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Evaluating The Drying Performance Of A Solar PV/T Hybrid System For Drying Solanum Lycopersicon

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Abstract:-
The current study involved the development of a PV/T Hybrid solar dryer (PV/T System) which utilized solar photovoltaic (PV) panels to power intake fans and increase air movement. Tomato (Solanum Lycopersicon) was subjected to drying trials. An estimation was made on the drying efficiency and performance characteristics of the PV/T Hybrid solar dryer (PV/T System). Drying is a commonly employed technique for extracting moisture from food, often employed for the purposes of storing and preserving it. Fruits and vegetables are the primary commodities in the agriculture sector. Due to its exceptional nutritional worth, it is necessary to preserve it. Optimal preservation of a food's nutritional value may be achieved by ensuring its freshness. There are several methods for preserving this food, but the most widely used one is nut drying because to its ability to extend the item's durability. These goods can have a moisture content of up to, and in some cases exceeding, 89%. This study aims to evaluate the efficiency of solar drying and sun drying methods in the dehydration of vegetables. Drying rate and weight. The chamber facilitated the transmission of hot air to desiccate the slices of tomatoes. The moisture content of tomatoes reaches around 85% during drying, which takes half the time compared to typical drying methods. The technology demonstrates a notable improvement when compared to the natural convection system.

Introduction: -
Preservation of agricultural products is important to keep them fresh for a long time without deterioration in quality. Drying is a popular technique to preserve agricultural products by eliminating the moisture content (MC). Various drying methods are used to dry vegetables and fruits, such as solar, convective, freeze, fluidized bed and microwave drying. Drying by solar energy is inexpensive and environment friendly. Also, the abundant availability of this energy and its renewable nature has attracted researchers. Open sun drying (OSD) is a conventional method to dry food products since ancient times. OSD method has several disadvantages such as more drying time, degradation of products by micro-organisms, loss caused by animals and birds, and contamination by dirt (Banout et al., 2011; Sallam et al., 2015). India is the biggest consumer and producer of chillies on the globe. The major chilli producing states in India are Telangana, Andhra Pradesh, Karnataka, Madhya Pradesh and Orissa. Since green chillies are used in cooking and consumed daily, it is cultivated by farmers round the year. Fresh chilli has high amounts of vitamin C and vitamin A. Fresh chillies have seasonal variation in terms of cost, high wastage, huge MC and limited shelf life. Dried green chillies have fixed cost, low wastage, high quality and longer shelf life. Okra (Abelmoschus esculentus) is a member of mallow family. It is mostly cultivated in warm temperature regions include tropical and subtropical regions (Huang and Zhang, 2016). The major okra producing countries are India, Pakistan, Egypt, Nigeria and Ghana. It can be directly taken as a raw or cooked one and used as additive for beverages, dairy products and soups. It has high nutritional values, since it consists of vitamins Band C, potassium, calcium, dietary fibre and folic acid.
The major Tomato producing States in the country are Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Maharashtra, Chhattisgarh, Bihar, Telangana, Uttar Pradesh, Haryana and Tamil Nadu. These States are account for 91% of the total production of the country. The production of Tomato during the 2022-23 (Third Advance Estimate) is estimated to be about 8.4% lower as compared to the previous year. However as compared to past 5 years average production, it is 5.4% higher. Wangetal. (2018) performed experiments on a forced convection ITSD dryer with the addition of auxiliary heating device to dry mango slices. They investigated the drying behaviour of mango slices at different air temperatures. De values of mango slices ranged from 6.41×10−11to1.18×10−10m2/s. The Page model was found to be the best model for mango slices.
Several studies have been carried out on a variety of solar dryers such as direct solar dryer (Bena and Fuller, 2002; Sallam et al., 2015), indirect solar dryer (natural (Kumar and Tiwari, 2007) and forced convection (Mohanraj and Chandrasekar, 2008), mixed solar dryers integrated with auxiliary devices (Wang et al., 2018; Baniasadi et al.2017), for different types of agricultural products. Agricultural produce such as pine apple (Bena and Fuller, 2002), onions (Kumar and Tiwari, 2007), grapes (Raj et al., 2019), chilli (Banout et al., 2011; Castillo Téllez et al., 2017), mango (Wang et al., 2018), copra

(Mohanraj and Chandrasekar, 2008), banana (Amer et al., 2010; Abhay et al., 2017), apple (Kaleta et al., 2013), cabbage (Claussen et al., 2007), apricot (Baniasadi et al., 2017), beans, okra (Doymaz, 2005; Wankhade et al., 2013), and turmeric (Karthikeyan and Muruga velh, 2018) were dried. Some numerical studies have been reported on drying agricultural products (Abhay et al., 2018; Arun sandeep and Chandramohan, 2018; Arun Sandeep et al., 2018; Aktas et al., 2016). From the literature survey, it has been observed that very few studies are available on natural convection ITSD dryer (Abhay et al., 2017,2018). Also, a limited number of parameters were estimated and analysed from the drying data of Tomato and green chilli.

Drying is the process which plays major role in the food preservation that is often carried out after harvest, especially with highly perishable crops. By using Thermal energy, the vegetables, fruits and meat can be stored for a longer time and it is easy for transportation by decreasing the moisture content. If the process is done in a proper way like by adjusting the temperature and time management. Most of the developing countries are facing the problem related Preservation of Agricultural produce. Average of Decreased Moisture Content at 3 Experiments as the population increasing the Growing dietary needs are increasing. All the countries the quantities of Vegetables and fruits spoil due to infrastructure, insufficient processing Capacities and difficulties of marketing growing because of competition across the world agricultural markets.

2. Materials and Methods.

2.1 Experimental setup PVT/ hybrid systems are gaining popularity now-a-days for various applications like grape drying, drying of agricultural products etc. The absorber plate is made up of copper. One end of the air chamber is open for air passage. A blower is installed on one side and the other side is utilized for the drying purpose. Capacity of the PV panel is of 100W. It is made up of polycrystalline silicon solar cells. Solar panels were connected to the batteries through charge controllers. End of the circuit is connected to an electric load. Specifications of the experimental setup, dimensions of the solar air heater, rating of the blower and the panel are depicted in Table.1. The power produced from the solar PV cells is used to run the blower. This is done to improve the efficacy of SAH. By this method, external power consumption can be reduced. This allows to intensify the overall accomplishment of the system. This air from the blower is used to cool the SAH. Thus, in this work, one strategy of intensifying the accomplishment of SAH is by providing cooling with the blower. Another method of intensifying the efficacy of SAH is by providing transverse ribs in the air passage at regular spacing.

S. No	Particulars of Solar Panel	Specifications
1	Rated Power	100W
2	Voltage (Max)	20 V
3	Current (Max)	5.55 A
4	Open Circuit Voltage (VOC)	20V
5	Short Circuit Voltage (ISC)	5.8 A
6	Thermocouples	K Type
7	Inclination of panel	13^0

Table1 List of Specifications

Fig:1Experiment set Up

2.2 Methodology: -

An ITSD was designed and fabricated at Matrusri Engineering College, Hyderabad, India. The ITSD consists of a trapezoidal/Rectangular duct to which fans are fixed at inlet of the duct, solar photo voltaic (PV) panels, solar air collector (SAC), drying chamber as shown in Fig. 1. SAC is oriented at an angle of 45° with respect to horizontal surface facing North– South direction based on the latitude of Hyderabad, India (18° N). It has a gross dimension of 0.149m×0.658m×0.06m. It consists of glass, corrugated absorber plate of V shape and rockwool insulation to prevent heat losses. The glass material is normal window glass and it has a thickness of 5mm. The absorber plate is made of copper because copper has high thermal conductivity. The absorber plate has a thickness of 1mm and is coated with black paint to increase the absorptivity of the material. V corrugations are provided on the absorber plate to increase the surface

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area and thereby increase the radiation incident on it. Also, it is useful to enhance the turbulence of air flow inside SAC. The total number of corrugations used is 38. A trapezoidal shaped duct is fixed at the entrance of SAC, which is fabricated using galvanised iron (GI) sheet metal with a thickness of 3mm. Two DC fans (7.5cm diameter, 12V, 0.25A) are fixed at the entrance of the duct to enhance air flow. The duct has gross dimensions of 0.4m×0.1m at the entrance. The electrical power needed for the fans is generated by two solar PV panels (Access solar, 10 Wp). The PV panels were fitted in such a way that their angle is parallel to SAC. Two solar panels were used to run these two DC fans. Each fan has 12V capacity; therefore, a 17V solar panel was used to run each fan. A normal PV panel consists of silicon cell sandwiched between conductive layers. The silicon in PV cell has two different junctions (n-type and p-type). Therefore, the setup is a forced convection system but the power needed for fans is generated using renewable energy. Appropriate holes were provided at the rear end of the trapezoidal duct to measure air flow velocity (two locations) by anemometer while the temperature (single location) was measured by RTD sensor. The holes were sealed by M-seal to avoid air leakage and heat loss. The outlet of the trapezoidal duct is connected with inlet of SAC. There is a gap between the glass and absorber plates which allow air to flow. The heat loss from SAC is prevented by covering the three sides (bottom and longitudinal sides) with rockwool insulation of 25mm thickness. The drying chamber is made up of aluminium sheet (thickness 0.5mm) and has a gross dimension of 1.05m×0.4m×2m. It has four trays to keep the product to be dried, made of GI Sheet and plastic mesh of dimensions of 0.8m×0.3m. Thermocol sheets (thickness of 5cm) were used to prevent heat loss 8 RTD sensors were used in the setup to measure the air temperatures. These were: at the inlet of SAC (outlet of trapezoidal duct), the inlet of drying chamber (or outlet of SAC), four measurements at each tray inside the chamber. The components and accessories of ITSD with specifications are given in Table 1. Table 2 shows the instruments which were used during experiments and their specifications. (TEMPSENS /J Type thermocouples) sensors were used to find air temperatures. Let Ti, To, T1, T2, T3, T4, T5, T6, T7, and T8 be the temperatures at collector inlet (trapezoidal & Rectangular duct outlet), collector outlet (drying chamber inlet), trays − 1, 2, 3, 4 and ambient, respectively. Solar insolation, air velocity and RH were measured using solar power meter, hot wire anemometer and humidity transmitter, respectively. Mass reduction of sample pieces was measured using weighing balance (electronics). Data logger used for data collection and integration is portrayed. The initial MC of sample was estimated after it was dried in a hot air oven.

Fig:2 Data Logger

2.2. Experimental procedure: -

The drying experiments were conducted in Matrusri Engineering College, Hyderabad, India (Longitude 78.47° E; Latitude: 17.4065° N) in March 2024 to study the drying behaviour of the tomato. Fresh tomatoes were bought from the local vegetable market, and washed thoroughly to eliminate any dirt present on them. And they were laid on a cotton cloth to remove any excess water present while being washed. To increase the drying rate, the tomato was cut into pieces and placed in the drying chamber, A total of 1kg of green chilli was used for drying. 200g of green chilli were placed on each tray (trays 1, 2, 3 and 4) and the remaining 200g were dried by OSD method. The reduction in moisture in the product was measured by weighing the sample mass each hour. During the drying process, other parameters such as temperature, velocity, humidity and solar radiation were also measured. Using the mass reduction data, other drying parameters of tomato were estimated. To prevent heat loss from the dryer, the inner walls of the dryer were properly insulated and the doors were closed tightly. Experiments were performed on two different days to identify the effect of forced convection in ITSD setup. Initially experiments were conducted with inlet fans powered by solar PV panels. The assembly of solar PV panels and fans was removed from the setup and experiments were performed as natural convection case. The results were compared.

Results and Discussion: -

Calculations: -

1. $x(t) = M(t) - Ms / MS$
2. $x(t=0) = Mi - Ms / Ms$

where

X(t) = water content at any instant t (kg water | kg DM)

M(t) = wet product mass (kg)
Ms = dry matter mass (kg)

Table:2 Drying of veg with and without dryer at High Speed		
Time	With dryer (in gms)	Without dryer (in gms)
10.00	121	160
11.00	117	147.6
12.00	109	135.3
1.00	100	126
2.00	90	116.3
3.00	78	105.3

Fig 3 Wt. of Tomato at Low-Speed **Fig: - 4 wt. of Tomato at High Speed.**

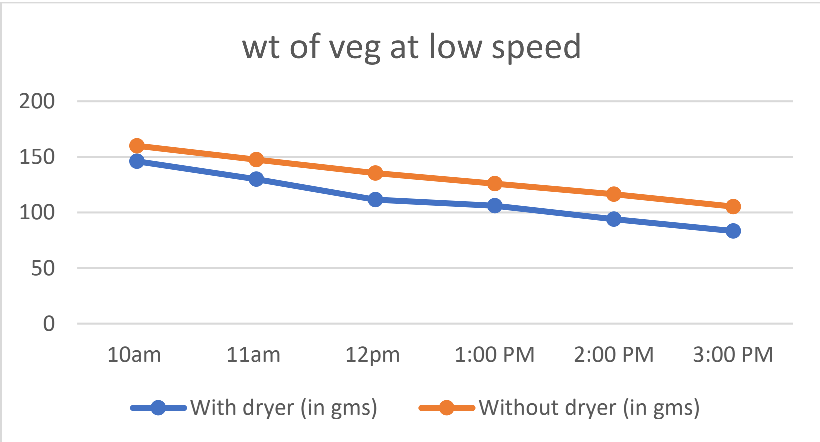

Fig 5 comparison drying weight of veg with and without dryer at low speed

Table:3 Drying of veg with and without dryer at Low Speed		
Time	With dryer (in gms)	Without dryer (in gms)
10.00	146	160
11.00	130	147.6
12.00	111.6	135.3
1:00	106	126
2:00	94	116.3
3:00	83.3	105.3

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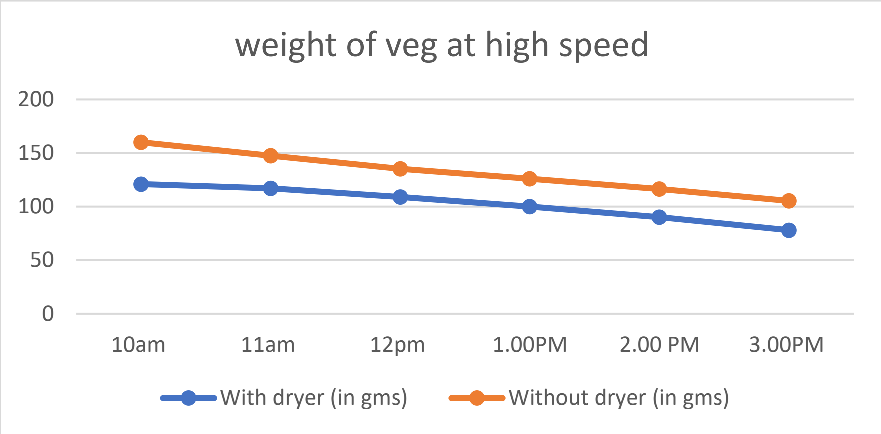

Fig 6 comparison weight of veg with and without dryer at high speed

Table:4 - Absolute humidity at Low speed

Timings	With out dryer	With dryer
10.00	3.8	2.05
11.00	4.9	1.98
12.00	6.03	2.98
13.00	8.5	3.47
14.00	10.11	4.96
15.00	12.48	5.02

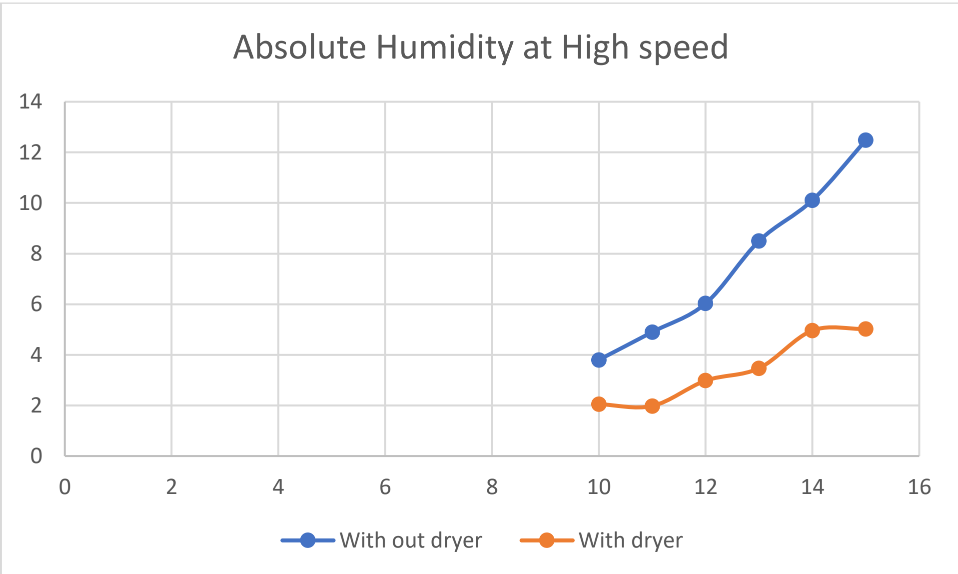

Fig:7- Comparison of Absolute humidity at low speed

Table 5: - Absolute humidity at High speed

Timings	With out dryer	With dryer
10	13.06	4.21
11	14.6	5.28
12	15.9	6.35
13	20.8	9.32
14	22	10.47
15	26.4	12.89

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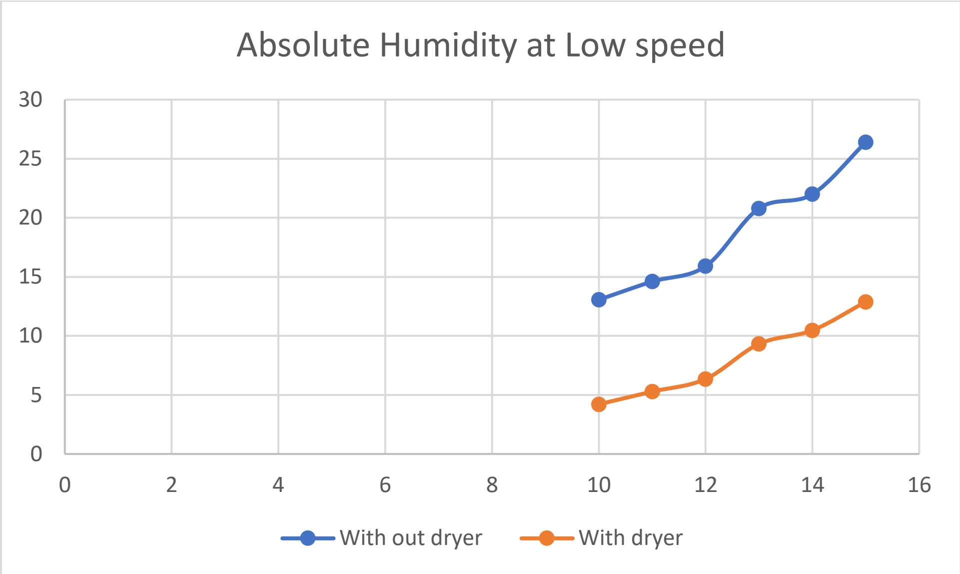

Fig:6- Comparison of Absolute humidity at High speed

Conclusion: - The tests were conducted, and the results led to the following findings.
The ambient air temperature can be greatly raised by the solar drier, speeding up the rate at which food products dry. When compared to products drying outside in the sun, products inside dryers require less upkeep due to factors like rain or pest (both human and animal). Additionally, the dryer may be employed to dry other varieties of produce, including grapes, pears, and green apples. Monitoring is simpler than the natural sun drying method. The system has a low initial investment cost and is powered by solar energy. Furthermore, a simple, low-cost solar drier was developed using materials that were readily available in the vicinity, as indicated by the test results. Green chillies and tomatoes were implemented in this investigation. Some tomatoes were desiccated, while others were allowed to dry naturally in the air. The moisture content of the tomatoes was subsequently compared in relation to temperature and time. According to the results of our experiment, the highest temperature that can be reached within the drying chamber is around two o'clock in the afternoon. On a day with full sunshine, the temperature ranges from roughly fifty-two to fifty-six degrees Celsius on average.
In a single day of uninterrupted sunlight and consistent weather conditions, the solar drying process was able to remove up to 45-55% of the moisture content from the drying chamber. This method is particularly effective for drying low moisture content food products. According to empirical evidence, individuals have the ability to construct personal solar dryers within their own residences, particularly in developing countries where there is a significant increase in energy demand. The efficiency of the solar dryer is sufficient, making it a viable alternative to freezing food. During periods of economic downturn, recessions can prove to be advantageous. The dryer has the capability to preserve food items for an extended period of time, preventing spoilage.
It has been observed that the dryer's air temperature ranges from 52 to 64 degrees Celsius. The dryer requires approximately five hours to reach this temperature. Based on observations, the drying process for food products can vary and may range from 3 to 7 days. By utilizing a solar air dryer, significant time savings can be achieved. The process of drying produce can be completed in a relatively short amount of time, typically around 3.5 - 4 hours.

- Depicts the initial stage of sun-drying tomatoes.
- The tomatoes are subjected to roughly 5 hours of sunlight between 10 AM and 3 PM.
- The initial weight of the tomatoes is around 200 grams, but after undergoing complete dehydration by sun drying, their weight reduces to about 72 grams. The tomatoes undergo a process of sun-drying for a duration of 5 hours on the third day as well.
- The moisture content has decreased by 89%.

References: -

1. Sushrut S.Halewadimath, Prajwal Subbhapurmath, Naveen Havaldar, Karthik
2. Hunashikatti, "Experimental analysis of solar dryer for agricultural products" 2015.
3. Amit Singh Rawat, Kuldeep Singh Rawat and Jitender Singh Uprari, "Designed and experimental analysis on direct natural convection soalr dryer to dry tapioca" 2015.
4. H.mortezapour, S.J. rashedi, H.R. Akhavan and H. Maghsoudi, "Experimental analysis of a solar dryer equipped with a novel heat recovery system for onion drying" 2017.
5. Debbarma et.al, (Moulana Azad National Institute of Technology) "Designed and developed a low- cost bamboo solar dryer to dry green chillies" 2016.

6. T. Somasekhar, M. V. Kishore, P. Naveen Kishore, "Design and development of Solar water heater to enhance Thermal Efficiency" in IJRASET, VOL10, Issue 12, Aug 2022.
7. P. Naveen Kishore, T. Somasekhar, "Design and Fabrication of MultiPurpose Agricultural Machine" in IJIRT, VOL9, Issue 4, Sep 2022.
8. P. Naveen Kishore, D. Linga Raju, "Experimental Investigation of changes in Microstructure FSW in AA6061/SiC/Coconut shell Ash MMC's" in Journal of Propulsion Technology, Vol 44 No.6 (2023).
9. T. SOMASEKHAR, M. V. Kishore, P. Naveen Kishore, Augmenting the Efficiency of PVT Solar Air Heater Using DC Blower and Transverse Ribs ISSN: 1001-4055 Vol. 45 No. 1 (2024)
10. Saxena, A., Varun, & El-Sebaii, A. A. (2015). A thermodynamic review of solar air heaters. Renewable and Sustainable Energy Reviews, 43, 863–890. doi: 10.1016/j.rser.2014.11.059
11. Abhishek Saxena and Varun Goel, Solar Air Heaters with Thermal Heat Storages, Chinese Journal of Engineering Volume 2013, Article ID 190279, 11 pages http://dx.doi.org/10.1155/2013/190279
12. Mario Palacio, Camilo Ramírez, Mauricio Carmona, Cristóbal Cortés, Effect of phase-change materials in the performance of a solar air heater, Solar Energy, 247, 2022, 385-396, https://doi.org/10.1016/j.solener.2022.10.046.