.M	38	80	70	58
12:00 A.M	40	80	72	60
1:00 P.M	39	78	72	62
2:00 P.M	39	76	71	64
3:00 P.M	38	74	68	63
4:00 P.M	35	70	64	57

NOTE : These are the measured temperatures in our trial during clear sky. This may vary according to atmospheric condition.

TABLE 2

RECIRCULATION MODE						
	10%	20%	30%	40%	50%	70%
Atmospheric Temperature	40°C	40°C	41°C	41°C	41°C	41.2°C
Solar Collector	60.2°C	61.08°C	62.06°C	63.03°C	63.08°C	64.9°C

Temperature						
Collector To Dryer Pipe Temp	54.3°C	55°C	55.5°C	56°C	56°C	60°C
Cabinet Temperature	52.8°C	53.2°C	53°C	53°C	53.2°C	55°C
Recirculation Pipe						
Temperature In	45.2°C	47°C	46.2°C	46.2°C	47°C	47.2°C
Temperature Out	47.8°C	50°C	48.08°C	49.8°C	50.1°C	48°C
Humidity						
Humidity (In)	41.00%	38.00%	38.00%	34.00%	32.00%	32.00%
Humidity (Out)	36.00%	35.00%	34.00%	30.00%	29.00%	29.00%

RECIRCULATION MODE						
	10%	20%	30%	40%	50%	70%
Atmospheric Temperature	40°C	40°C	41°C	41°C	41°C	41.2°C
Solar Collector Temperature	60.2°C	61.08°C	62.06°C	63.03°C	63.08°C	64.9°C
Collector To Dryer Pipe Temp	54.3°C	55°C	55.5°C	56°C	56°C	60°C
Cabinet Temperature	52.8°C	53.2°C	53°C	53°C	53.2°C	55°C
Recirculation Pipe						
Temperature In	45.2°C	47°C	46.2°C	46.2°C	47°C	47.2°C
Temperature Out	47.8°C	50°C	48.08°C	49.8°C	50.1°C	48°C
Humidity						
Humidity (In)	41.00%	38.00%	38.00%	34.00%	32.00%	32.00%
Humidity (Out)	36.00%	35.00%	34.00%	30.00%	29.00%	29.00%

	RECIRCULATION PIPE FULLY OPERATED				**RECIRCULATION PIPE OFF**
	READING 1	READING 2	READING 3	READING 4	
Atmospheric Temperature	35.1°C	32.2°C	32°C	34.5°C	33.3°C
Solar Collector Temperature	58.6°C	56.8°C	57°C	59.8°C	56°C
Collector To Dryer Pipe Temp	54°C	53.8°C	53°C	54.8°C	55°C
Cabinet Temperature	52°C	51.5°C	51°C	51.5°C	55°C
Recirculation Pipe					

Temperature In	45°C	43.4°C	44°C	43.8°C	
Temperature Out	48.8°C	48.2°C	49°C	49.8°C	
Humidity					
Humidity(In)	43.00%	42.00%	42.00%	47.50%	
Humidity(Out)	39.00%	29.00%	34.00%	33.00%	

	READING 1	READING 2	READING 3	READING 4	RECIRCULATION PIPE OFF
Atmospheric Temperature	35.1°C	32.2°C	32°C	34.5°C	33.3°C
Solar Collector Temperature	80°C	76.3°C	76.9°C	69.7°C	59.9°C
Collector To Dryer Pipe Temp	78.0°C	74.3°C	72°C	74°C	57°C
Cabinet Temperature	66°C	62°C	62°C	62.5°C	48°C
Recirculation Pipe					
Temperature In	52°C	51°C	50.2°C	52.4°C	
Temperature Out	58°C	56°C	54.2°C	56.2°C	
Humidity					
Humidity (In)	43.00%	57.00%	31.00%	56.00%	
Humidity (Out)	29.00%	46.00%	27.00%	44.00%	

ADVANATAGES

- Complete independence from weather conditions due to high drying temperatures and the ability to dry up to low final humidity,
- protection from dust and rainwater contamination.
- Good control over the drying process
- Food does not come into direct sunlight, which reduces the colour and vitamins.

LIMITATIONS

- Complex to build in local workshops

TIPS FOR BETTER OPERATION

- The collector's face should be south in the northern hemisphere and north in the southern hemisphere.
- The collector should move away from the shade of trees or buildings for outdoor experimentation.

II. PRECAUTIONS

- Collector plate and recirculating duct should not be touched due to their temperature.
- The wiring in the temperature control box should be checked from time to time.
- Gloves should be free of worms when removing the tray from the drying chamber.

GOALS ACHIEVED

The main purpose of the current dryer design and fabrication is to provide enhanced drying efficiency and at the same time maintain food quality.

- The solar dryer is able to achieve higher operating temperatures by directing the spent air from the drying chamber with a higher temperature than the inlet air and taking advantage of the hot air. Yet high operating temperatures, especially outlet air, with minimal humidity, are caused by air recirculation
- Achieve temperatures in the range of 35 degree C to 90 degree C in the drying chamber.
- Use solar energy as well as use heating elements to heat the air entering the heating chamber which further increases the usability of the dryer as it is possible to complete indoor use. Along with that.
- Good temperature control is being stabilized in the dry chamber by installing a temperature control box on the wall of the drying chamber and using a temperature sensor to accurately measure the temperature of the hot air inside the drying chamber and by feeding input for control. So lets To control current in heating elements and motor-fan assemblies. Thus energy efficiency is achieved by maintaining SET temperature in the drawing chamber. Visual display of current operating temperature and SET temperature is also possible.

III. FUTURE IMPROVMENTS

Despite being an efficient dryer, there is always room for further improvements and developments by bridging the gap between solar researchers and food technicians. While food technologists are unaware of the capabilities of the new generation of solar dryers, solar technologists are unaware of the technical requirements of the various processes involved in food processing.

Any technical project is susceptible to various modifications and alternatives. However some future technical improvements are suggested:

- Adding solar panels and separate one. Building a power supply unit to run the entire dryer.
- A solenoid-valve can be attached to both ends of the recirculation duct and a display panel can be set behind the solar dryer to control the programmable humidity and humidity sensor to display the internal humidity. When the humidity in the air exceeds a certain value, it will help to stop air circulation.
- Introduction of laminated silica gel sheets into honeycomb comb panels to remove further moisture in the drying chamber.

IV. CONCLUSION

Solar-based technologies are currently playing an important role in food processing, but they are limited to micro- to small-scale processing. However, indirect solar drying no. of opportunity to use it extensively and to study it, and for the purpose of future study. Due to changing lifestyles in India and elsewhere, there is a huge demand for healthy ready to eat (RET) foods and indirect solar food processing can make a big contribution to meet such demands.

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