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# Design and Analysis of Absorbing plate of Hybrid Type Solar Dryer for drying Ginger and Tomato

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## ABSTRACT

The solar drying technology is a quick and easy process of drying of food product in a hygienic way. The present investigation represents a development of hybrid type of solar dryer which can be used both in day and night time. The main objective of this research to do simulation for Steady state thermal analysis of absorbing plate (corrugated Aluminium sheet, 5 mm thickness) and various results obtained like temperature variation, total heat flux, directional heat flux by using Ansys software. The maximum range of temperature, total heat flux variation, directional heat flux generated were 96.83°C, 0.14 W/mm$^2$ and 0.081605 W/mm$^2$ respectively .The boundary condition such as the amount of heat flow conducted i.e. 10660 watt in the bottom face of absorbing plate and convective heat transfer coefficient as 100 W/mm$^2$ $^0$C were assigned. The food products such as ginger and potato were tested for drying and temperature profile at various point were obtained.

## 1. Introduction

Technology and Human development are the two sides of a single coin. Human development without the intervention of technology is not possible.

Technology surrounds us in different prospects and in different spheres of our life. One of them is the use of Solar dryer which uses clean energy. Clean energy is the form of energy which does not provide any negative externalities. Solar dryer is an alternative method and quick process of drying food products in hygienic way.

Varun et al. [1] had developed an indirect type of solar dryer which was used for agricultural purpose. It was tested under forced convection and mass flow rate was calculated. A. Agarwal et al. [2] had done experiment to study the effect of flow rate, temperature distribution, and heat transfer phenomenon by drying food products. A.K.Srivastava et al. [3] had done analysis by taking phase change material as Lauric acid and can be used during in sufficient amount of solar energy during drying process. Various parameters such inlet hot air temperature, inlet velocity of air was determined with change in temperature. J. Kaewkiew et al. [4] had done a comparison study between green house solar dryer and without solar dryer for drying chilli and got effective result in solar drying as compared to open drying process. A. Lingayat et al. [5] had done experimental study by using indirect solar dryer for agricultural purpose for drying banana. S. Chouicha [6] et al. had done experiment for hydration of delegate Nour dates under the three solar drying techniques. Romero, V.M. et al. [7] had done simulation for vanilla drying in indirect solar dryer. Boubekri et al. [8] had done experiment on hybrid type of solar dryer by drying slices of potatoes and used a heater provided to supply heated air inside the drying chamber. E. Tarigan [9] had CFD simulation for analyzing average drying temperature and found the significant lower change in temperature in bottom three treys as comparison to upper trey. D.K. Rabha et al. [10] had experimental study by taking ghost chilli and sliced ginger for drying with an adequate temperature range. P. S. Chauhan et al. [11] had calculated various thermal performance of PV integrated green house solar dryer. The insulation and reflectors were provided for increasing performance of solar dryer. El Sebaii et al. [12] had evaluated drying effect indirect solar for drying mint and thymus and a blower was provided for circulating heated air.

## 2. Material And Methods

In this research, the solar dryer has been designed considering various system parameters such as inlet temperature of air, humidity, moisture carried by air per minute and outlet temperature of air. The materials are considered for various parts of the dryer and dryer is fabricated by various processes. For design calculations dry bulb temperatures (DBT) and relative humidity (RH) at inlet and outlet are shown in Figure-1 was considered. The parameters are based on brief study of atmosphere in the coastal areas of Bhubaneswar.

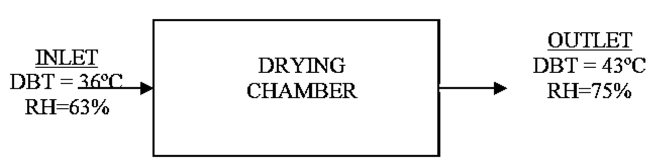


Figure 1 shows System parameters at inlet and outlet
Mass of Product (Mp) = 20 kg
$M_i$= Initial moisture content= 71%
$M_f$ = 20%

$$M_w = \frac{20(0.71-0.2)}{1-0.2}$$ =12.75 kg of water to be removed from 20 kg of wet fruit (1)

$$\dot{m}_a C_p (T_2 - T_1) = m_w L$$

By using above energy balance equation mass flow rate of dry air and volume flow rate of dryer air calculated as 1061.912 kg of dryer and 0.012229 Kg/sec of dry air assuming 24 hours to be dried.

The main component of the dryer is the solar collector, which is covered by glass and surrounded by glass wool which acts as an insulator. The heated air transferred from the solar collector and passes on to the food kept at the trays. As the temperature of air increases, the relative humidity reduces and moisture carrying capacity of air increases, and accordingly the performance of the dryer increases. The dry and warm air absorbs moisture from food, become saturated moisture air. The saturated air is withdrawn from the drying chamber by the exhaust fans. The dryer being made of a good heat conducting material, transfers heat to the immediate dry air within the unit via convection. The dry air gets heated with via convective transfer of heat from the hot surface of the dryer. Air blowing units; create convective air currents in the room, circulating warm air in the entire drying room. This warm air, passes across the food holders, through the perforations on the food holders, thereby drawing moisture from the food placed over the holders. The main components of flat plate collector are 1. Transparent cover 2.Absorber plate 3. Insulation. The two numbers of tempered glasses were taken as transparent cover plate in order increase the transmittivity with a 2 inch gap in between them. The four number of DC blowers provided such as at inlet of collector, two at out let of collector and one at outlet of drying chamber( exhaust fan) which were run by PV panel, battery and charge controller. The absorber plate is flat Aluminum sheet of 5 mm in order to reduce the corrosion and leakage problem. As it is black painted, it absorbs the incoming sun light which is fixed to glass plate. The glass wool is provided for reducing side and bottom losses. The exhaust fan which is powered by PV panel is used to withdraw the moisture air from the drying chamber. The collector is tilted according to the latitude of the location. As the Bhubaneswar latitude is 20.2961°N, 85.8245°E, so it is tilted with an angle $20^0$ and facing due south. The dryer consists of a 20kg/ day fruits dryer manufactured with Aluminum sheet and Aluminum wire mesh as trays. The thermal design and specification is as follows:

## 3. Specifications

Table no. 1: Specification of material used in the solar dryer

| Sl.No | Parameter | Specifications |
|---|---|---|
| 1. | Collector | Flat plate air- heating solar collector |
| 2. | Loading | Opening doors at back side |

| | | |
|---|---|---|
| 3. | Number of Trays | 3 |
| 4. | Number of Doors | 2 |
| 5. | Air Circulation | Forced |
| 6. | Capacity of Drying | 20 kg-food products |
| 7. | Material selected | Stainless steel wiremesh, aluminium sheets, window glass, glass wool. |
| 8. | Flat Plate Air-Heating Solar Collector is of size | 1000mm x 1000mm |
| 9. | Solar Dryer Box size (Lx B x H) | 1000mm x 500mm x 500mm |
| 10. | Diameter of draft for exhaust fan | 300mm |
| 11. | Solar pannel | Pmax=20 watt, Vmax=17 V, Imax=1.18 A, Voc=21.50, Isc=1.29, Tolerance= ±3%, Maximum system voltage=600 V, Air mass= 1.5, Temprature= $28^0$C |
| 12. | Charge controller (CCR) | 12 V, 6 A |
| 13. | Inverter | 100 WATT, IGBT model |
| 14. | Blower | 12 V, 0.6 A |
| 15. | Battery | 12 V, 20 A |
| 16. | Coil | 50 WATT, 5 A |

Table no. 2 Budget estimate of solar dryer

| Sl.No. | Material | Quantity | Price/ individual | Total |
|---|---|---|---|---|
| 1 | Steel angle | 80kg | 75.00 | 6000.00 |
| 2 | Steel flat | 45kg | 75.00 | 3375.00 |
| 3 | Aluminum sheets | 5kg | 275.00 | 1375.00 |
| 4 | Steel mesh | 6kg | 130.00 | 780.00 |
| 5 | Solar panel- 12v/20watt | 1 | 1200.00 | 1200.00 |
| 6 | DC Fan | 4 | 600.00 | 600.00 |
| 7 | Glass wool/foam | 18sqft | 45.00 | 810.00 |
| 8 | Glass (2 numbers) ($1^{st}$ glass thickness- 4mm,$2^{nd}$ glass thickness 3mm) | 1*1mtr (2 numbers) | 800.00 | 800 |
| 9 | Fixing clamps | 8nos | 12.00 | 96.00 |
| 10 | Welding sticks | 30nos | 20.00 | 600.00 |
| 11 | Kabja,locker | -- | -- | 200.00 |
| 12 | Color | -- | -- | 500.00 |
| 13 | Night coil | 1 nos | -- | 250 |
| | | | Total cost | 16,586.00 |

## 4. Fabrication Process

The dryer has been fabricated with the help of aluminum sheets, Angle bars. The various parts of the dryer have been fabricated by various processes. The Sheet Metal Cutting: Sheets are cut to the dimension of top and bottom frame, side frame, back supporting frame and three trays by shearing process. The frames are joined by welding process (electrical arc welding). The exhaust fan is fixed on the top of the drying chamber to withdraw the saturated air. Trays are aluminum wire meshed for proper airflow and placed inside the dryer at equal space. To keep the trays the angle bars are fixed on the side frame of the dryer. The collector is tilted with an angle $20^0$ according to the latitude of the location and facing due south. As the Bhubaneswar latitude is 20.29 $^0$N to 85.82 $^0$ E.The collector is fixed with glass plate (5 mm), absorbing plate (3mm aluminum sheet) and glass wool (75mm).The collector having 1 $m^2$ is fixed with the drying chamber. At inlet of collector no of hole is provided for the proper flow of air. The fabrication of different parts of dryer is shown in figure.

Figure 2. Different components during fabrication process

## 5. Result Analysis

In this study, steady state thermal analysis of Absorbing plate (corrugated aluminium sheet, 5 mm thickness, $1m^2$, (length× breadth=1mm×1 mm) had been done by Ansys software.

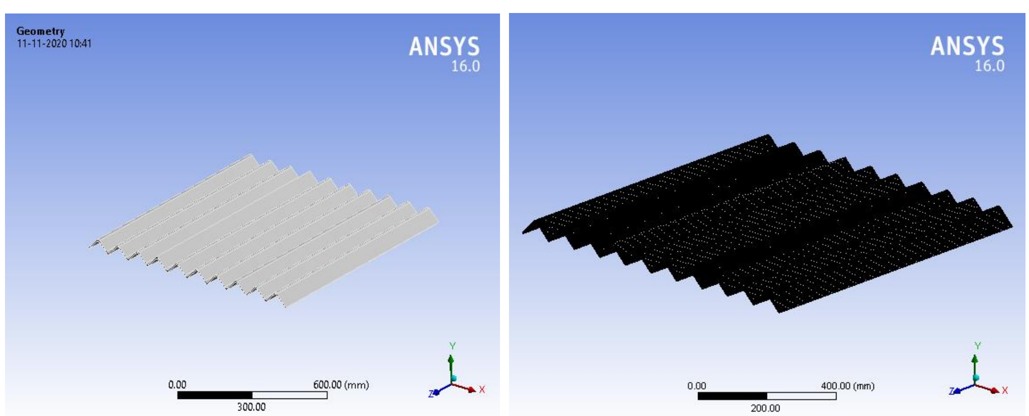



Figure 3. Geometry modeling and meshing of Absorbing plate

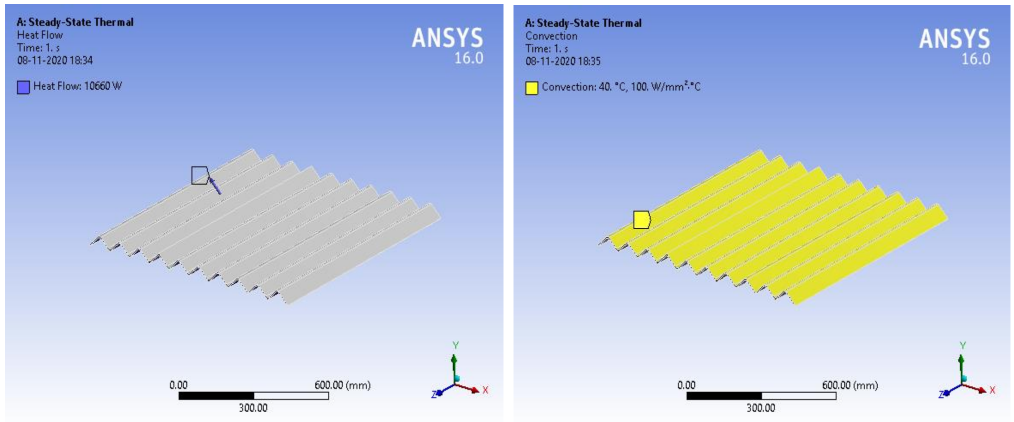



Figure 4. The selecting of bottom, top face and assigning load

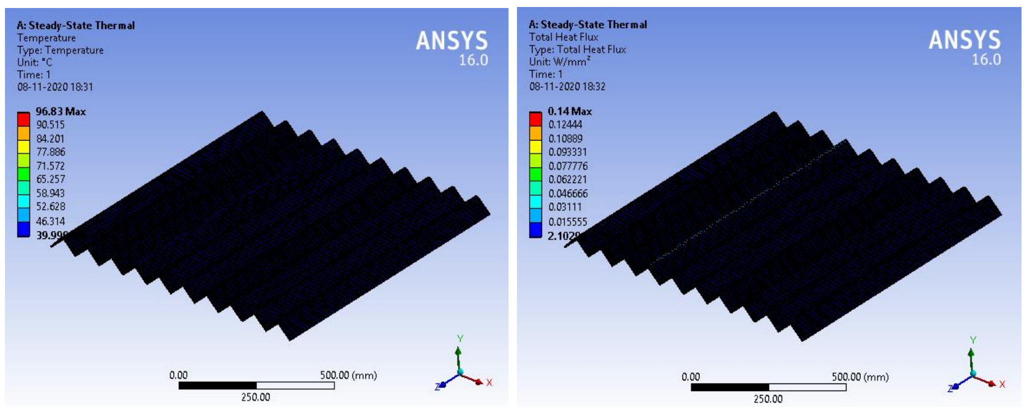



Figure 5. Temperature, total heat flux variation of absorbing plate

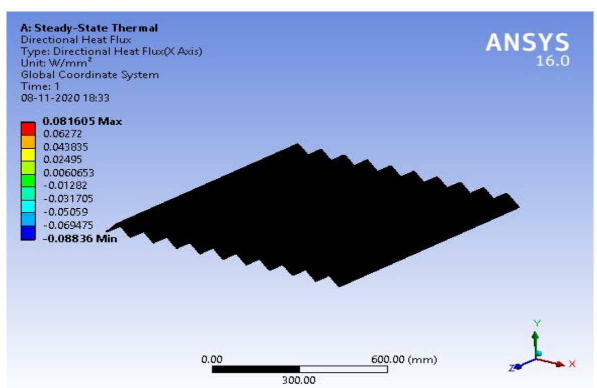



Figure 6. Temperature, total heat flux, directional heat flux variation of absorbing plate

## *A. TESTING OF DRYER*

To study the performance of the dryer ginger, bread, tomato, and potato have been dried. The comparison of weight reduction of these materials dried in open sun light and dried in solar dryer. It can be seen that the percentage of weight reduction more in case of dryer in with a less time.

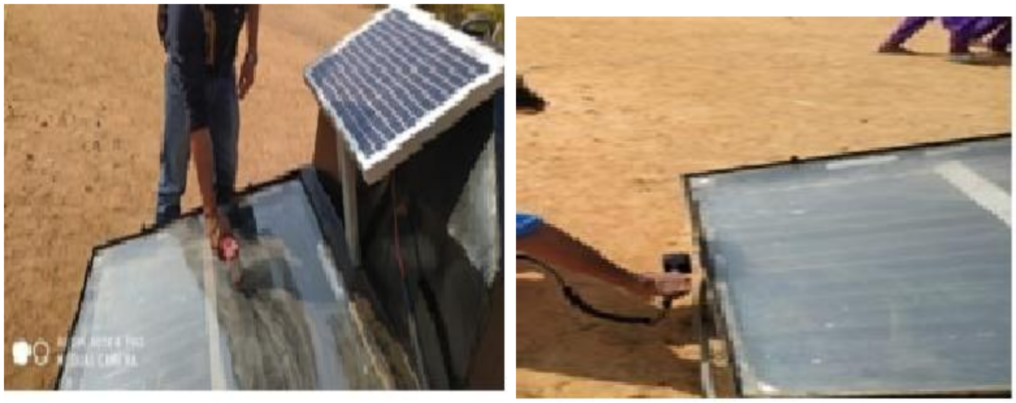
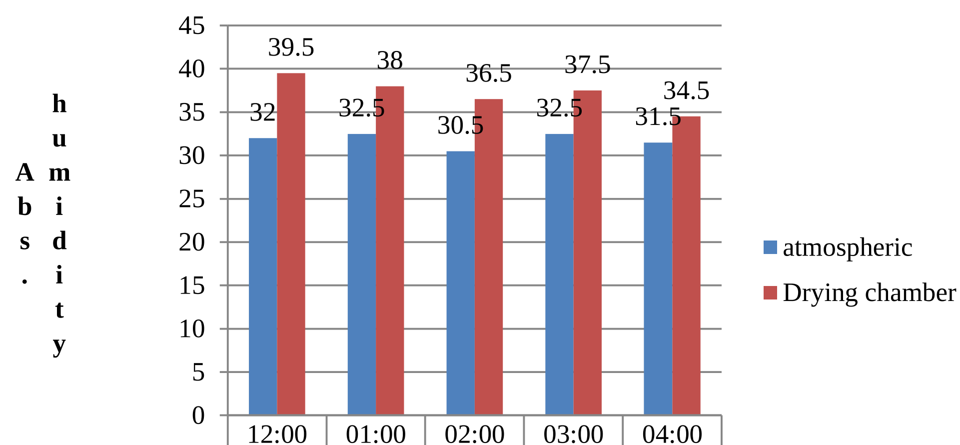


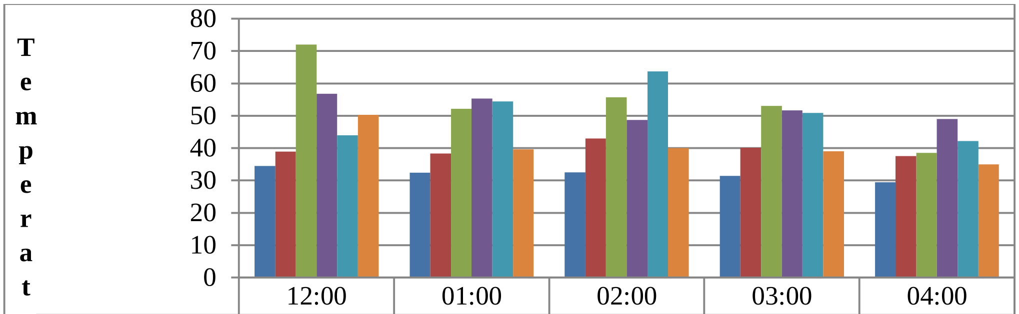
Figure 7. Experimental set up during Testing of Solar dryer


Figure 8. Drying of ginger before and after drying



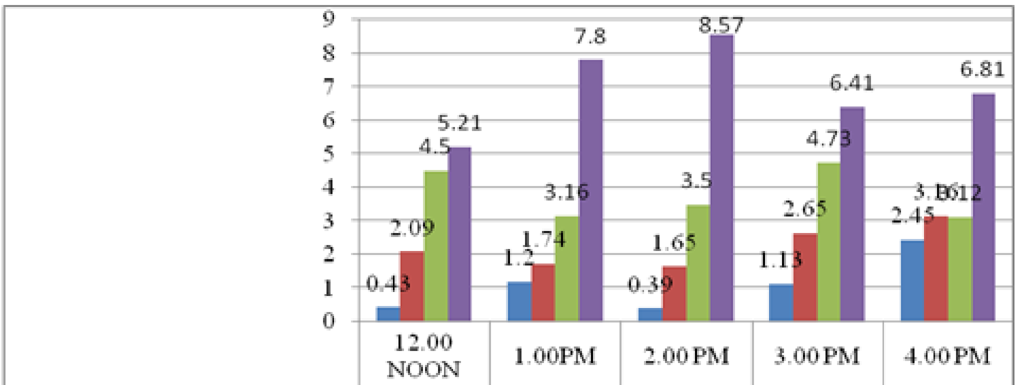

| | 12:00 | 01:00 | 02:00 | 03:00 | 04:00 |
|---|---|---|---|---|---|
| atmospheric | 32 | 32.5 | 30.5 | 32.5 | 31.5 |
| Drying chamber | 39.5 | 38 | 36.5 | 37.5 | 34.5 |

Figure 9. Absolute humidity vs. Time during drying of Ginger




| | 12:00 | 01:00 | 02:00 | 03:00 | 04:00 |
|---|---|---|---|---|---|
| atmospheric | 34.5 | 32.4 | 32.5 | 31.4 | 29.5 |
| inlet collector | 38.9 | 38.3 | 43 | 40.1 | 37.6 |
| outlet collector | 72 | 52.2 | 55.7 | 53.1 | 38.5 |
| drying chamber | 56.8 | 55.3 | 48.7 | 51.7 | 49 |
| outlet dryer | 44 | 54.4 | 63.7 | 50.9 | 42.2 |
| Glass plate | 50.3 | 39.6 | 40 | 39 | 35 |

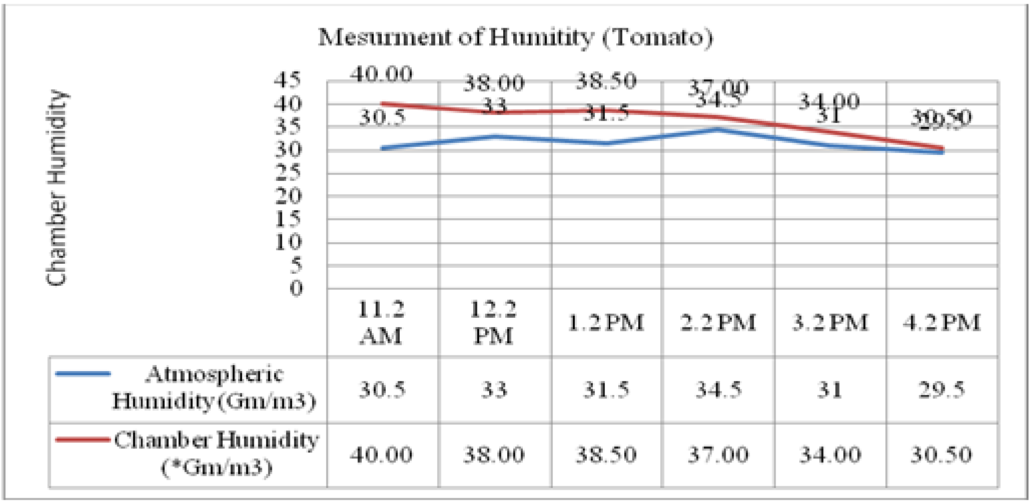
Figure 10. Temperature vs. Time during drying of Ginger




| | 12.00 NOON | 1.00PM | 2.00 PM | 3.00 PM | 4.00 PM |
|---|---|---|---|---|---|
| atmospheric in mtr/sec | 0.43 | 1.2 | 0.39 | 1.13 | 2.45 |
| inlet collector mtr/sec | 2.09 | 1.74 | 1.65 | 2.65 | 3.16 |
| outlet collector in mtr/sec | 4.5 | 3.16 | 3.5 | 4.73 | 3.12 |
| outlet dryer in mtr/sec | 5.21 | 7.8 | 8.57 | 6.41 | 6.81 |

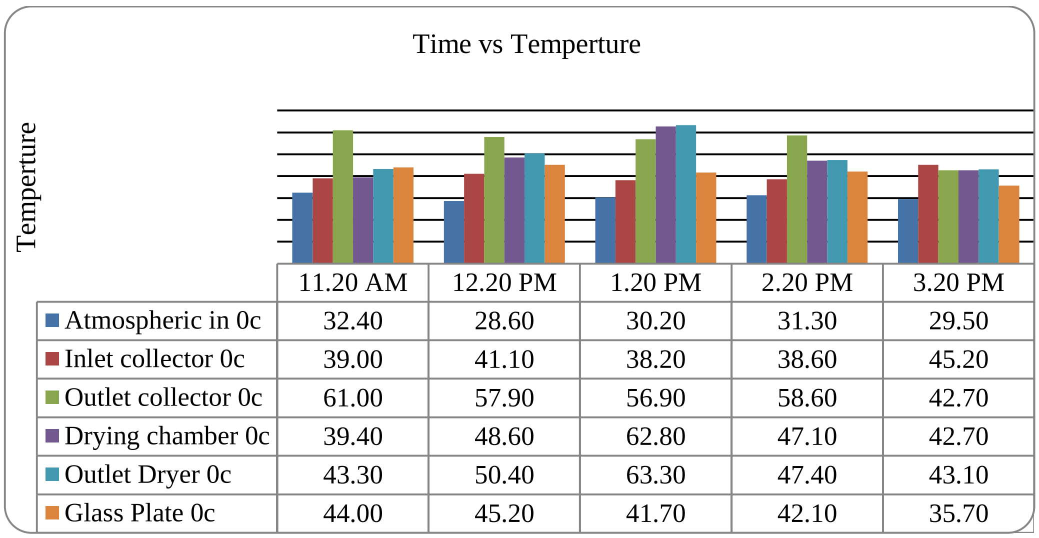
Figure 11. Velocity vs. Time during drying of Ginger

Figure 12. Drying of Tomato in the drying chamber




| | 11.2 AM | 12.2 PM | 1.2 PM | 2.2 PM | 3.2 PM | 4.2 PM |
|---|---|---|---|---|---|---|
| Atmospheric Humidity (Gm/m3) | 30.5 | 33 | 31.5 | 34.5 | 31 | 29.5 |
| Chamber Humidity (*Gm/m3) | 40.00 | 38.00 | 38.50 | 37.00 | 34.00 | 30.50 |

Figure 13. Absolute humidity vs. Time during drying of Tomato




| | 11.20 AM | 12.20 PM | 1.20 PM | 2.20 PM | 3.20 PM |
|---|---|---|---|---|---|
| Atmospheric in 0c | 32.40 | 28.60 | 30.20 | 31.30 | 29.50 |
| Inlet collector 0c | 39.00 | 41.10 | 38.20 | 38.60 | 45.20 |
| Outlet collector 0c | 61.00 | 57.90 | 56.90 | 58.60 | 42.70 |
| Drying chamber 0c | 39.40 | 48.60 | 62.80 | 47.10 | 42.70 |
| Outlet Dryer 0c | 43.30 | 50.40 | 63.30 | 47.40 | 43.10 |
| Glass Plate 0c | 44.00 | 45.20 | 41.70 | 42.10 | 35.70 |

Figure 14. Temperature vs. Time during drying of Tomato

## 6. Discussions

In this paper the experiments on the solar dryer have been conducted. To measure the humidity, temperature, wind velocity and diameter. The dryer is kept in an open field so that the dryer can be exposing to sun rays. Parameter such as relative humidity, temperature, wind velocity and diameter are observed hour to hour interval. In this paper, steady state thermal analysis of Absorbing plate (corrugated aluminium sheet, 5 mm thickness, 1m$^2$, (length× breadth=1mm×1 mm) by Ansys software had been done. In the meshing part entire domain had been divided into numbers of sub domain and no of elements and nodes generated are 86742 and 475179 respectively. To solve the above problem easily, this discritizing method has been adopted. In the bottom face of absorbing plate the amount of heat flow conducted i.e. 10660 watt has been provided. Then the top face of absorbing plate has been selected and film coefficient or convective heat transfer coefficient =100 W/mm$^2$ $^0$C. After giving the above boundary condition i.e. the heat flow conducted and convective heat transfer coefficient, the final result we had got Temperature variation of absorbing plate and maximum temperature generated 96.83°C. Total heat flux variation of absorbing plate and maximum heat flux generated was 0.14 W/mm$^2$. Directional heat flux variation of absorbing plate and maximum directional heat flux generated as 0.081605 W/mm$^2$. It has been observed during day time, that the inside temperature of the solar dryer, collector increases with time, up to 2p.m. and then decreases. It happens due to the increase of sun rays and the black coating of solar dryer, the temperature of absorbing plate is highest because it is black coated. As the air is heated inside the collector, so relative humidity of air reduces at outlet of collector. Due to increase in temperature the moisture carrying capacity of the air increases and accordingly the performance of dryer increases. With increase in temperature of air the relative humidity reduces and the dry and warm air absorb moisture from food, become saturated moisture air. The saturated air is withdrawn from the drying chamber by the exhaust fan which is integrated top of the drying chamber. The dryer being made of a good heat conducting material, transfers heat to the immediate dry air within the unit via convection. The dry air gets heated with via convective transfer of heat from the surface of the dryer. This warm air passes across the food holders, through the perforation on the food holders there by drawing moisture from the food placed over the holders.

## 7. Conclusion

The analysis of absorbing plate (corrugated Aluminium sheet) was done and various result such as temperature variation, total heat flux variation and directional heat flux were obtained. Solar dryer according to the design replace the traditional way of drying food material. By this process the dried food materials obtained are hygienic and prevent from contamination. Further it has capacity to dry large amount of food materials. It can enhance the market value of the food materials for example the market price of 100 gm dry ginger powder is 85 INR while the 100 gm ginger price is about 40 INR. Primitive solar drying method is that in which we directly expose the food materials to sun while in case of solar dryer it involves the process of drying food by blowing hot air through the chamber. The warm air removes the moisture from food materials. The warmer the air, the more amount of moisture it removes. It also seen that the reduction of weight is more in case of conventional food drying method. The temperature of the drying chamber is nearly 70$^0$C while the atmospheric temperature is 36$^0$C.as the main purpose of solar dryer to dry food material during day time we use heating coil and try to dry the food material during night and obtained significant results. It also it is easily assembled and easy to transportation.

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