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Experimental Analysis of Indirect Solar Dryer with Thermal Energy Storage and PV Panel

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A B S T R A C T

This thesis represents the drying of chili and potato chips with the use of thermal heat storage (THS) device in the indirect mode solar dryer (ISD). The aims of this experiment are charging the PCM material in day time, when solar radiation is more and PCM is releasing heat when the irradiation is inadequate for drying a product. The dryer is made of a rectangular tube solar based air collector, fan, phase change material, drying chamber, and a 50W solar panel. Solar air collector and drying chamber characteristics have been also calculated for investigation of the thermal performance of dryer. At no-load condition, the dryer is also tested for defining the maximum thermal performance under the use of PCM. The analysis of drying of chili showed that moisture content of chili is reduced from initial value of 89.47% (wb) to final moisture content of tray 1, tray 2, tray 3 and open sun are respectively 8.40%, 14.59%, 18.97%, and 29.77% (wb). Likewise, the experimental investigation doing for drying of potato demonstrated that moisture content was diminished from introductory estimation of 85.05% (wb) to conclusive moisture content of 3.89%, 7.84%, 14.84%, and 39.39% (wb) of Tray1, Tray2, Tray3 and open sun drying respectively. The overall average efficiency of rectangular tube solar heater and of drying chamber is 64% and 22.08% respectively. The outcome of experiment is that due to utilizing the phase change material, the temperature and humidity of the drying chamber is higher than the environment temperature and moisture of air in evening and night.

The drying rate of product is mainly depending upon humidity and velocity of air that is passed through dried product. The maximum temperature of the overall solar dryer is recorded in the duration of 12:00-1:00 PM. The collector temperature depends upon the mainly solar irradiation. The time taken for dry potato slices and chili is 7 hour and 14 hours respectively.

Keywords:Thermal heat storage,Indirect mode solar dryer, PCM material, Solar air collector, chili and potato chips.

1. Introduction

Solar energy is the essential source of all renewable energy. The sun is a huge source of energy and earth capture energy approx. 1.8xl011 MW, which is multiple thousand times bigger than the general energy use rate on the earth [1]. Hence forth this can fulfill the requirement of energy in the present and future wishes of this planet. Thus, it is one of the most extreme promising sources of energy. Dislike petroleum products and atomic power, it is a naturally clean form of energy supply. Besides, it is free and accessible in sufficient amount in all place of the region where in maximum number of populations stay. Solar energy is more powerful position as compared with conventional energy [2] [3]. In a tropical nation like India greatest of the energy demand might be met by methods of use of simple system that can change over solar energy into usable form of energy. Solar energy is delivered by the sun due to the response of hydrogen atom to changing into helium particle and generate large amount of energy. The distance between sun and earth is 150 x 106 km and temperature of sun surface increases up to approx. 6000°C. Due to the high temperature of the sun, the energy is discharge by radiation to the environment [4] [5]. For financial related improvement of a country, energy plays an important role. Sources that are simply available, accessible and eco-friendly are used for financial related improvement in the future of the country in the aspect of energy. Two types of energy are available in the world, one is renewable energy and other is non-renewable energy. In present circumstance our existence is standing up to two major troubles: one is to deal the exponential demand of energy in the development of country and other is to deal global regional and local environmental impacts coming out from supply and use of conventional energy. The Non-exhaustible power source is the kind of solar energy and conventional is coal, Oil and LPG etc. The renewable energy is promising a solution to the issues for keeping up the current state of human progress [6] [7]. In the above

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conclusion, we find that the utilization of renewable energy assets ought to be completely fulfilled the requirement of energy and this will build the accessibility of energy for future individuals. Renewable energy supply has also played an important role in extending development to the agriculture technology in developing countries to extend their productivity [8-11]. The power production in view of different assorted kind of essentialness in India up to 31 April 2021 is given by following the pie chart and table 1:

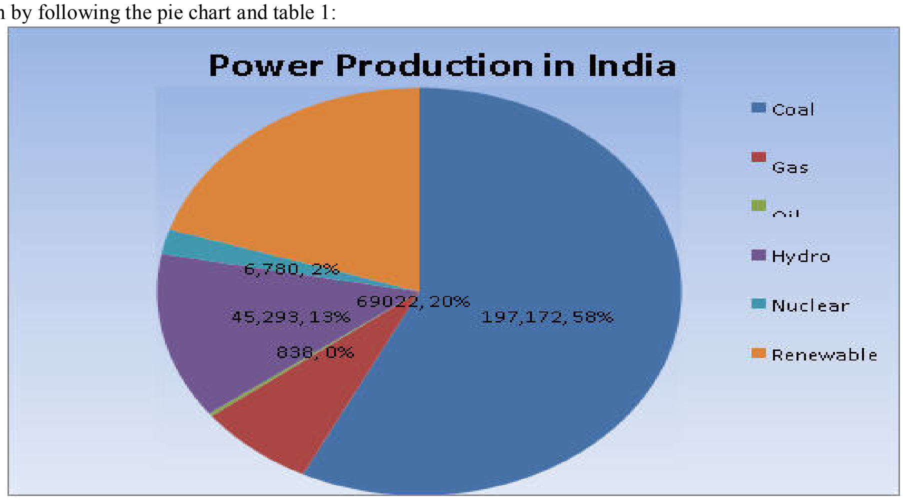

Fig.1- Electricity production in India [2]

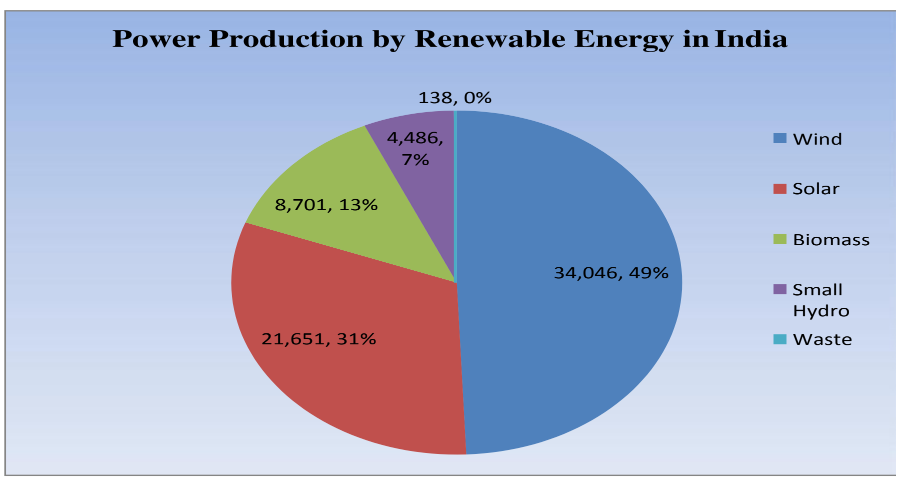

Fig. 2- Electricity productions in India by renewable energy [3]

Table1- Power production in India [2,3]

Energy	MW	% of total
Total Thermal	222907	64.8%
Coal	197172	57.3%
Gas	24897	7.2%
Oil	838	0.2%
Hydro(Renewable)	45293	13.2%
Nuclear	6780	2.0%
RES	69022	20.1%
Wind Power	34046	9.9%
Solar Power	21651	6.3%
Biomass Power	8701	2.5%
Waste to Power	138	0.04%
Small Hydropower	4486	1.3%
Total Power	344002	100%

2. Problem formulation

Food scientists came to the conclusion that food is prevented from bacteria, yeast, and enzymes if the moisture constituents in the food are lowered in between 10% to 20% by wet basis. The flavor and most of the nutritional value is also preserved and concentrated [12-15]. Commonly used method for drying crop in developing country is open sun drying. In this process, the drying is by using shorter wavelength and also using the process of natural convection as the crops lie on the ground, due to this method the process is the cheapest and easily available as the source of energy is the sun. Among these limitations is the augmentation in crop loss due to partial drying which leads into fungal infection, worms, birds and rodent's germination, variability in climate and sudden weathering. Moreover, the ability of the sun to dry is a function of numbers of factors; therefore, uniformity is not easily achieved. Due to these inadequacies in O.S.D, it has led to the development of solar drying techniques. Solar drying provides products with more energy as compared to open sun condition hence increasing the vapor pressure of the moisture within the crop. Some different analysts were detected that different material properties of various kinds of PCM under different conditions and its applications in solar-based energy storage. A typical solar dryer better upon the normal O.S.D system in four necessary ways in which[13-20]:

i. It is quicker. Materials will be dehydrated in dryer take less amount of time as compared to open sun drying. Solar dryers reduce drying times in two ways. In which, Firstly the transparent coating over the system intercepts heat within the dryer, elevating the temperature of the air. Secondly, the increasing the incident area of radiation that permits for larger insolation is found.
ii. It is more efficient. Time required for drying of a product is decreased and the number of crops lost to decay is lowered after harvesting. Using the solar dryer, a bigger percentage of food is saved there for human consumption.
iii. It is hygienic. Since controlled drying takes place hence less chance to be contaminated by pests and reducing the chance of the growth of toxic fungi.
iv. It is healthier. Drying materials have retained their nutritional value such as vitamin c due to drying at the controlled environment. A new bonus is that crop can look better which boosts their market in the region and therefore provides higher money returns for the farmer.

The aim of this investigation is to build up an indirect solar-based dryer during which the crop is dried by the stream of hot air in drying chamber. The issues of low and medium scale load might be solved if the solar dryer is design and constructed with the consideration of limitations. The advantage and disadvantage of several solar dryers given below:

Types of dryer	Advantage	Disadvantage
Direct sun	• Lessexpensive • Simple	• Damage food by UVradiation
Indirect sun	• Protection of product fromUV • Negligible damage from environmenttemperature.	• More complex • In comparison of thedirect solar dryerexpensive.
Mixed mode	• Less damage of product from extreme temperature	• More complex and expensive than directsun • Damage food by UVradiation
Hybrid	• Without solar energy canbe operated • Food lossminimum • Better control ofdrying • Fuel mode dryer faster thansolar	• Expensive than othertype. • Dependence onfuel.

So, along the above lines, this work will be upheld the importance of indirect mode solar-based drier that is reliable in simplicity and economically, constructed using of locally available materials and to check the execution of this solar dryer.

3. Experimentation on solar dryers

3.1 Experimental setup-layout

Drying experiment is examined at the roof of Department of Mechanical Engineering B. N. College of Engineering and Technology, Lucknow (U.P) – 226201 India in several days during the month of June 2021. The latitude, longitude & altitude of Lucknow are 26.270N & 82.070E and 95 m above the sea level. The setups figure is shown in Fig.3 and 4, depicts a schematic of the block diagram and Photo of indirect solar dryers. Indirect solar dryer has rectangular pipe solar collectors, the effective collector area is 0.804 m2 and drying chamber made of plywood of size (0.77 m×0.54m×0.5m) which have three number of trays of size (0.685 m x 0.460m) and the distance between tray was 0.15m. ISD has mainly two parts of chamber one plenum chamber and other is drying chamber. PCM material (Paraffin wax) of 25 kg is kept in a plenum chamber of size (0.265m × 0.54m ×0.5m). A fan of 3.36 W, 12V DC capacities was used to drive the air to the outside through the solar dryer chamber.

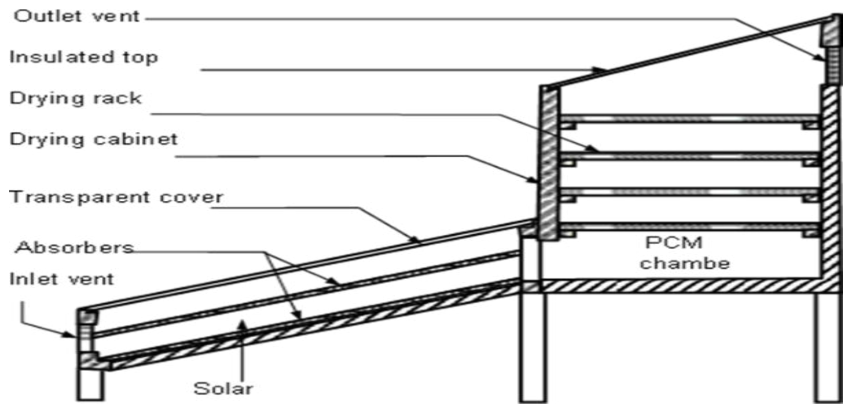

Fig 3-Line Diagram of sectional view of solar dryer

The block diagram of the air flow in solar dryer is follows

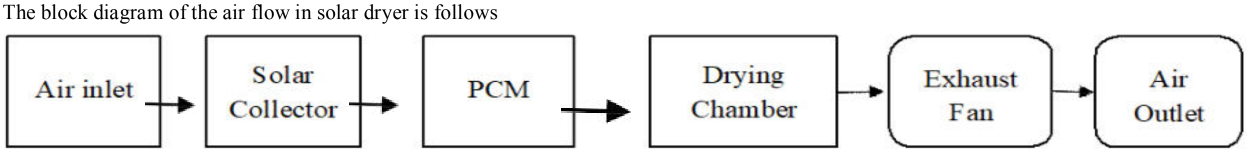

Fig. 4-Block diagram of solar air heater and dryer assembly

A–Frontview B-sideview

Fig 5- Flat plate solar collector with drying chamber

4. Mechanism and methodology

4.1-Mechanism:

Drying is mainly including two major and concurrent procedures: (I) heat convert the moisture present in the products in the form of vapor, and (ii) mass is transfer by transfer of liquid present in the product in the form of vapor. The factor that directs the rates of the processes decide the drying rate. The numerous dryers may use heat exchange by convection, conduction, radiation, or a blend of these. Regardless, in every solar based dryer and other regular dryers, heat be stream to the outer surface first and after that into within the solid, with an exemption of dielectric and microwave drying.

4.1.1- Moisture flow internally in material

The moisture transfer inside the solid is taking due to the concentration gradient which is dependent on the qualities of the solid that may be porous or nonporous. Consequently, the structure of the solid decides the method for which interior fluid stream occurs and these mechanisms can incorporate [7]

i. Diffusion continuous in homogeneous solids,
ii. Capillary flow in granular and porous solids,
iii. The flow of moisture caused by shrinkage and pressure gradients,
iv. The flow of moisture caused by gravity, and
v. Flow caused by a vaporization-condensation sequence.

4.2Experimental calculation

In the projected methodology, the energy balance of indirect drier equation is written by considering air heater and drying chamber separately because they are the individual systems. So, the governing equation of the calculation is taking the drying rate and Tpcm at steady state condition. the amount of thermal energy given to air by collector is used for meeting thermal losses from numerous individual parts of air collector and drying chamber through conduction, convection, and radiation. The subsequent calculation has been done for the solar dryer. Some assumptions are given below which is account in experimental calculation.

i. Air is uniformly flow throughout solar collector and drying chamber.
ii. Temperature of PCM is same throughout the container at one time.
iii. The effect of air is negligible during weighing a product.
iv. Air flow is taking steady flow.

5. Result and Discussion

5.1Dryer evaluation test

The different- different tests were performed out during the evaluation of the dryer with the use of PCM.

5.1.1No load tests

The no-load test was done for achieved to realize the maximum feasible increase in the temperature of the solar collector and drying chamber as compared to that of the ambient temperature. Moreover, paraffin wax is used as a thermal heat storage material. The tests are done in June 2021. Temperature; solar radiation and speed of wind have been recorded at some stage in the test and were used within the calculation of the efficiency of the collector.

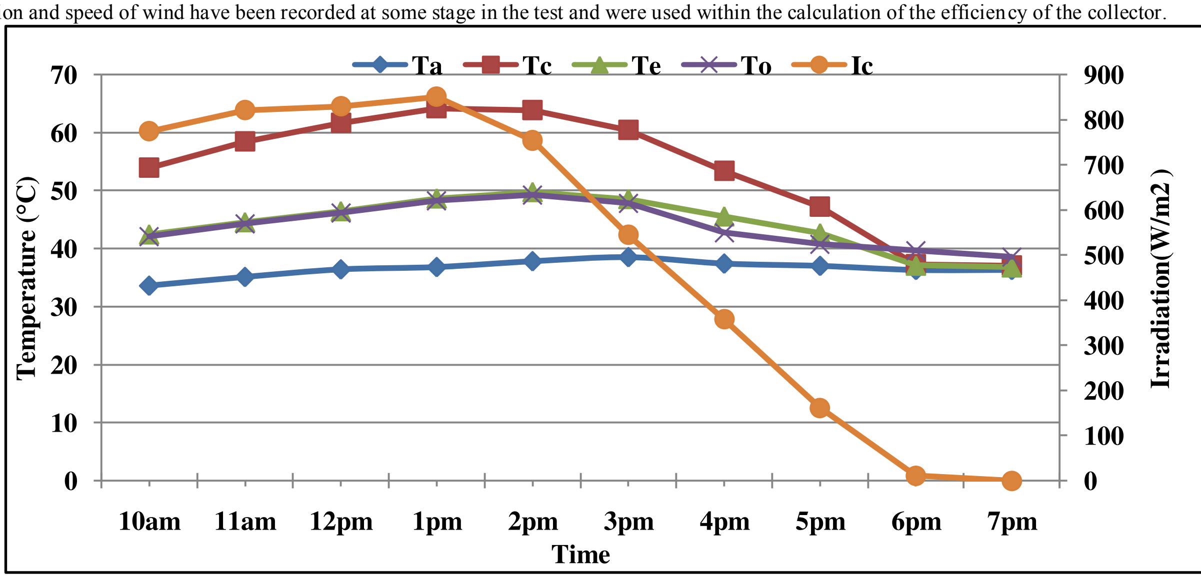

Fig. 6- Variation of temperature w.r.t. time for drying at no loading condition

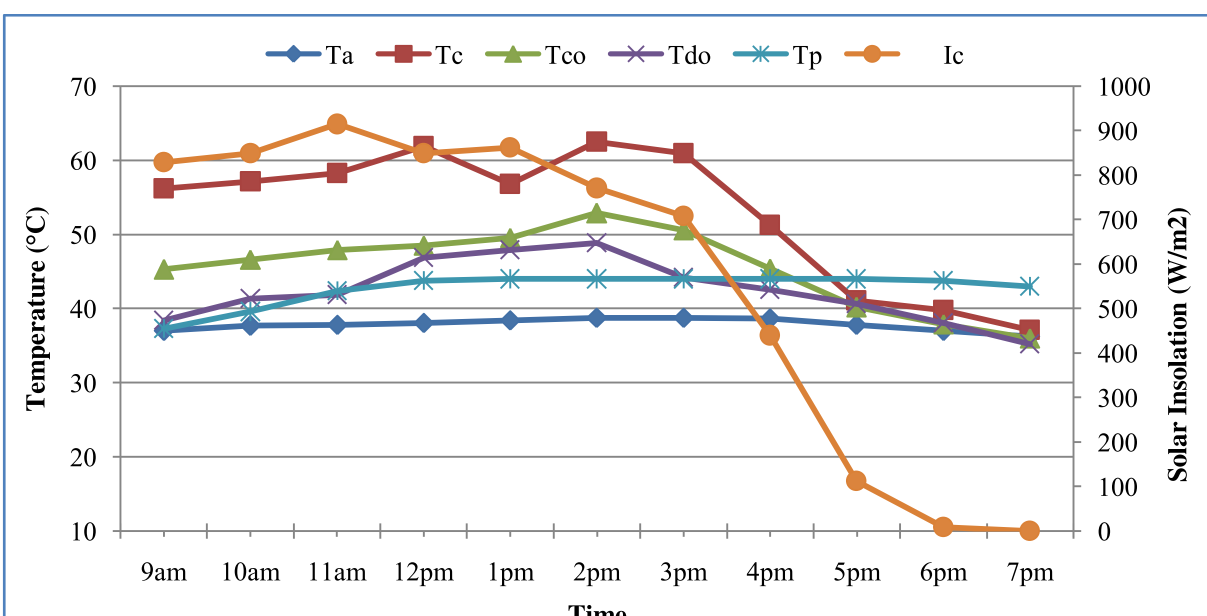

Fig.7- Variation between temperature w.r.t. time for drying of blanched green chili on 11/06/2021

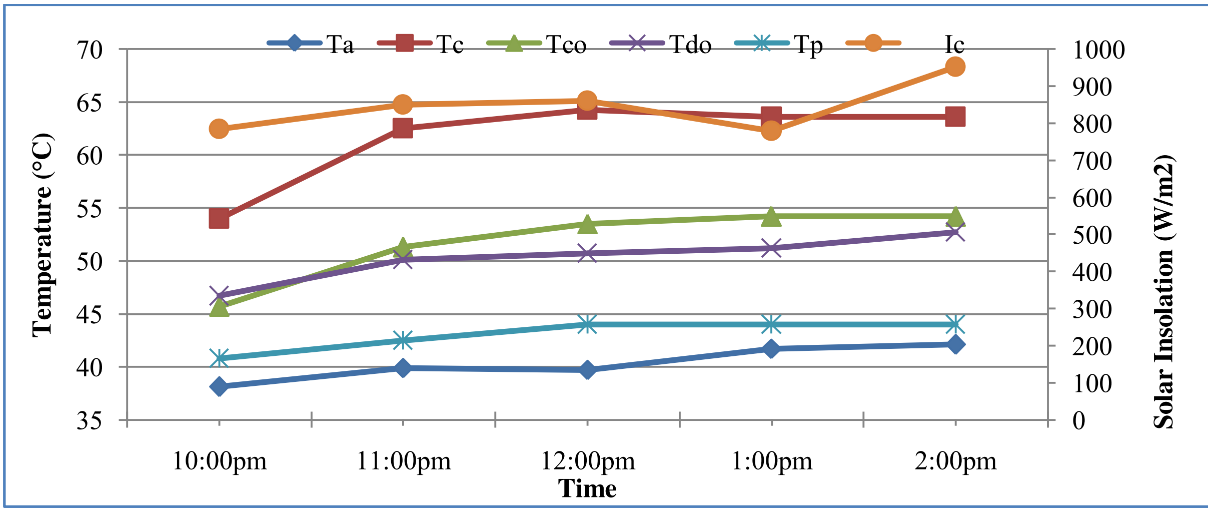

Fig.8-Variation between temperature w.r.t. time for drying of blanched green chili on 12/06/2021

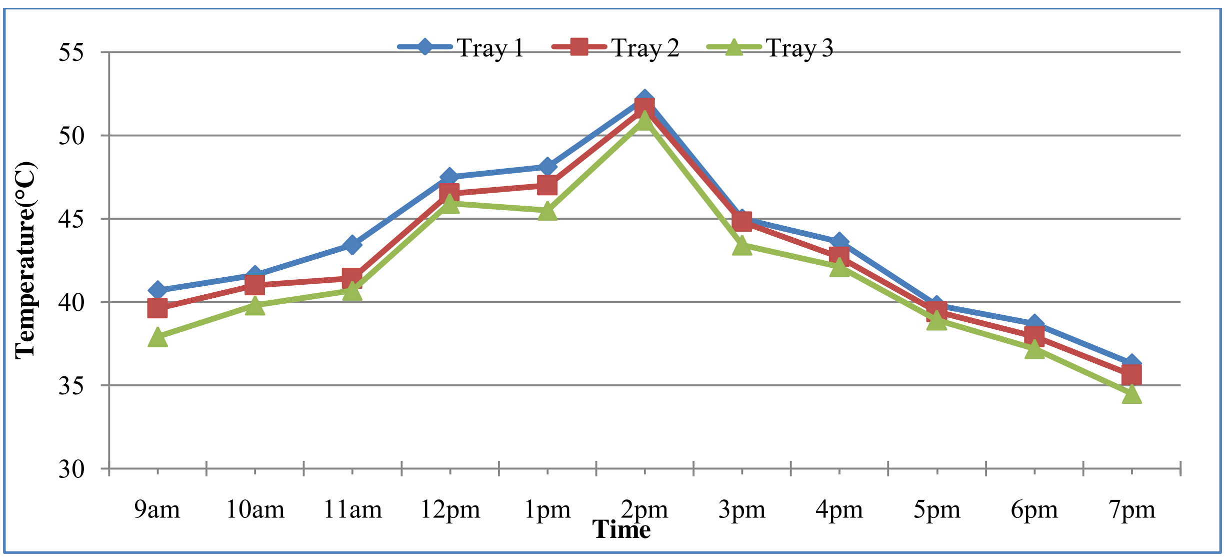

Fig. 9-Variation between tray temperature and time for drying of blanched green chili on 11/06/2021

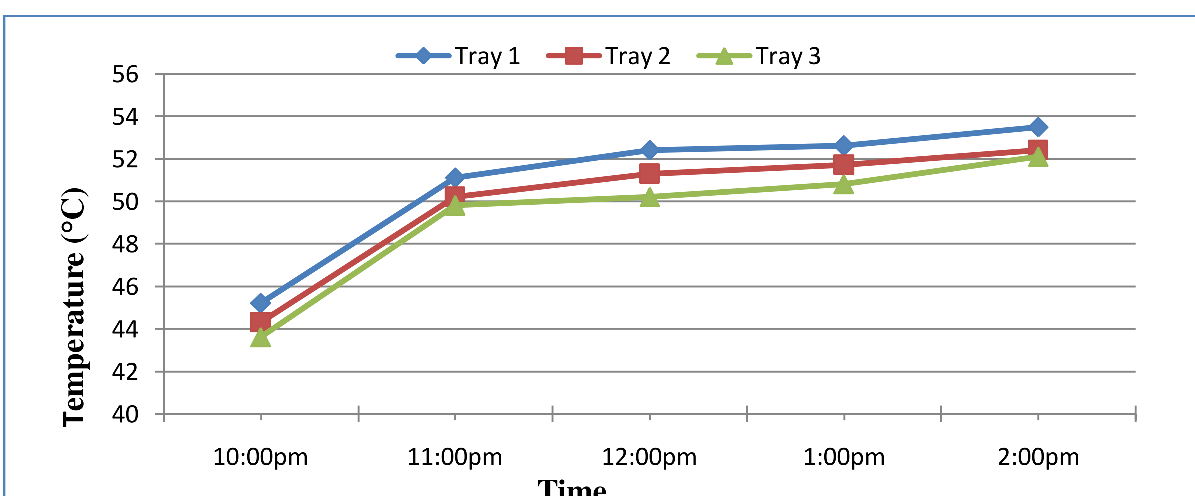

Fig.10- Variation between tray temperature and time for drying of blanched green chili on 12/06/2021

The above fig.7, 8, 9 and 10 show temperature variation. The variation of temperature is the same as no load condition. It is observed that the maximum temperature is between 12:00 PM to 2:00 PM on June 11, 2021 and June 12, 2021. When the environment temperature is going to below the paraffin wax temperature, PCM is starting to transfer the heat to the air. After 5:00 pm o'clock the PCM is coming in the main role of heat transfer.

Table 2-Moisture content of blanched green chili and drying with different time duration and days

Date:11/06/2021		Moisture content of chili(%)		
Timing	Tray 1	Tray2	Tray3	Open
9:00am	89.47	89.47	89.47	89.47
11:00am	85.83	86.30	86.61	86.26
01:00pm	79.48	81.78	84.43	81.60
03:00pm	72.04	76.20	77.82	75.09
05:00pm	55.49	62.15	67.59	65.77
07:00pm	41.50	47.76	54.85	65.77
Date:12/06/2021				
10:00am	41.50	47.76	54.85	65.77
12:00pm	15.76	28.18	35.51	47.78
2:00pm	8.40	14.59	18.97	29.80

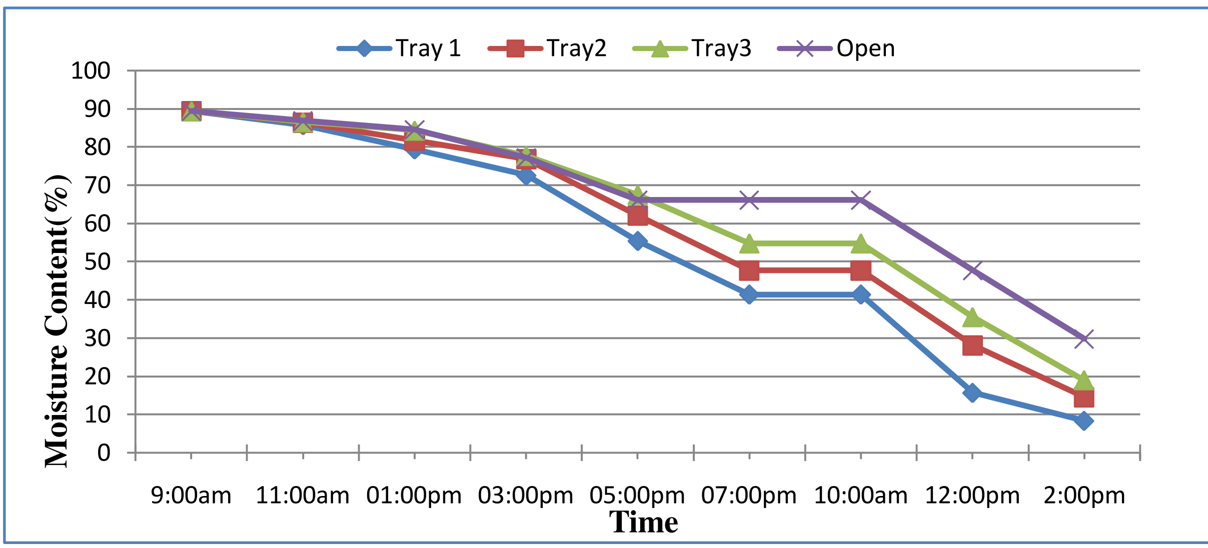

Fig.11- Variation between moisture content and time for drying of blanched green chili

The fig.11 shows the relationship between moisture present in green chili and time with a different date are taken from table 2. The initial moisture content of blanched green chili is 89.47% on wet basis reduced up to of different tray 8.40%, 14.59% and 18.97% on a wet basis. The final moisture content of blanched green chili in open sun drying was 29.77%. The time taking for drying green chili is 14 hours.

Table 3- Drying rate variation of the tray with the different time and days

Date-11/06/2021	**Drying rate of blanched green chili**			
	Solar dryer		**Open sun drying**	
Time	$(-dx/dt)$ $\times 10^{-3}$ (s^{-1})	$W = \frac{S}{A}(-dx/dt)$ $\times 10^{-3}$ $(Kg/m^2.s)$	$(-dx/dt)$ $\times 10^{-3}$ $(s^{-1}$	$W = \frac{S}{A}(-dx/dt)$ $\times 10^{-3}(Kg/m^2.s)$
9am-11am	0.138	11.572	0.134	11.212
11am-1pm	0.108	9.037	0.118	9.874
1pm-3pm	0.093	7.838	0.910	7.614
3pm-5pm	0.092	7.698	0.070	5.857
5pm-7pm	0.045	3.765	0	0
Date-12/06/2021				
10am-12pm	0.036	3.012	0.066	5.527
12pm-14pm	0.013	1.115	0.031	2.593

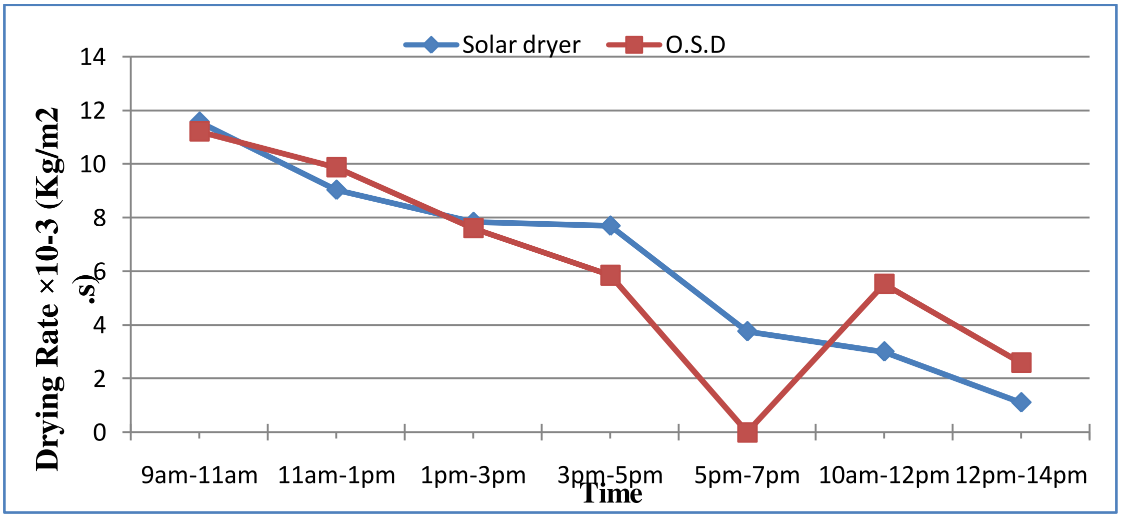

Fig.12- Variation between drying rate and time for drying of blanched green chili

The fig.12 shows the relationship between the drying rate of the tray and time of blanched green chili with a different date 11 June and 12 June, 2021. The drying rate of solar dryer is representing as the average value of three trays at varied time. Solar drying rate curve the shows the moisture transfer rate decreases with time. The maximum drying rate is at initial hour and decreases gradually with respect to increasing time. The main reason is much unbounded water present in the crop at initial level. In the process of open sun drying the drying rate is obtained zero because solar radiation is not present in time duration 5:00pm-7:00pm. The drying rate of chili in solar dryer is better than open sun drying and time taken for drying chili in solar dryer less time as compare to open sun drying.

Table 4- Instantaneous efficiency of collector and dryer with time on 11/06/2021

Time	Collector efficiency(n_c)	Dryer efficiency(n_d)
9:00am	0.37	0.35
10:00am	0.42	0.30
11:00am	0.41	0.32
12:00pm	0.48	0.10
1:00pm	0.57	0.11
2:00pm	0.62	0.18
3:00pm	0.60	0.46
4:00pm	0.58	0.28
5:00pm	0.46	0.17
6:00pm	0.55	0.98

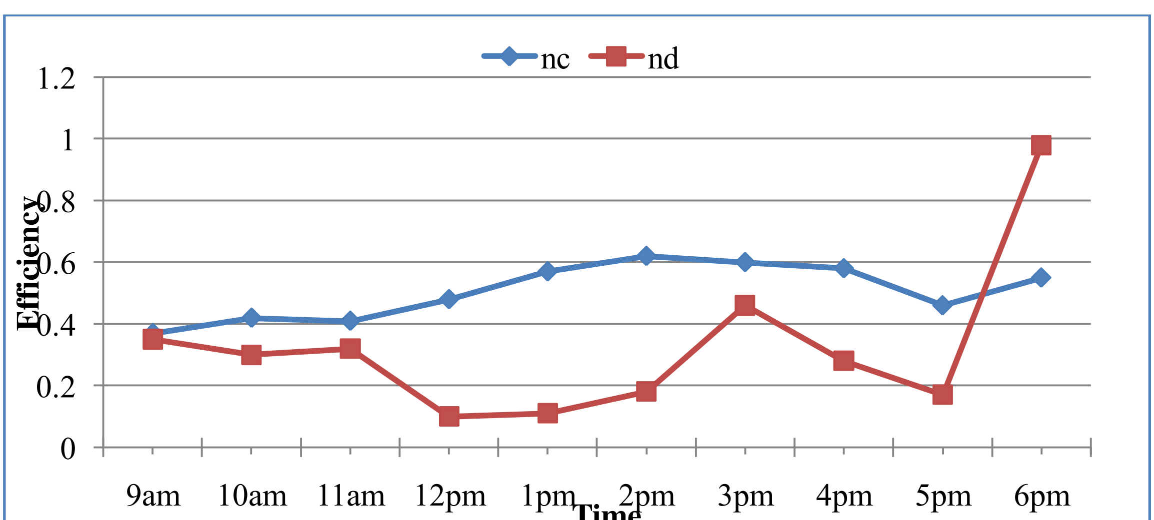

Fig.13-Variation between efficiency and time for drying of blanched green chili on 11/06/2021

The fig. 13 shows the collector efficiency and dryer efficiency with a day of time of date June 11, 2021. The data of the graph is taken from table 4. The dryer efficiency was reaching maximum 98% at 6:00 PM and minimum 10% at 12:00 PM on date June 11, 2021. The dryer chamber efficiency increases after 5:30 PM because of heat transfer taking place through PCM container and decreasing the input energy. The collector efficiency is maximum 62% and minimum 37% on June 11, 2021. The average efficiency of solar collector and dryer on June 11, 2021 were 50.6% and 32.7% respectively.

Table 5- Collector and solar dryer efficiency with time on 12/06/2021

Time	Collector efficiency(n_c)	Dryer efficiency(n_d)
10:00am	0.46	0.14
11:00am	0.55	0.09
12:00pm	0.61	0.18
1:00pm	0.58	0.20
2:00pm	0.52	0.12

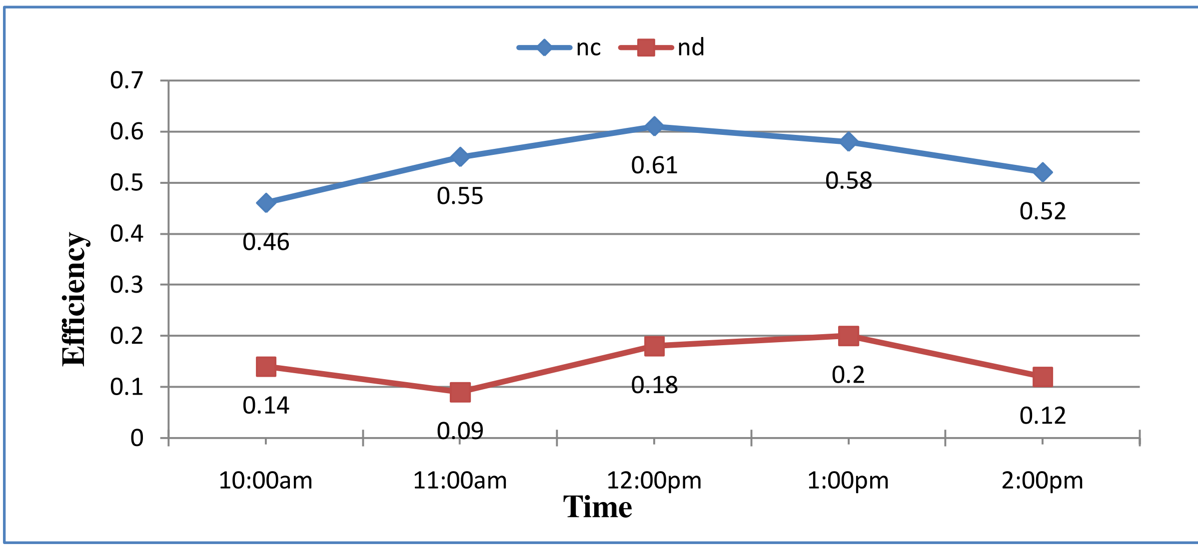

Fig.14-Variation between efficiency and time for drying of blanched green chili on 12/06/2021

The fig. 14 shows the collector efficiency and dryer efficiency with a day of time of date June 12, 2021. The data of the graph is taken from table 5. The dryer efficiency was reaching maximum 20% at 1:00 PM and minimum 10% at 11:00 AM on date June 12, 2021. The collector efficiency is maximum 62% and minimum 46% on June 12, 2021. The average efficiency of solar collector and dryer on June 12, 2021 were 54.9% and 13.7% respectively.

The purpose of this study is to see how cutting parameters affect the MRR and SR in the WEDM process. EN 8 is fairly machinable using the WEDM process, according to the results of this study. For two responses—material removal rate and surface roughness—optimized process conditions have been found. From this research, the following conclusions can be drawn. Surface roughness increases at first, then decreases with Ton, and material removal rate decreases as Toff increases. The impact of Toff on MRR is greatest and has a contribution of 66.02 percent. Second most predominant characteristic is Ip with a contribution of 32.54 percent. With a contribution of 0.5962 percent, Ton is the least influencing parameter on SR. With a contribution of 60.52 percent, Ton is the most influencing parameter on SR. Toff is the second most important factor, accounting for 14.78 percent of the total. Ip has the least impact, accounting for 11.28 percent of the total. In the SM study, craters increase with increased Ton due to increased discharge duration, while debris increases with increased Ip and decreased Toff. More material melted and evaporated as the Ip increased, increasing the value of current and hence the spark energy. Increased Toff reduces surface roughness since no spark is created during this period and material is flushed away, resulting in a smoother surface. Microcracks can also be seen as a result of uneven heating or cooling.

Experiment on potato chips

Each dryer tray is contained 450gm of the potato chips. From different test executed, it turned into observed out that, Oven drying is used to determine the initial moisture content of the potato which resulted in a mean value of 85.05%wb [20]. The reduction in weight of the potato chips has been recorded and used to calculate the moisture loss of the slices during the duration of drying based on the determined initial moisture content. The overall performance of the dryer became calculated based on the drying rate and drying performance characteristics as to the various tests. On the basis of the experimental data, the results and performance characteristics of solar have been reported. For seen the performance of PCM in solar dryer the test is started at 12:00 o'clock in noon. The time consuming by potato sliced for drying is 7 hours. The environment condition on date 17June, 2021 is not good in between 3:00-4:00 o'clock. In the bad environment condition, heat is evolved by the PCM in the drying process, due to which the drying process is takes place continuously but in slow manner.

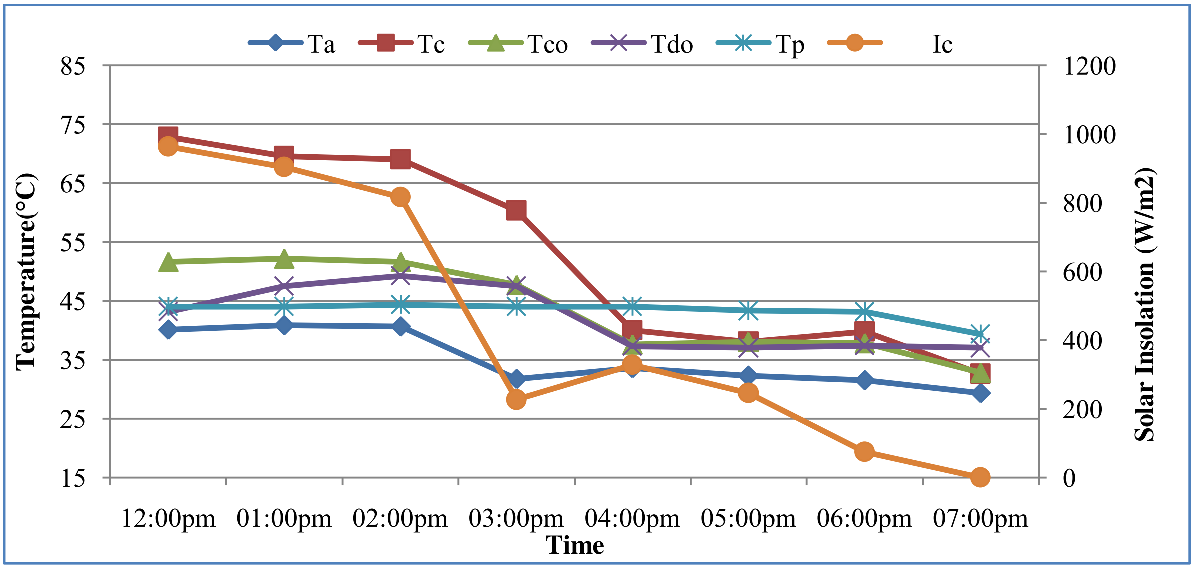

Fig.15-Variation of temperature and solar insolation w.r.t. time for drying of potato chips

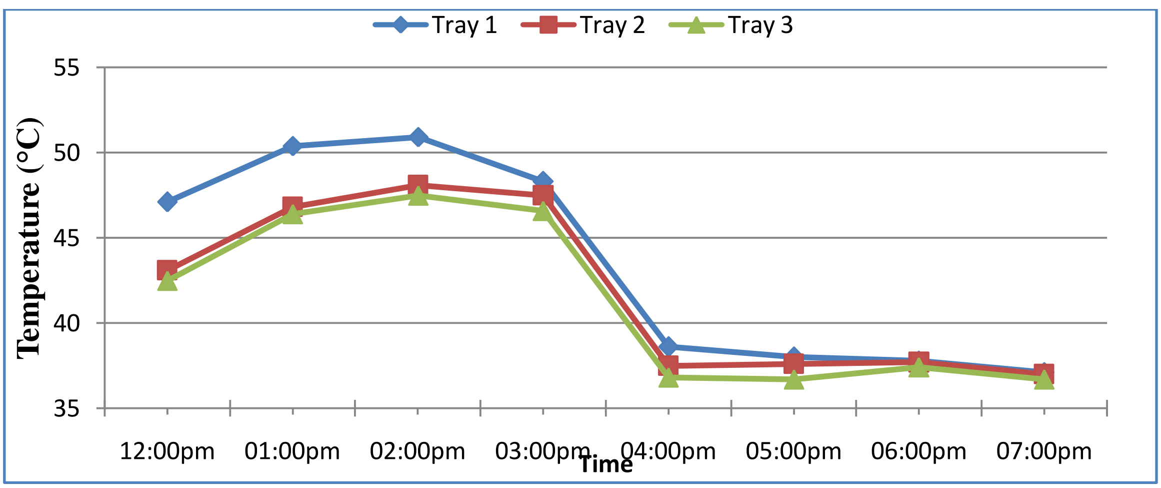

Fig. 16- Variation between tray temperature and time for drying of potato chips

The fig.15 and fig.16- shows temperature variation of dryer and its various position w.r.t. time. The maximum temperature of the collector is 72.8 °C at 12:00 PM o, clock. The environment condition is not cloudy in between 3:00 pm to 4:00 pm. The environment temperature is suddenly decreases and PCM coming into the main role for drying process. The tray temperature is increased from 47.1°C (12:00 PM) to maximum is 50.9°C (2:00 PM) and after reaching the peak point gradually decreases. After 3:00 PM the temperature was suddenly decreases due bad whether condition. PCM is starting to transfer heat to drying product in during bad environment condition in between 3:00 pm to 4:00 pm.

Table 6-Moisture content variation of the tray with time

	MOISTURE CONTENT(EXPERIMENTAL) of POTATO			
Time	**Tray 1**	**Tray2**	**Tray3**	**Open**
12:00pm	85.05	85.05	85.05	85.05
1:00pm	75.08	77.35	78.29	77.65
2:00pm	47.44	53.60	61.99	58.73
3:00pm	29.92	30.64	42.50	48.62
4:00pm	19.91	24.41	35.93	43.83
5:00pm	12.63	17.96	29.18	42.96
6:00pm	3.89	13.75	21.77	40.86
7:00pm	3.89	7.84	14.84	40.86

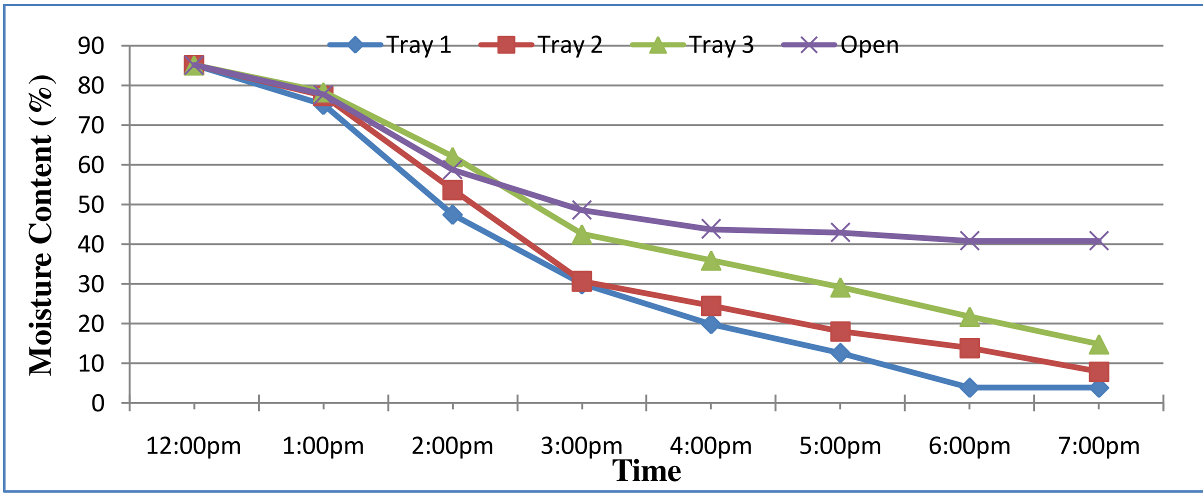

Fig 17- Variation between moisture content and time for drying of potato chips

The fig.17 shows the relationship between moisture content in potato chips and time on 17th June 2021. The moisture content is calculated from the weight of the dry product at every hour time of interval. The initial moisture content of potato chips is 85.05% on wet basis reduced up to of different tray 3.89%, 7.84% and 14.84% on a wet basis respectively. The final moisture of potato chips in open sun drying is 39.39%. The time duration taken for drying potato chips is seven hours. The open sun drying product is not completely dry due to poor environment condition.

Table 7- Drying rate variation of the tray with the different time

Date-17/06/2021			**Drying rate of potato chips**	
	Solar dryer		**Open sun drying**	
Time	$(-dx/dt)$ ×10-3 (h^{-1})	$W = \frac{S}{A}(-dx/dt)$ ×10-3 (Kg/m2.h)	$(-dx/dt)$ ×10-3 (h^{-1})	$W = \frac{S}{A}(-dx/dt)$ ×10-3 (Kg/m2.h)
12-1pm	0.1577	13.1956	0.1490	12.467
1-2pm	0.1423	11.9070	0.1380	11.547
2-3pm	0.0500	4.1838	0.0340	2.845
3-4pm	0.0107	0.8953	0.0090	0.753
4-5pm	0.0090	0.7531	0.0072	0.603
5-6pm	0.0063	0.5296	0.0040	0.3356
6-7pm	0.0040	0.3347	0	0

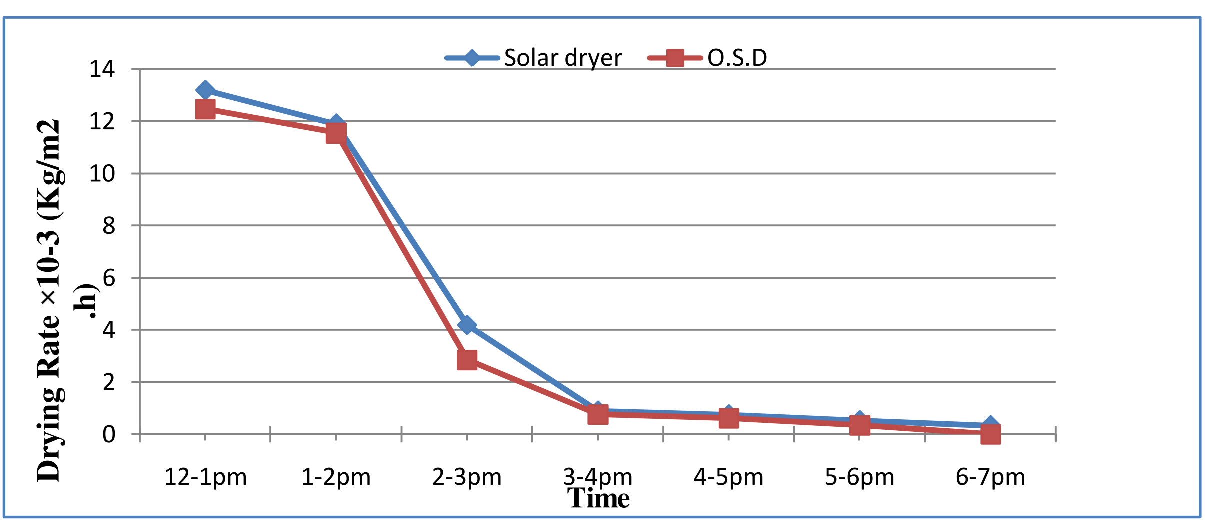

Fig.18- Variation between drying rate and time for drying of potato 17/06/2017

The fig. 18 shows the relationship between the drying rate of average solar dryer and open sun drying with respect to time of potato chips. Both drying rate curve are following the same pattern. The maximum drying rate of product is in starting hour of drying due to unbounded water present in the product. The drying rate gradually decreased with time. It was seen that solar drying are much better than open sun drying.

Table 8- Instantaneous collector and solar dryer efficiency with time

Time	Collector efficiency(n_c)	Overalldryerefficiency(n_d)
12:00pm	0.48	0.46
1:00 pm	0.44	0.29
2:00 pm	0.50	0.22
3:00 pm	0.58	0.07
4:00 pm	0.49	0.08
5:00 pm	0.64	0.24
6:00 pm	0.31	0.27

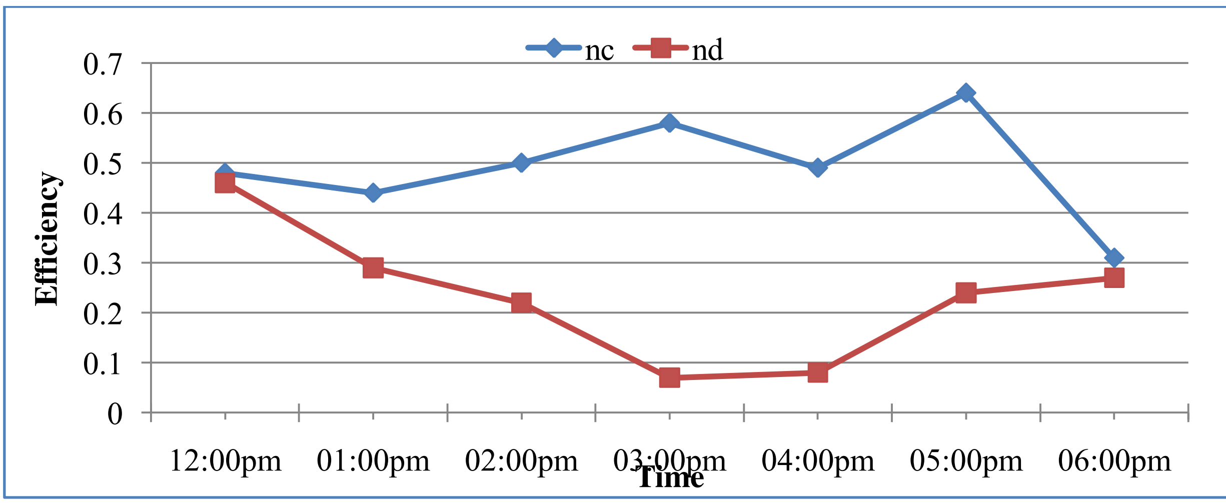

Fig.19- Variation between efficiency and time during drying of potato chips

The fig. 19 shows the collector efficiency and dryer efficiency with a time of day. The data of the graph is taken from table 8. The dryer efficiency was reaching maximum 46% at 12:00 PM and after which decreases. The collector efficiency is maximum 64% at 5:00 PM o' clock. The efficiency after 6:00 PM is not considered due to unavailability of the solar based energy.

The performance of the indirect solar dryer using paraffin wax (June 2021) is compared with the previous mixed solar dryer work (March –April, 2016) without the use of PCM material with the help of observation table 7 and 8. The comparison is done by considering the parameter drying chamber input and output temperature, solar radiation and efficiency of solar dryer in drying of potato slices in the both cases. Time duration for doing the previous project work is 10:00am to 5:00pm, where is in my project work is 1200pm to 7:00pm. The time and date for doing the experiment is different so it is using the hour in time axis in place of exact time. The comparison graph of the both work is given below: -

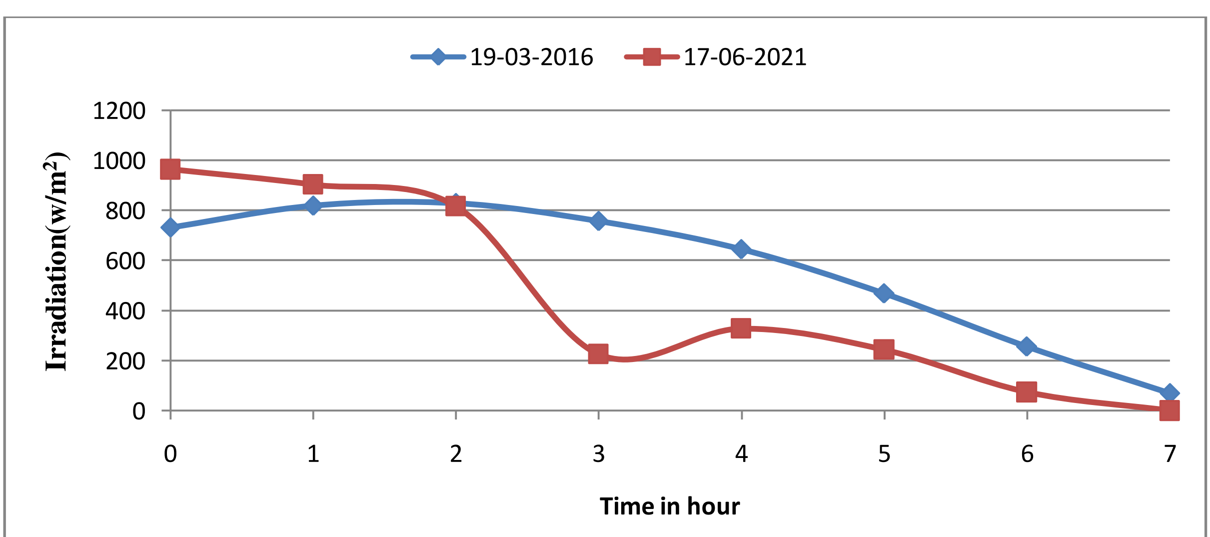

Fig.20-Variation of solar insolation on different-different date with time

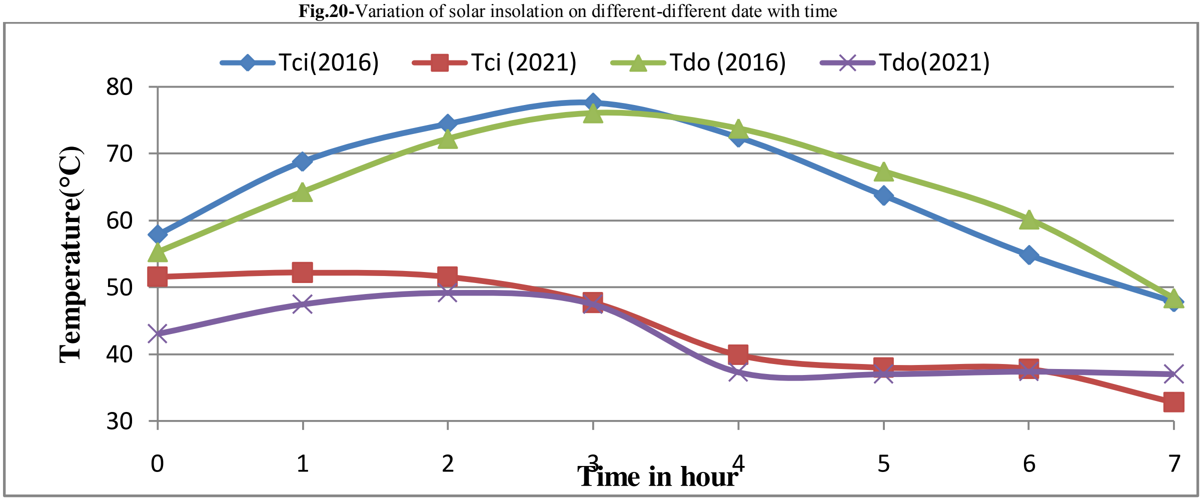

Fig.21- Variation of temperature on different-different date with time

Fig.20 and 21 are represent the variation of solar radiation and various point temperature on date 19 march 2016 and 17 June 2021. Solar radiation in both the work is varied due the project timing is different for both the experiment. In 2016 the time duration of experiment was 10:00am to 5:00pm whereas time in 2021 it is 12:00pm to 7:00pm. In 2021 solar radiation show the irregularity at the third hour because there was cloudy sky is present at that time. The temperature range of previous work is 11-43°C higher than the environment, whereas in my research work the temperature range is 6-33°C higher than the environment temperature. The decrease in the temperature range is due to the higher fan speed, higher mass flow rate and restricted the solar radiation which is coming from top surface in mixed mode dryer. In the previous work, after 12:00 o'clock the sun rays was falling perpendicular to the roof glass so drying chamber outlet temperature was more than inlet of drying chamber.

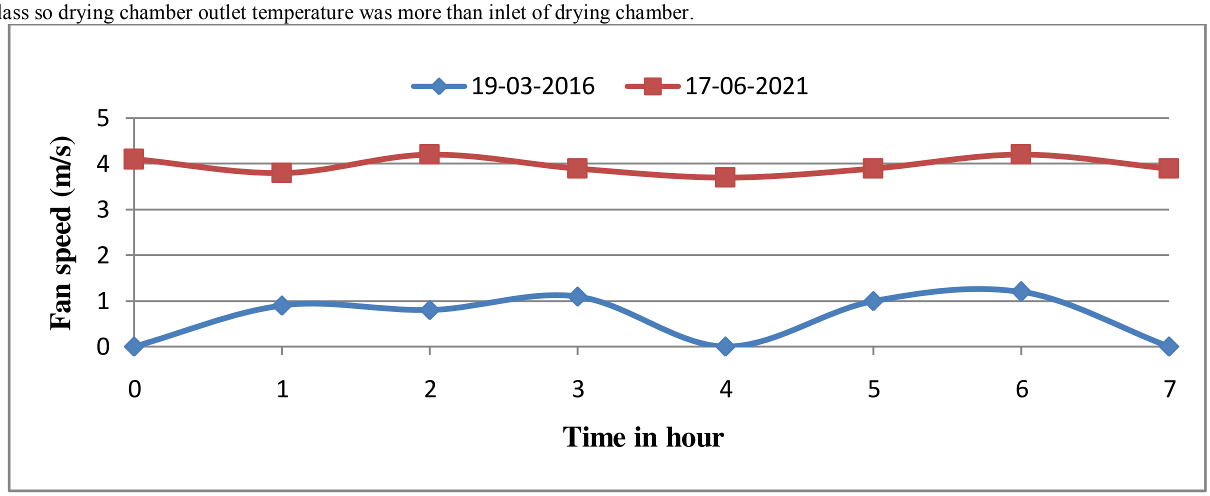

Fig.22-Variation of fan speed on different-different date with time

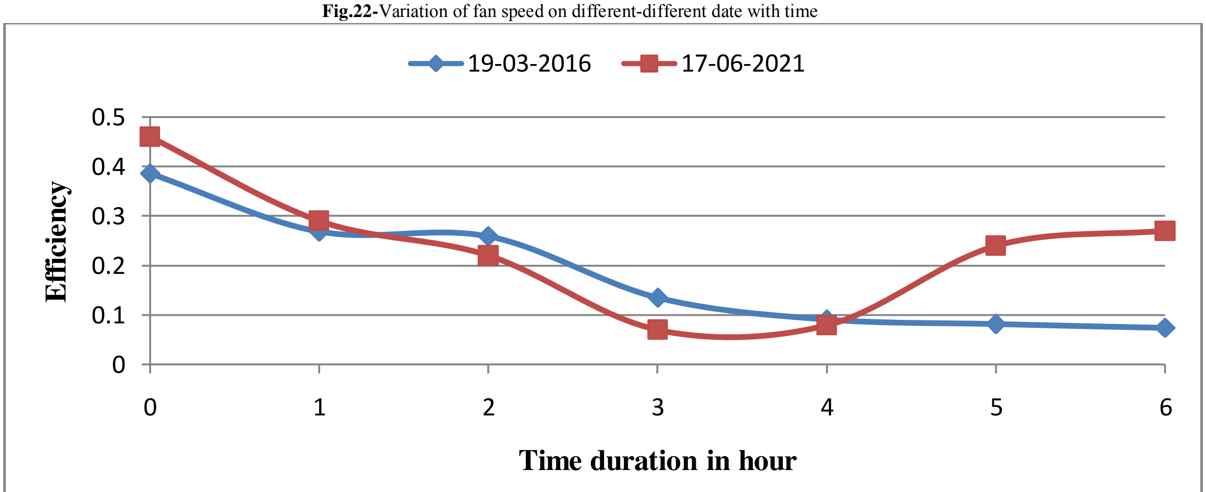

Fig. 23-Variation between efficiency of dryer on different date

The above fig22 and 23 shows the outlet fan speed and the efficiency of dryer with respect to different date and various mode of dryer. Fan speed in 2016 was become zero because it was depending on the electricity whereas in 2021 a solar and battery are used for driving fan. The avg. efficiency of the solar dryer on previous work is 20.28%, whereas in my research work it is 22.08%. The increase the efficiency is due to the availability of PCM. The maximum solar air collector efficiency was in previous work 72.80%, whereas in my research solar air collector efficiency was 64%. The decrease in the efficiency of solar collector is due to increase in the mass flow rate of hot air.

6. CONCLUSION

Conclusion: From the experiment did on the Indirect mode solar dryer, the following conclusions we made.

- The solar-powered dryer can raise the blow air temperature to a significant high for expanding the drying rate of farming products. The maximum temperature of the solar air heater and drying chamber is obtained in between 12:00-1:00 PM o'clock.
- Also, from the test did, the collector temperature depend upon solar radiation, inclination angle and the wind speed and how much quantity passed through the drying chamber.
- The dryer chamber maximum temperature has in between 50-60°C, which is required for passive solar based dryers. Higher temperatures prompt breaking of the grains and introduction to bacterial and bug attacks.
- The dryer showed the adequate capacity to dry sustenance or things sensibly and quickly to a safe moisture level and increase the quality nature of the dried product.
- There is used PCM so the drying product is not necessary to take out from the solar dryer chamber and no problem associated with product re-wetting.
- The effectiveness of dryer is not only dependent on loading condition and weather condition but also on the PCM condition.
- The time taken for drying the potato sliced from initial MC 85.05% (wb) to 3.89%, 7.84% and 14.84% on wet basis of respectively first, second and third tray were seven hours, whereas in open sun drying the final moisture content was 39.39% on wet basis.
- The time taken for drying the blanched chili from initial MC 89.47 % (wb) to 8.40%, 14.59% and 18.97% on wet basis of respectively first, second and third tray were fourteen hours, whereas in open sun drying the final moisture content was 29.77% on wet basis in same timeframe.
- The results show that the quality of the product in the solar dryer is better as compare to open sun drying. The product quality of crops using PCM with dryer is better than the without using the PCM material dryer.
- The equilibrium moisture content depends on ambient temperature and relative humidity of environment and it is not a constant value.
- The dryer efficiency is depending on the environment condition and loading capacity.
- The dried product is free from dust and unavoidable contaminations in solar dryer with compare to open sun drying.

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