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COMPARATIVE EXPERIMENTAL STUDY OF FORCED CONVECTION & NATURAL CONVECTION SOLAR DRYER FOR FOOD MATERIAL

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ABSTRACT

This study aims to compare two different types of solar dryer, natural convection solar dryer and forced convection solar dryer .In forced convection solar dryer fans are used for drying. A 4 mm single glass plate used to cover the collector, to reduce convective loses to the atmosphere. The collector slope was adjusted to 27° and south faced, which is suitable for the geographical location of Jaipur (26.9260° N, 75.8235° E). Experiment on the solar air heaters were performed in the clear days of feb-march 2015. We develop a solar food dryer. The energy we are getting in this experiment are used for removing the moisture that result in reducing the weight of product which we are to be dried. These types of dryer mainly used in the small scale and home appliances. The fans were installed for the forced convection and the energy obtained directly from sun through photovoltaic power system ,the advantage of solar food dryer are to protect in the dryer from the dust ,animals ,birds, vitamin losses lots of devices available in the market to remove moisture but it is the safe ,best and economical way for the farmer.

1. INTRODUCTION

The main source of solar energy is sun in the earth .The world is dependent on the sun. So we should utilize that energy. This energy is of pollution free. In sun drying there are losses in the vitamins ,colors and damages. So to avoid these losses we provide solar food dryer .the solar dryer is prevents from the rain, animal, bird eating. So it is safe and best way to preserve and most convenient. Approx. 165 trillion (kw) solar energy received by the earth and 30% of total received energy reflect back to the space, and approximately 47% energy transformed to low temperature heat energy, and 23% of heat energy used for evaporation, and 0.5% cis of pollution free med in kinetic energy of wind and waves.

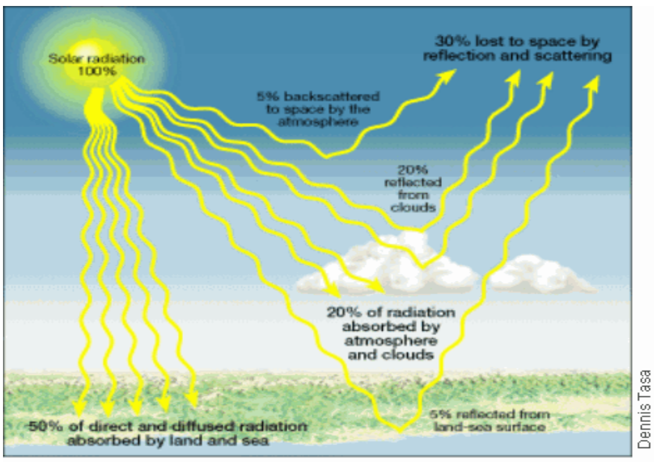

Figure 1: shows solar radiation system on earth.

The Solar radiation is one of the cheap and easily available energy source in the world and it is most capable renewable energy sources in the world because of its large quantity, and its non-pollutant behavior, and infinite source as compared to highly costly and scarcity of fossil fuel.

There are two types of solar dryer one is natural convection solar dryer and other is forced convection solar dryer. In natural convection solar dryer air flow inside the dryer naturally and in the forced convection air flow inside the dryer by using fan. In case of forced convection solar dryer air circulation inside the solar dryer will be uniform in drying fruits and vegetables. However we can choose the design by the help of simulation using analysis fluent. And also we can do analysis on material of the solar dryer and optimum thickness of the material which is used in the construction of the solar dryer.

Originally, the solar dryer are designed for drying vegetables and fruits. In Suresh Gyan Vihar University Jaipur we dried these products -mint, potato chips, fenugreek and red chilies etc.

More than 80% of food is being produced by the small farmers, so small farmers' needs these type of instrument with low cost and low maintenance like solar dryer.

Solar drying process- Sun drying is called air drying/or solar air drying. In the drying process air circulation inside the dryer play the important role. So the efficiency of the solar dryer is highly depend on the air circulation across the absorber plate inside the dryer. Those products which are drying inside the dryer may receive energy direct or indirect. Receiving energy causing raise the temperature and increase the rate of evaporation of the moisture from its surface. Drying rate play the role in calculation of efficiency of the solar dryer. And some other parameter also affect on the efficiency of the solar dryer like- atmospheric temperature, humidity of the atmosphere, movement of the air inside the dryer.

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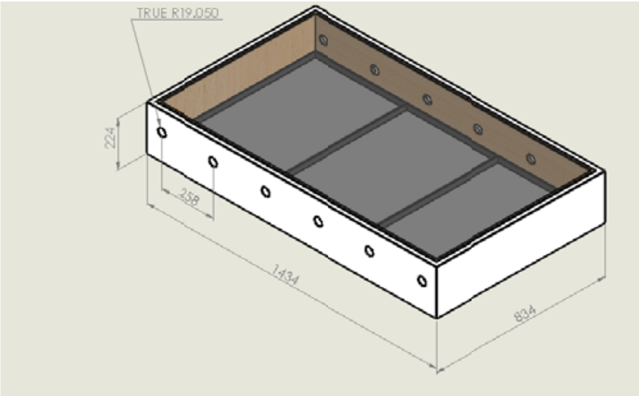
Drying process is highly depend on the shape and size of the product and also depth of the solar dryer.



2. OBJECTIVE

2.1. PROBLEM DESCRIPTION

- To compare the thermal efficiency of natural convection and forced convection solar dryer respectively.
- To investigate the effect of air flow rate in thermal efficiency of solar dryer.
- To promote public awareness on the application, benefit, and necessity of solar drying.
- To prove solar dryer as device for harnessing energy from the sun.
- To show the power of the sun.

2.2 PROBLEM ASSUMPTION

- Heat losses caused by conduction, wind and thermal radiation of the insulation from the back and sides of the collector are assumed negligible.
- Specific heat of air at constant pressure (**C_p**)is assumed to be constant (1.005 kJ/kg.K).
- The temperature at any point on absorber plate is assumed to be equal.

2.3 PROBLEM LIMITATION

- Experiment was conducted at 27° collector slope angle..

3. CONSTRUCTION DETAILS

After study of different papers and measurement analysis some construction material is used to construct a solar dryer. Those materials name, properties and photos are presented.

3.1-Wooden box- wooden box is made by the plywood. It is black painted inside, to increases the heat absorvity . The trays is hold by wooden box. Wood itself a bed conductor of the heat generally we don't have requirement of insulation.

1.	Area (m^2)	1.33
2.	Thickness (mm)	13
3.	Length(m)	1.35
4.	Width (m)	0.75
5.	Thermal conductivity	0.23

3.2- **Glass -** Glass is used as the cover of the solar dryer it placed at the above part of the solar dryer. that glass is transparent so it allow some percentage of solar radiation inside the drying chamber and some reflected back and some absorbed. Glass is used to trap the solar radiation inside the chamber in other words we can say it reduced the value of irradiation.

1.	Thickness (mm)	4
2.	Length (m)	1.35
3.	Width (m)	0.75
4.	Density (Kg/m^3)	2500
5.	Specific heat (J/Kg K)	750
6.	Thermal conductivity (W/mK)	1.4
7.	Convective heat transfer coefficient(W/m^2K)	2.8

3.3-Trays – Trays are made by the aluminum. Aluminum trays also painted black to increase the absorvity. Generally aluminum has good thermal conductivity so these trays able to heat quickly. These trays are placed inside the dryer and all the drying products spread over trays. Some heddle generated in between the trays, if the dryer placed at an angle of 27 than the product never slipped and collected at the lower part of the dryer.

Figure 4: shows potato chips in trays

1.	Area (m^2)	.33
2.	Thickness(gauge)	30
3.	Density (Kg/m^3)	2700
4.	Thermal conductivity (W/mK)	200
5.	Specific heat (J/KgK)	900
6.	Poisson ratio (N/A)	0.33

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7.	Tensile strength (N/m^2)	68935600
8.	Yield strength (N/m^2)	27574200
9.	Shear modulus (N/m^2)	2.7e01

3.4- Thermocol – it is used to insulate the solar dryer from outside. It is reduced some heat loss. It is pasted outside of the dryer by the help of finical.

Figure 5: solar dryer with thermocol insulation

1.	Density (g/cm^3)	0.96-1.6
2.	Melting point(°C)	240
3.	Thermal conductivity (W/mK)	0.33
4.	Refractive index(kHz)	1.6dielectric const.
5.	Molecular formula	$(C_8H_8)_n$

3.5-Holes- 1.5 inches holes are constructed in the wooden box for air circulation inside the drying chamber.

3.5 –Solar Panel---50 watt.12 volt D.C. solar panel used in this dryer .

4. EXPERIMENTAL PROCECURE

Four experiment runs in full load condition were carried out for red chilies, fenugreek , potato chips and mint during the period of feb-march in the year 2015. First of all, all product drained by the clean water .And the product were weighted weight machine and spread out over the trays in single layer in the solar dryer. To compare the performance of the solar dryer in the different-2 design and also compare with the conventional sun drying.

Drying was started from 9:00 AM and stop it at 3:00 PM. Weight loss of the samples in the solar dryer and open sun drying samples were measured during the drying period 1 hour interval with an weight machine.

Four thermocouples were used to measure the different-2 temperature at different-2 places. And also measure the air temperature along the air flow direction. A Pyrhanometer or solar meter was used to measure the solar radiation intensity at horizontal position and at 27degree angle. The relative humidity measured by the digital humidity meter and air temperature measured by the thermocouple 5 cm above from absorber plates. The air velocity was measured by the vane type anemometer at inlet and outlet of the solar dryer. After completion of the drying the all products was collected. Around 2 kg red chilies reduced to .754g, 2000g fenugreek reduced weight to 300 gm and 2000 g mint reduced weight to 230 gm. All four different-2 conditions of the dryer consumed different -2 time period for complete dry.

FIG. red chilies in solar dryer

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DATA ANALYSIS PROCESS

1.**To determine the loss of moisture**

Moisture loss of red chillies ,coriander , fenugreek

1. %of moisture removed

$$= \frac{\text{initial mass of sample - final mass of sample}}{\text{Final mass of sample}} \times 100$$

2.to determine the drying rate by using the formula

R =drying rate

M=loss of mass of sample

T=time interval

R =m/t

Calculation of overall heat transfer coefficient(U)

resistance= conductivity/thickness

$R_{THERMAL}$=0.013/0.33=.0394

$R_{PLYWOOD}$=0.013/0.23=0.0565

R_t=0.0394+0.0565=0.0959

$R_T = R_{SI} + R_t + R_{SO}$

Where….

R_{SI}=Resistance in inside surface

R_{SO}=Resistance in outside surface

For horizontal heat transfer R_{si}=0.13&R_{so}=0.04

$R_{T=}$0.13+0.0959+0.04=0.266 w/mk

Overall heat transfer coefficient(U)=1/residence

$U=1/R_T$

U=1/0.266=3.76

U=3.76 ANS.

Material	thickness	conductivity
1. plywood	0.013	0.23
2. thermocol	0.013	0.33
3. glass	0.004	1.4

5. OBSERVATION

After installation, the solar dryer were left operating several days under normal weather conditions. The LM- 35 temperature sensor wires were positioned at different point in the solar dryer. The solar dryer was tilted 27° angle and south faced. Experiment on the solar dryer was performed in the days of Feb.-March 2015 in Jaipur, Rajasthan, India. The test was conducted between 09;00 AM and 3:00 PM solar time. The reading was taken at the interval of every 1 hours.

5.1. OBSERVATION TABLES

Date;-**23/02/2015**
Note :- F.C(force convection),N.C.(natural convection),g (gram),wt(weight)

Table 5.1: Observation of fenugreek in solar dryer(day 1)

Time of day	Weight (Forced convection)(g)	Weight (Natural convection) (g)	Temp (.N.C). (°C)	Temp (.F.C). (°C)	N.C Plate (°C)	F.C. plate (°C)	Solar flux Horizontal (W/m²)	Solar flux at 27° (W/m²)
09:00	1000	1000	37.3	35.6	42.2	40.2	680	556
10:00	920	895	39.1	38.2	45.3	44.2	863	773
11:00	900	870.5	40.7	39.1	48.2	46.4	1080	1951
12:00	740.3	720	45.8	40.4	65.1	47.1	1183	1025
01:00	690.2	669.4	43.9	45.9	67.7	55.2	1145	1025
02:00	577	490.3	43.3	42.8	61.1	53.2	1345	1030
03:00	478	433	45.5	45.4	59.9	53.7	1050	730

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Date: **24/02/2015**

South facing at 27°

Note :- F.C(force convection),N.C.(natural convection),g (gram),wt(weight)

Table 5.2: Observation of fenugreek in solar dryer(day second,)

Time of day	Weight (F.C) (g)	Weight (N.C) (g)	Temp F.C. (°C)	Temp. N.C. (°C)	Temp. F.C. Plate (°C)	Temp. N.C. Plate (°C)	Solar flux Horizontal (W/m²)	Solar flux at 27° (W/m²)
09:00	280.3	243.6	33.8	38.1	46.4	53.3	450	493
10:00	267.6	174	34.2	41.4	50.3	56.2	460	480
11:00	254.3	165.4	34.6	39.4	51.3	59.2	466	546
12:00	202.4	145.3	35.2	39.9	52.2	60.7	502	565
01:00	190.5	120	38.2	37.3	49.2	61.9	550	445
02:00	165	108	37.2	41.4	44.9	54.3	420	347
03:00	161	102	35.4	38.1	41.7	49.9	417	322

Date: **25/02/2015**

South facing at 27°

Note :- F.C(force convection),N.C.(natural convection),g (gram),wt(weight)

Table 5.3: Observation of red chilies (day 1)

Time of Day	Weight (F.C.) (g)	Weight (N.C.) (g)	TEMP (F.C.) (°C)	Temp (N.C.) (°C)	TEMP PLATE (F.C.) (°C)	TEMP PLATE (N.C) (°C)	Solar flux Horizontal (W/m²)	Solar flux at 27° (W/m²)
09:00	1000	1000	30.4	33.3	33.1	36.5	702	734
10:00	989	977	37.1	35.3	33.8	37.5	754	934
11:00	970	895	38.4	44.9	48.9	62.4	888	1004
12:00	950	860	39.3	54.1	54.4	79.7	928	1086
01:00	915	810	39.8	56.3	60.3	80.3	954	1250
02:00	868	796	39.1	49.1	62.5	79.9	927	1154
03:00	805	730	38.6	45.5	64.4	67.4	905	1103

Date: **26/02/2015**

South facing at 27°

Note :- F.C(force convection),N.C.(natural convection),g (gram),wt(weight)

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Table 5.4: Observation of red chilies in solar dryer. (day 2)

Time of day	Weight (F.C) (g)	Weight (N.C.) (g)	Temp (F.C) (°C)	Temp (N.C) (°C)	Temp Plate (F.C) (°C5.6)	Temp Plate (N.C.) (°C)	Solar flux Horizontal (W/m²)	Solar flux at 27° (W/m²)
09:00	805	730	39.5	40.5	36.6	37.6	775	796
10:00	776	711	43.4	44.5	44.5	42.4	743	776
11:00	686	676	39.3	46.1	49.8	56.9	904	1002
12:00	545	510	43.2	46.9	56.9	62.9	1032	1078
01:00	440	418	44.7	48.4	62.7	72.6	1085	1121
02:00	386	343	46.0	56.4	67.8	79.7	1276	1294
03:00	244	217	44.3	54.1	68.7	80.4	1165	1187

Date: **27/02/2014**

South facing at 27°

Note :- F.C(force convection),N.C.(natural convection),g (gram),wt(weight)

Table 5.5: Observation of coriander in solar dryer.

Time of Day	Weight (F.C) (g)	Weight (N.C) (g)	TEMP (F.C) (°C)	TEMP (N.C) (°C)	TEMP PLATE (F.C) (°C)	TEMP PLATE (N.C) (°C)	Solar flux Horizontal (W/m²)	Solar flux at 27° (W/m²)
10:00	985	960	44.3	46.3	51.6	56.9	1183	1058
11:00	840	800	44.6	48	56.9	65.8	1236	1150
12:00	785	740	45.9	54.0	65.9	76.8	1265	1204
01:00	546	510	55	60.2	72.0	80.6	1260	1208
02:00	455	430	56.7	57.7	74.7	82.1	1264	1232
03:00	210	190	54.8	58.8	65.9	79.6	1227	1217

6. RESULT AND DISCUSSION

In the dryer the uniform air flow is not possible with natural convection. Because in natural convection atmospheric air is generally more fluctuate. But in the forced convection the air distribution uniform is possible because the fan of 20 watts give the uniform flow in solar dryer . Therefore the forced convection solar dryer study focuses on the results and conclusion of the whole solar dryer.The temperature fluctuates throughout the day so the soar dryer temperature fluctuates respectively as well as air velocity profile also fluctuates throughout the day. Here we are analyzed the different-2 models with different-2 parameter.

This above temperature shown t he temperature contour on the absorber plates. The area of the dryer is 1.44 m^2 and the hole size is 1.5 inch.

7. CONCLUSION

Good air flow distribution can be improving the drying efficiency of the solar dryer in forced convection with the help of fan.

So the performance of solar dryer was highly dependent on solar radiation and ambient temperature. it is very useful tool to predict the air velocity, temperature and pressure inside the chamber. Mostly improper air distribution inside the chamber depend on the inlet and outlet hole size. So in the natural convection solar dryer hole size play the vital role in solar dryer. Experiment successfully done so I want suggests some parameter according to solar dryer.

(a) Temperature inside the drying chamber must be 55-60° with under load condition and 65-70° can be with overload condition but in overload condition the air velocity should be more than 2 m/s.
(b) Efficiency of natural convection solar dryer should be more than 15%.
(c) In the summer season we can use the steel absorber plate but in the winter season we have to use aluminum absorber plate.
(d) 1.5 inches hole are more effective in solar dryer both type of solar dryer forced convection &natural convection.
(e) The efficiency of solar dryer is a function of airflow rate and it increases with the increase of air flow rate.

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