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Historical Trends and Recent Developments in Solar Greenhouse Dryer Operated Under Active Mode: A Review

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Abstract

Background/Objectives: Today the greenhouse drying technology has reached at a remarkable stage due to its tremendous contribution towards saving the agricultural products from spoilage. This has helped the whole world to progress at a fast rate as they are able to save a lot of conventional energy requirements which was being wasted earlier in food. The main objective of this paper is to provide a general idea of progress that has occurred in the field of active greenhouse solar dryer time to time. **Methods:** This paper focuses on some historical work in the field of active greenhouse drying and recent development in this field to improve the performance in terms of temperature and quality of the agricultural products. **Findings:** This review paper provides detailed and systematic information of research carried out in the field of solar greenhouse drying operated under forced convection mode. **Applications:** This review work not only provides the general reference to the researchers working in the same field but also helps to farmers for the possible modifications in the method of drying and further improvements in future.

Keywords: Convective Mass Transfer Coefficient, Forced Convection, Performance, Solar Greenhouse Dryer

1. Introduction

At present, the rapidly growing population throughout the world has imposed a huge gap between demand and supply of food. This problem though serious, can be solved either by increasing food supply or by controlling population growth or by both. Apart from these, the most suitable and practical solution may be the reduction in the food losses[1]. Agricultural products have the tendency to get spoiled during the post-harvest process[2,3]. The annual financial loss has been estimated to be approximately 104 million US dollar due to deficient handling and poor storage facility[4]. This loss mainly occurs due to the presence of moisture content which enhances the growth of bacteria and yeasts in them. These biological microorganisms support for spoilage attacks[5,6].

Drying is the process that plays an important role in restricting the microorganism growth by reducing the moisture content up to an optimum level[7]. Thus, it is essentially the best way to preserve the agricultural products from spoilage[8]. Solar drying process not only saves the crops but also maintain the original color, taste etc so that increase the market value of it. Due to above-mentioned advantages and need of drying process, small scaled dried food industries have grown up at a very fast rate all over the world to meet the domestic as well as international demands.

Various drying techniques can be categorized as solar drying, industrial drying and open sun drying. A device used for the purpose of solar drying is known as the solar dryer. Solar dryers can be classified as passive solar dryers and active solar dryers. Three sub-groups of active and passive solar dryers can also be identified: viz., direct mode, indirect mode, and the mixed-mode type as shown in Figure 1.

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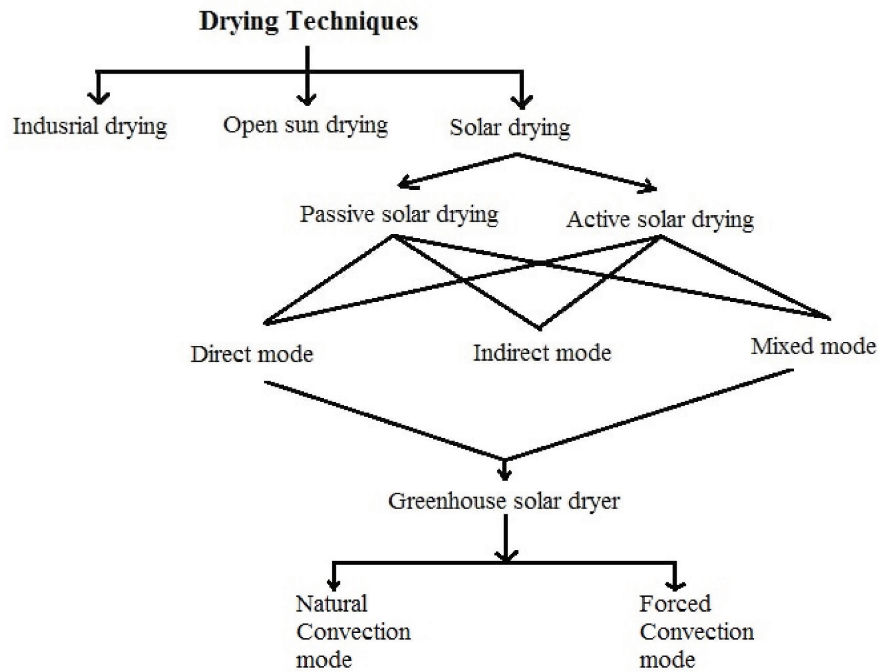


Figure 1. Classification of greenhouse solar dryer.

The greenhouse solar dryer basically comes under the category of direct solar drying and sometimes mixed mode solar drying system. Greenhouse is an enclosed structure which traps the solar radiation of shorter wavelength. Long wavelength solar radiation in the form of infrared radiation is emitted by earth's surface and gets stored inside the greenhouse increasing the greenhouse temperature. Greenhouse structure can be used to perform multitask including crop cultivation, soil solarisation, poultry farm, aquaculture etc. Low-temperature drying is ideal for vegetable and cash crop drying and it can be easily achieved in greenhouse structure. The solar greenhouse dryer can operate under natural convection mode and forced convection mode depending upon the moisture content of the product to be dried. Here in this paper variety of active solar greenhouse dryer constructed on the basis of structure, mode of convection, provision of auxiliary equipment etc have been discussed. The purpose of the discussion is to know the significance of active mode or specially constructed solar greenhouse dryer over others.

2. Researches on Greenhouse Solar Dryer under Forced/ Active Mode

In a solar dryer, convection plays a major role to transfer of heat and mass inside and outside of the chamber. Convection would be either natural or forced. The even span roof type solar greenhouse dryer is constructed at IIT Delhi, India[1]. The objective of this set-up is to evaluate the convective heat and mass transfer coefficient of jaggery. An even span roof type solar greenhouse dryer is operated under natural and forced convection mode. The greenhouse dryer oriented in east-west direction had an effective floor area of 1.2 m×0.8 m. The cover of dryer was made by UV film. An air vent of 0.043 m^2 areas was provided on the roof top to act as natural convection. Similarly, one fan was provided to produce force convection. Jaggery drying in a greenhouse under natural and forced convection mode is shown in Figure 2(a) and (b) respectively. The drying test was performed for 800 gm and 2000 gm of jaggery. It was finally observed that the drying of jaggery under forced convection mode was faster than the drying in natural convection mode.

(a) (b)

Figure 2. Jaggery drying in a greenhouse under (a) Natural convection mode (b) Forced convection mode.

The low cost forced convection solar tunnel dryer to dry red sweet pepper and garlic is built at North of Argentina[2]. A drying tunnel having the wooden frame of dimension 1.3 m×1.2 m×1.9 m was built inside the greenhouse. The greenhouse drier of the metallic structure had a dimension of 1.3 m×7 m×3.70 m. This structure is covered with 150°μm thick UV and infrared protected polyethylene plastic. Face view and plant view of the tunnel greenhouse drier is shown in Figure 3(a) and (b) respectively. Products placed in several trays were moved on carts inside the tunnel. Two fans, one near to input door and the other on the opposite side were provided in the tunnel ceiling to force the hot air from greenhouse to drying tunnel. Maximum temperature inside the dryer under no-load condition was 60 °C. Red sweet pepper with a longitudinal cutting took around three days to lose its moisture from 6 % to 0.15 % on dry basis. While, the moisture content of garlic was reduced from 2 % to 0.1 % on a dry basis in mean drying period of 3 days.

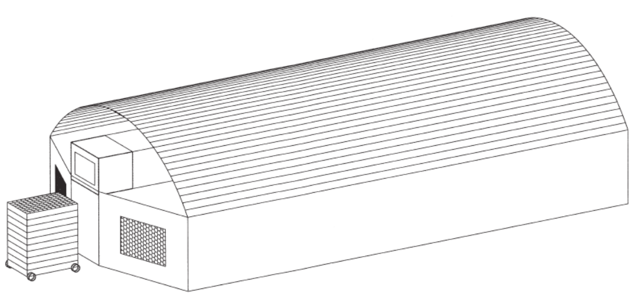


Figure 3(a). Face view of the tunnel greenhouse dryer.

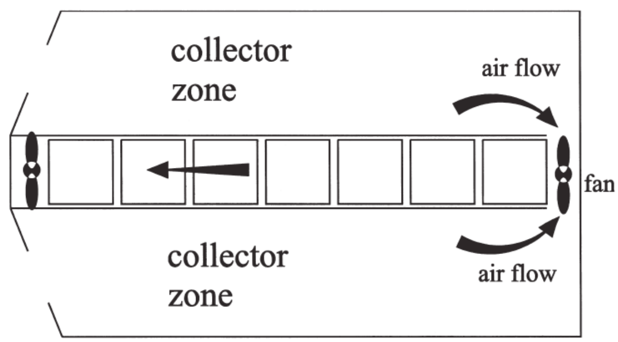


Figure 3(b). Plant view of the tunnel greenhouse dryer.

The mixed mode forced convection solar tunnel dryer installed at the Agricultural University[3]. Experiments have been performed to dry hot red and green chillies as per local environmental conditions. The dryer was 20 m long and 1.80 m wide. The solar tunnel dryer was composed of a flat plate solar air heating collector covered with plastic, a drying tunnel unit, 2 DC fans and a 40W photovoltaic module. The solar tunnel dryer with its component is shown in Figure 4. The dryer had the loading capacity of 80 kg. The moisture content of red chilli was reduced from 2.85 to 0.05 kg kg^{-1} db in 20 h while an improved and conventional sun drying took 32 h to reach to 0.09 and 0.40 kg kg^{-1} db of moisture content respectively. Similarly, in case of green chilli drying, the solar tunnel dryer took 22 h to reduce the moisture content from 7.6 to 0.06 kg kg^{-1} db while for improved and conventional sun drying methods the moisture content was

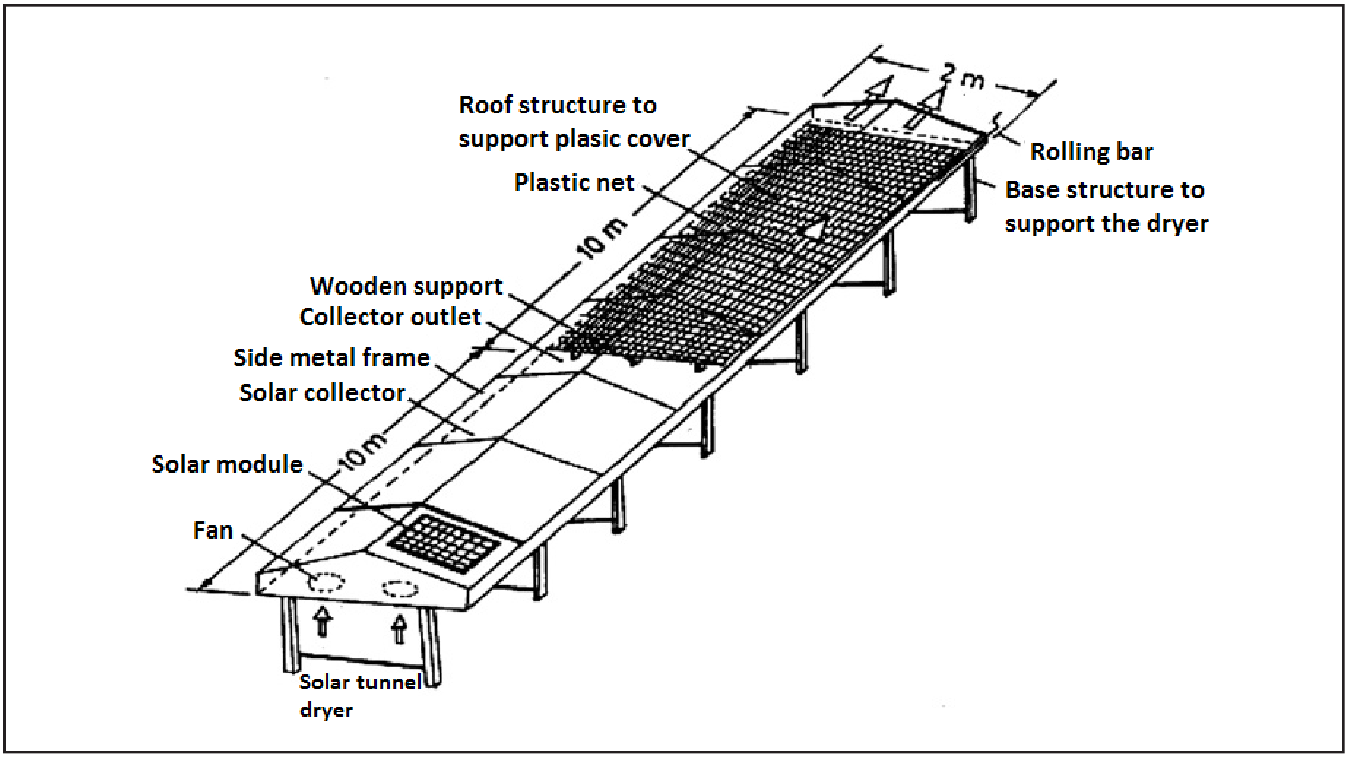


Figure 4. Solar tunnel dryer.

reduced to 0.10 and 0.70 kg kg¯1 db in 35 h respectively. Results show that pungency and colour are also maintained inside the dryer.

Two distinct experiments taking peppermint as a whole plant and peppermint as leaves were conducted at the Mechanization Centre of Meet El-Dyba, Kafr El-Sheikh Governorate Egypt[4]. The objective of the experiment is to evaluate the performance and drying kinetics of solar tunnel dryer. The dimension of each dryer was kept to be 2m×1m×0.8 m and covered with 200 mm thick transparent plastic film. Each dryer was provided with a fan to maintain air circulation rate of 2.10 m^3/min and a thermostat to maintain temperature of 50 °C or less. Solar tunnel greenhouse dryer is shown in Figure 5. When the greenhouse was loaded by 4 kg/m^2 and operated by continuous fan, it was found that the drying rate enhanced by 22.78 % and 24.8% whereas drying time reduced by 9 hrs and 8 hrs for the whole plant and leaves respectively.

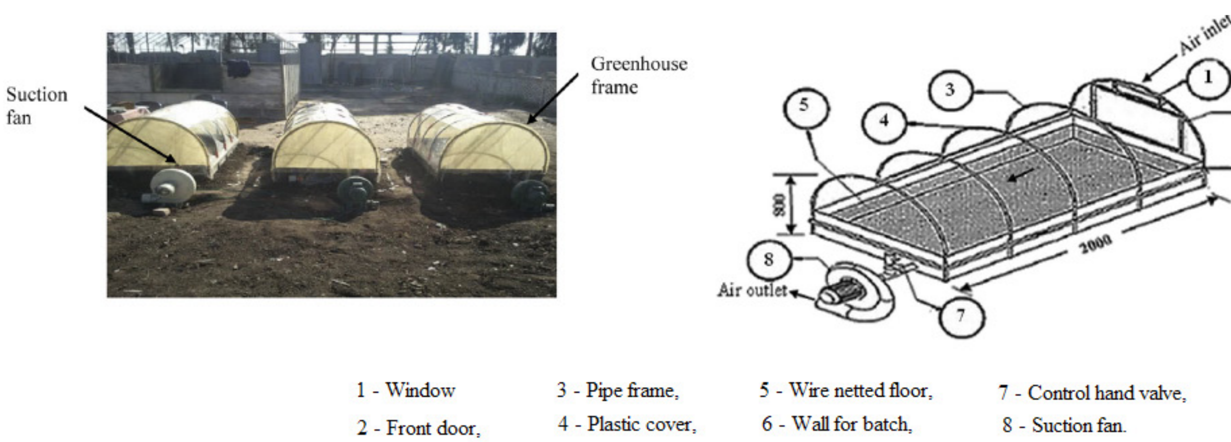


Figure 5. Solar tunnel greenhouse dryer.

An experiment for drying of onion flakes had performed to know the effect of convective mass transfer coefficient under open sun and greenhouse[5]. For this purpose, an even span roof type solar greenhouse dryer having an effective floor area of 1.2 m×0.78 m was installed at IIT Delhi, India. The greenhouse dryer was made up of PVC pipe and covered with UV film. An air vent of 0.0722 m² area on roof as well as a fan on the sidewall of greenhouse was provided to serve as natural convection and forced convection mode respectively. Onion drying in greenhouse under open sun and natural convection mode is shown in Figure 6(a) and under forced convection mode is shown in Figure 6(b) respectively. Three sets of experiments were performed taking quantities of onion flakes as 300 g, 600 g and 900 g for 33 h in each case. It was observed that the convective mass transfer coefficient has increased by 90 % and 135% as the mass of onion flakes was increased from 300 g to 900 g in case of open sun drying and greenhouse drying respectively under forced mode. However, the convective mass transfer coefficient was found to be reduced to 30% in case of the greenhouse drying under the natural mode. The result clearly shows a significant effect of mass on convective mass transfer coefficient for open sun as well as greenhouse drying.

A greenhouse solar dryer with special provision of photovoltaic is constructed at IIT Delhi[6]. The main objective of such design is to enhance the efficiency of greenhouse solar dryer. Therefore for predicting the performance of a greenhouse, energy-exergy analysis has been performed and compared the thermal model with experimental findings. Front view of PV integrated greenhouse is shown in Figure 7. The effective floor area of the greenhouse is 0.605 m². The greenhouse dryer contained two PV arrays each consisting of 8 PV modules. The modules were mounted on a wooden structure and this wooden structure was placed on a steel frame inclined at 45°. The energy efficiency was calculated to be approximately 4%.

To overcome the problem arises due tothe higher mass flow rate of air. The DC fan has been used in village scale forced convection greenhouse type solar dryer[7]. The dryer was constructed at Silpakorn University, Nakhon Pathom, Thailand for drying peeled longan and banana. The data obtained were compared with open sun drying. The structure of the greenhouse was of parabolic shape and made up of galvanized iron bars covered with polycarbonate plate. The dryer consists of 3 DC fans installed in the wall opposite to the air inlet. A pictorial view of the greenhouse solar dryer is shown in Figure 8. For 100 kg

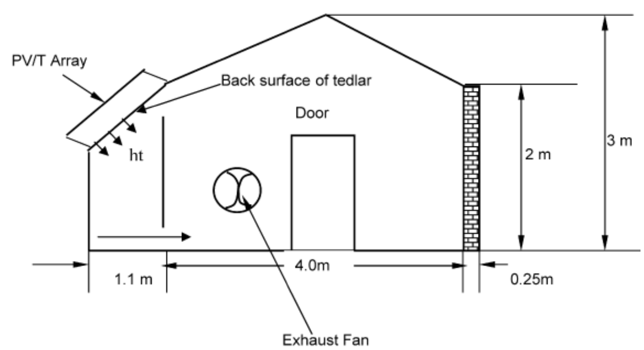
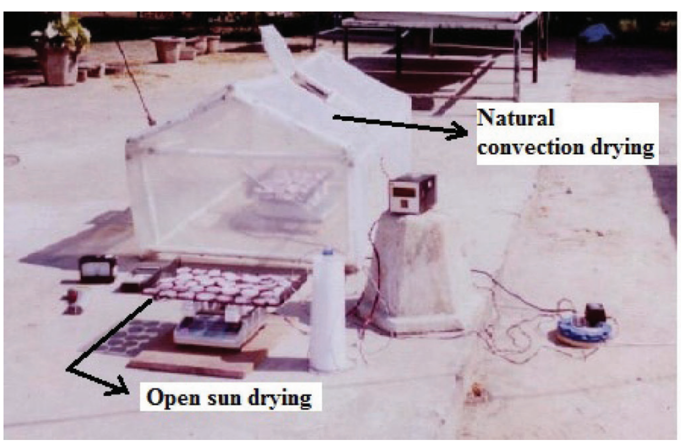
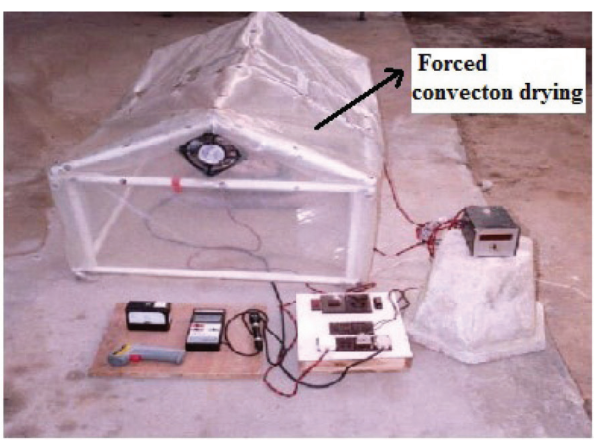


Figure 7. Front view of PV integrated greenhouse.



(a)



(b)

Figure 6. (a) Onion drying under open sun and natural convection mode in greenhouse (b) Onion drying under forced convection mode in greenhouse.

sample of each fruit, it was observed that moisture level of peeled longan from an initial value of 81 % wb reduced to the final value of 12% wb within 3 days in solar dryer whereas for the sun dried samples it reduced to 24% wb within the same time period. The moisture level of banana was found to be reduced from 70% wb to 24% wb within 4 days in the solar dryer and it reduced to 32% wb within the same period under open sun drying.

Special kind of parabolic shaped large scale greenhouse solar dryer used for rainy region is designed and developed at Champasak in Lao People's Democratic Republic[8]. The dimension of the greenhouse dryer was 20 m×7.5 m × 3.5 m having a black concrete floor. The dryer was covered with 6 mm thick polycarbonate sheet. For the circulation of air in the structure, 9 DC fans have been used. A pictorial view of the solar greenhouse dryer is shown in Figure 9. The greenhouse dryer was tested for 1000 kg of Banana, 200 kg of coffee and 300 kg of chilli having an initial moisture content of 68%, 52% and 75% respectively. The products were dried to a final moisture content of 20%, 13% and 15% within 5 days, 2 days and 3 days respectively. While the products dried to the same final moisture within 7 days, 4 days and 5 days in open sun drying respectively. The dryer gave the good quality product in less time and proved to be well suited for local environmental conditions.

Figure 9. Pictorial view of the solar greenhouse dryer.

Figure 8. Pictorial view of the greenhouse solar dryer.

After time period same hybrid Photo-Voltaic-Thermal (PV/T) greenhouse dryer was used to evaluate the convective mass transfer coefficient of 100 kg Thompson seedless grapes[9]. The greenhouse dryer had a floor area of 2.50 m×2.60 m×1.80 m. The roof of UV stabilized polyethylene sheet was inclined at an angle of 30°. Photographic view of hybrid PV/T dryer is shown in Figure 10. It has been found that the value of the convective heat transfer coefficient for grapes (GR-I) lies between 0.26 - 0.31 W/m² K for greenhouse and 0.34 - 0.40 W/m² K for open conditions respectively. While for grapes (GR-II) lies between 0.45 - 1.21 W/m² K for greenhouse and 0.46 - 0.97 W/m² K for open conditions respectively.

To maintain the uniform drying, continuous sun light is very important. It has been observed that mounted solar panels affect the capital cost of solar air heater as compared to conventional. Therefore roof mounted solar green house panel has installed at SuanPhoeng Educational Park, Ratchaburi, Thailand for drying of rosella flower and chilli as per international standards[10]. Use of this dryer not only reduces the drying time but also the quality of the product in terms of colour and taste will increase. The solar dryer having a dimension of 12m×9m×2.5m consisted of a solar collector covered with polycarbonate plate and an axial flow fan driven by an electric motor motor of 0.373 kW. Roof-integrated solar drying system is shown in Figure 11. The deep drying bin is provided to place 200 kg of samples for each experimental. The results obtained showed that moisture content of rosella flower reduced from an initial value of 90% (wb) to the final value of 18% (wb) within 3 days. While for chilli, moisture content gets reduced from initial value of 80% (wb) to the final value of 18% (wb) within 3 days.

Figure 10. Hybrid photovoltaic-thermal dryer.

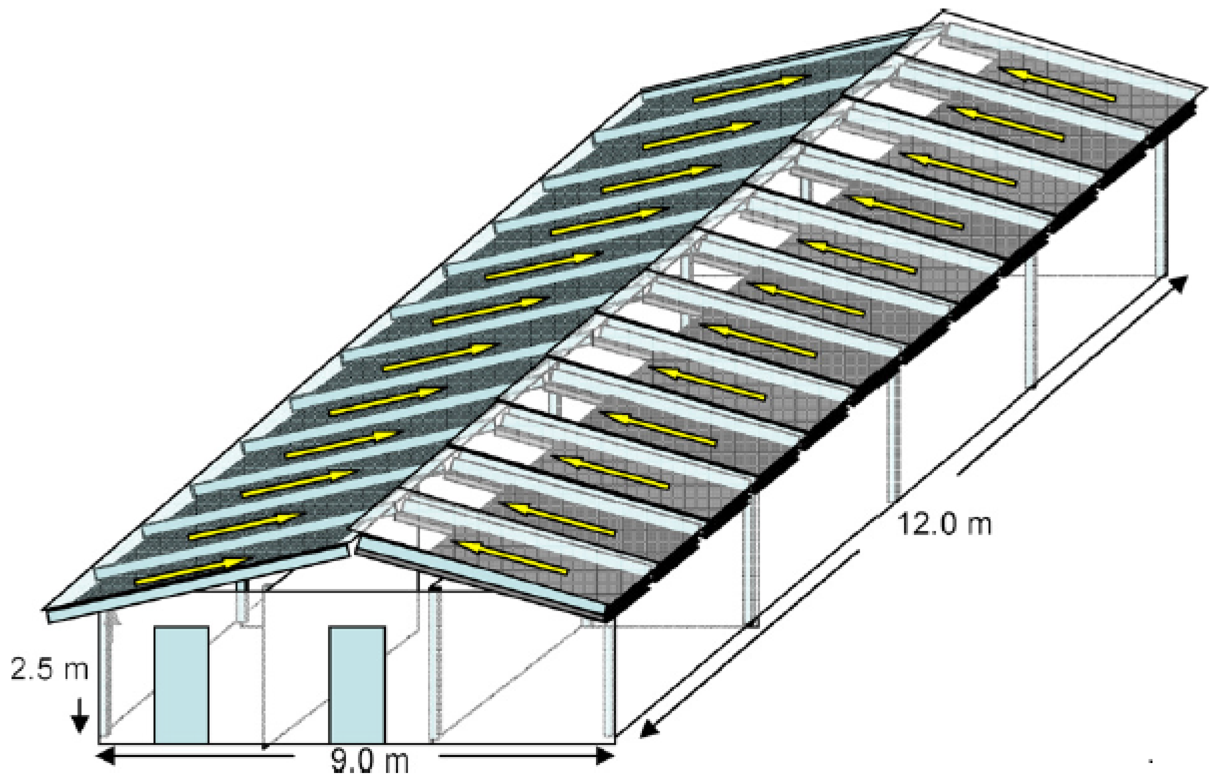


Figure 11. Roof-integrated solar drying system.

The newly designed single slope roof type PV/T greenhouse solar dryer installed at top of wind tower of SODHA BERS' complex, New Delhi, India[11]. The objective of the study is to found the optimum number of fans and developed the characteristic curves. The greenhouse dryer was made up of alumnium frame in which 5 mm thick glass was fitted using rubber gasket and had an effective area of 1.2m×0.54m. A pictorial view of the PVT greenhouse dryer is shown in Figure 12. The dryer consist eight semi-transparent PV modules each of 35 W powers connected in series and four fans. Results show that three optimized fans give better results.

Figure 12. East pictorial view of the PVT greenhouse dryer.

The hybrid solar green house dryer which can work in adverse rainy and cloudy days was designed, developed and installed at Nakhon Pathom in Thailand to dry osmotically dehydrated tomatoes[12]. The dryer had the extra provision of 100 kW-LPG gas burner to ensure a steady supply of hot air even in cloudy and rainy days. The dryer was constructed on a concrete floor and had a dimension of 20 m×8 m×3.5 m. The structure of the greenhouse dryer was parabolic roof type covered with polycarbonate sheet. Total nine fans have been used to maintain air flow. A pictorial view of the large-scale solar greenhouse dryer with LPG burner is shown in Figure 13. The drying temperature inside the greenhouse varied from 35 °C to 65 °C during the experiment. The osmotically dehydrated tomato with an initial moisture content of 54% wb was dried to final moisture content of 17% wb within 4 days whereas the same sample was dried to 29% wb within the same time period under open sun drying.

Further, modification has been done in same greenhouse solar dryer[13]. In which concrete floor has been used to obtain the higher heat gain and to reduce the drying time inside greenhouse solar dryer. Schematic diagram of the large-scale polycarbonate cover greenhouse solar dryer is shown in Figure 14. Three batches of chilli having 500 kg in each batch were found to be dried from an initial moisture content of 74% wb to a final value of 9% wb within 3 days in each case. The same sample was dried to a final value of 66% wb in natural sun drying within 3 days.

The performance of active and passive mode even span roof type greenhouse dryers has been evaluated under no load condition[14]. Even span roof type greenhouse dryer has effective floor area 1.50m×1.01m. The greenhouse dryer covered with polycarbonate sheet of thickness 3 mm consist of 2 vents at the bottom and 1 at the roof for inlet air circulation and moisture removal respectively. The solar greenhouse dryer under active mode and passive mode is shown in Figure 15(a) and (b) respectively. It was finally observed that maximum inside temperature in natural convection was 40.6 °C and maximum inside temperature for forced convection was 41.4 °C. The maximum relative humidity in natural convection was found to be 62.6 % and maximum relative humidity for forced convection was found to be 42.8%. These conditions sufficiently proved that forced convection was efficient than natural convection by 31%.

Figure 13. Pictorial view of the large-scale solar greenhouse dryer with LPG burner.

Figure 14. Schematic diagram of the large-scale polycarbonate cover greenhouse solar dryer with concrete floor.

(a) (b)

Figure 15. Solar greenhouse dryer under (a) Natural convection mode (b) Forced convection mode.

Other active mode roof type even span greenhouse solar dryer was installed at Guru Jambheshwar University of Science and Technology[15]. The greenhouse dryer fabricated with PVC pipe had an effective floor area of 1.2m×0.8m. The greenhouse dryer covered with a UV Cover of 200 microns consist a fan with a rated air velocity of 5 m/s on the sidewall of the greenhouse dryer. Experimental Set-up of greenhouse papad drying under forced Convection mode is shown in Figure 16. The average values of convective and evaporative heat transfer coefficients under forced mode were found to be 0.759 W/m^2 and 23.48 W/m^2 respectively.

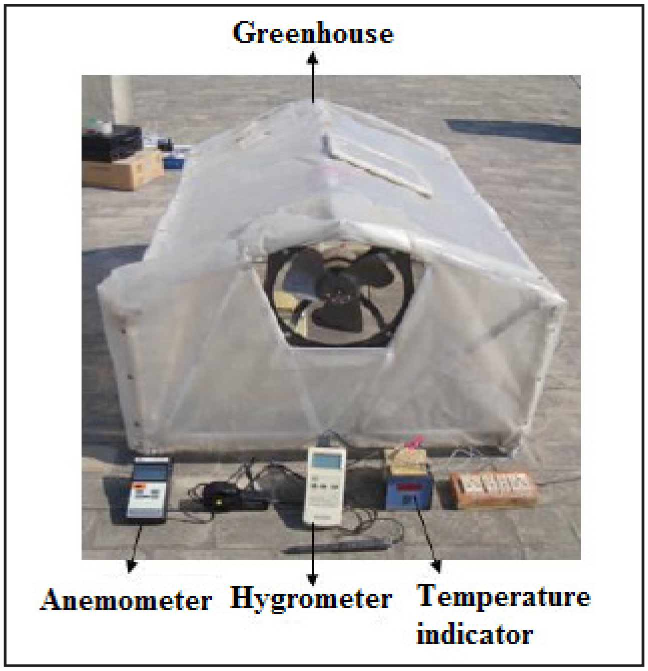
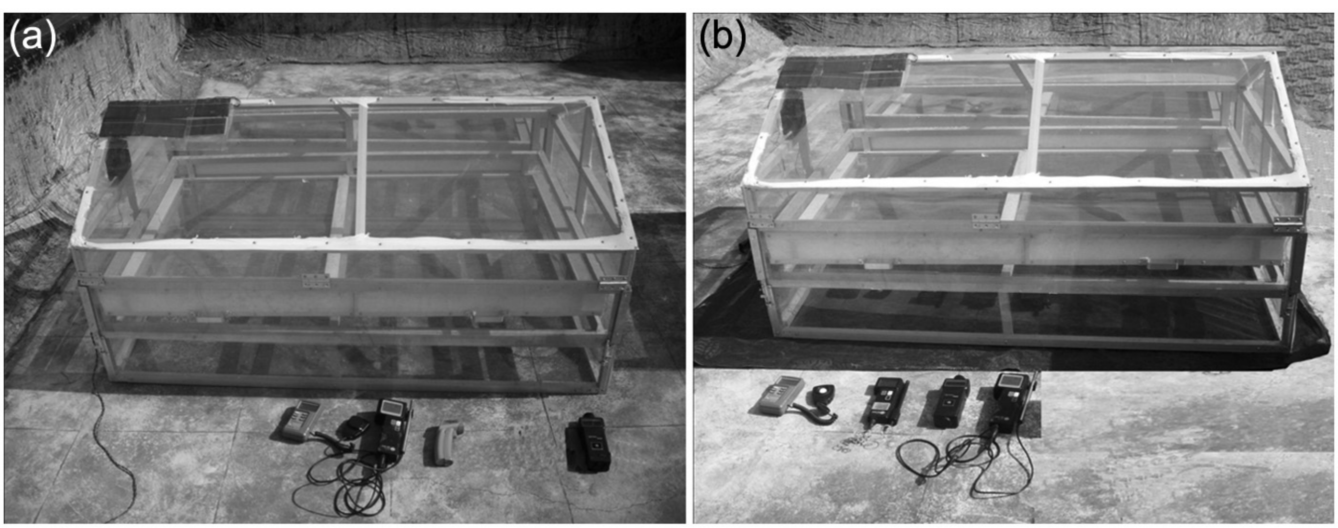


Figure 16. Experimental Set-up of Greenhouse papad drying under forced convection mode.

The researchers also used black PVC sheet on the floor and mirror in the north wall to reduce the heat losses and creating more suitable atmosphere for drying. For this purpose a roof type even span greenhouse solar dryer was designed, developed and tested under no-load at Maulana Azad National Institute of Technology, Bhopal, India[16]. The greenhouse dryer fabricated of PVC pipe had an effective floor area of 1.50m×1m×0.5m. The dryer was covered with polycarbonate sheet of 3 mm thickness and mirror was provided on its north wall. The greenhouse dryer was tested for two variants, one with an uncovered floor and the second with covered floor area by PVC black sheet. Experimental setup of modified active greenhouse dryer without covered floor conditions and with covered floor conditions is shown in Figure 17 (a) and (b) respectively. It was finally observed that due to application of black PVC sheet on the floor of greenhouse and mirror in the north wall, the heat gain and inside room temperature was increased and relative humidity decreased. Further experiment on this greenhouse solar dryer shows that opaque north wall is helpful to reduce the drying time inside greenhouse chamber[17,18].

If cost is not barrier then by using extra auxiliary equipment will helpful to reduce the drying time. The study was conducted in the laboratory of Department of Bio-system and Mechanical Engineering, Bogor, Indonesia to dry wild ginger inside the rack type solar greenhouse dryer[19]. The greenhouse dryer consisted of four blowers, burner, and cross-flow heat exchanger and was equipped with biomass fuel combustion stove to constantly supply the heat even in the cloudy and rainy condition. The rack type greenhouse-effect solar dryer is shown in Figure 18. Three conditions of drying experiment were carried out namely: 1. empty condition, 2. drying of 21 kg sliced wild ginger, and 3. drying of 60 kg of sliced wild ginger. The best drying performance was obtained for 60 kg sliced wild ginger at 47.2 °C and 30 hours that represented a drying efficiency of 8%.



(a) (b)

Figure 17. (a) Experimental setup of modified active greenhouse dryer under without covered floor conditions and (b) Schematic diagram of modified greenhouse dryer with covered inside floor.

Figure 18. Rack type greenhouse-effect solar dryer.

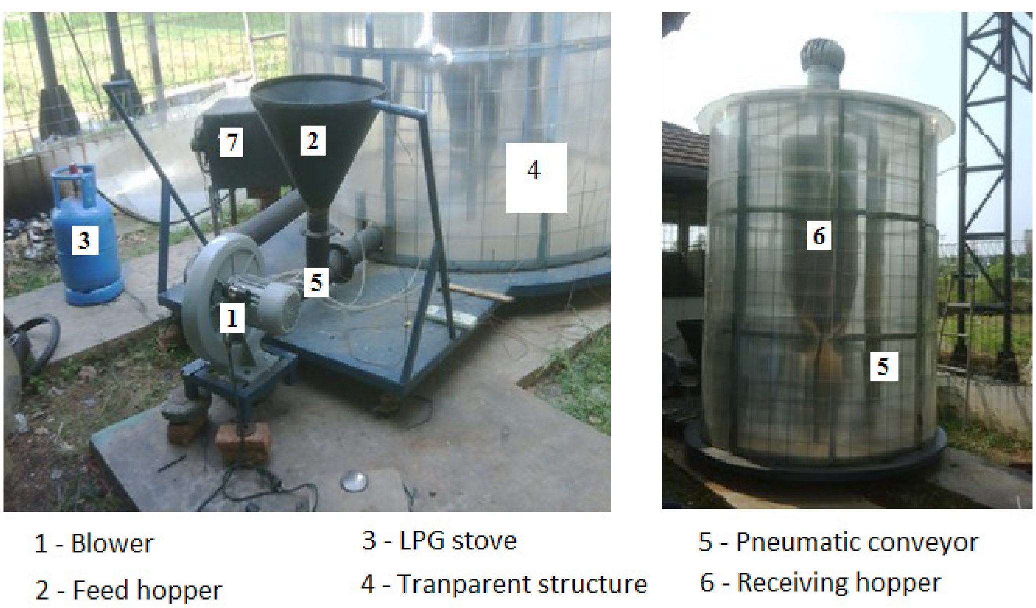
The Hybrid solar-biomass is constructed and evaluated at Asian Institute of Technology[20]. The constructed solar-biomass hybrid tunnel dryer is shown in Figure 19. The prototype of the solar-biomass dryer consist of a drying tunnel of length 4.25 m. Flat plate solar collector of length 4 m is integrated with the dryer to enhance the thermal efficiency. A glass wool of 4 cm thickness as well as a UV stabilized polyethylene sheet of 0.2 mm thickness was used to create insulation and glazing respectively. Five high-speed AC fans having capacity 14 W each was used to produce forced convection. Total 19.5 kg of fresh ripe chillies have been taken inside hybrid-biomass solar dryer for experimental purpose. Drying time to convert ripe fresh chillies from initial moisture content 76 % (wb) to final moisture content 6.6% (wb) in 12 hours. Similarly, mushrooms were also dried inside solar-biomass hybrid tunnel dryer. Experimental results show that drying time to convert 21 kg of mushroom from initial moisture content 91.4% to 9.8% is 12 hours.

Figure 19. Solar-biomass hybrid tunnel dryer.

The efficiency of solar greenhouse dryer is also increased by coupling it with solar air heater[21]. The new type of solar greenhouse dryer installed at the Research and Technology, Centre of Energy (CRTEn) in BorjCedria, North of Tunisia. The study was done to compare thin layer drying characteristics of sultana grape and red pepper under greenhouse and open sun conditions. The setup was comprised of two parts, 1. a flat plate solar air collector of dimension 2 m × 1 m inclined at 37° to horizontal plane and 2. an experimental east - west oriented chapel shaped greenhouse dryer having a dimension of 4m×3.7m×3m. The dryer was covered with Plexiglas of 3 mm thickness and consists of two centrifugal fans. A pictorial view of the solar greenhouse dryer is shown in Figure 20. The experiment was performed using 80 kg of peppers and 130 kg of grapes. The moisture content of red pepper was reduced from an initial value of 12.15 (g water /g dry matter) to a final moisture content of 0.17 (g water /g dry matter) within 17h in greenhouse solar drying, whereas open sun drying takes 24 h. The moisture content of Sultana grape was reduced to 0.22 (g water /g dry matter) from an initial value of 5.49 (g water /g dry) within 50 h in greenhouse solar dryer whereas it was dried to 0.23 (g water /g dry) in open sun drying.

Figure 20. Pictorial view of the solar greenhouse dryer.

Recirculation type integrated collector drying chamber solar dryer designed and constructed for drying rough rice[22]. Experimental set up showing major components of solar dryer and transparent structure of pneumatic conveyor and receiving hopper is shown in Figure 21(a) and (b) respectively. The experiment was performed under two different loads. In first case with a load of 104 kg of rough rice the moisture content was reduced from 28.4% to 14.3% within 5 hrs at a drying air temperature of 50 °C which showed an efficiency of 23.6%. While in the second case with a load of 200 kg of rough rice the moisture content reduced from 27.3% to 14.6% within 8 hrs showing an efficiency of 35.7% under drying air temperature of 47 °C.



(a) (b)

Figure 21. (a) Experimental set up showing major components of solar dryer; (b) Transparent structure showing pneumatic conveyor and receiving hopper.

Two greenhouse dryer: 1. Parabolic greenhouse (PG's), and 2. Parabolic Greenhouse with additional area-Enhanced Panels (PGEP) is design and developed to evaluate the thermal efficiency[23]. The greenhouse was installed in Rajmangala University of Technology Tawan – Ok in Chonburi, Thailand. The parabolic shaped greenhouse structure was having the dimension of 3.5×2×1.5m³ which could be reshaped into second structure of 3.5×3×1.5 m³. Transparent polycarbonate sheet was used as cover for greenhouse. Greenhouse was constructed on a concrete base covered with plastic sheet and consist 20 watt electric fan on the rear wall. Tests under no load as well as load conditions were performed. Photograph of parabolic greenhouse and new designed parabolic greenhouse with the additional solar collecting panels is shown in Figure 22(a) and (b) respectively. Total 40 rubber sheets were taken for the experiments which helped to show that air temperature inside the PGEP was 5 °C higher than PG's. The modification of enhancing the area proved out to be best with respect to more heat gain, less drying time and higher thermal efficiency for PGEP.

(a) (b)

Figure 22. (a) Parabolic greenhouse (b) New design parabolic greenhouse with the additional solar collecting panels.

Mixed mode type hybrid PVT greenhouse solar dryer is designed and developed as per the climatic condition of IIT New Delhi, India[24]. Photograph of photovoltaic integrated the greenhouse dryer is shown in Figure 23. The greenhouse dryer was made up of alumnium frame and had a floor area of 1.025m×1.04m. A glass of 3 mm thickness was fitted to the structural frame of the greenhouse with the help of rubber gasket. The greenhouse solar dryer was provided with a clearance of 0.1 m height at bottom for fresh air circulation and 2 DC fans to serve as natural as well as forced convection mode respectively. Results shows that the developed greenhouse solar dryer was best suited for red pepper and sultana grapes.

Figure 23. Photograph of photovoltaic integrated greenhouse dryer.

Novel designed of solar dryer consists of the evacuated tube connected in series, blower, electric heater, and pump and drying chamber. The setup is designed for salted catfish in Perlis, Malaysia[25]. Photograph of greenhouse solar dryer with heat exchanger is shown in Figure 24. Drying experiment has been done on 200 kg salted catfish divided equally and placed on 8 trays with the drying temperature fixed at 50 °C. The dryer reduced the moisture content from 73% (wb) to 30% (wb) within 18 h. The moisture extraction rate and specific moisture extraction rate obtained to be 6.3 kg/h and 0.385 kg/kWh respectively. The values for exergy efficiency varied between 29% and 82% with an average of 46%.

Figure 24. Photograph of greenhouse solar dryer with heat exchanger.

3. Conclusion

This paper presents a review on the solar greenhouse dryers operated under forced mode with different modifications made time to time. Based on the different researches and studies following outcomes have been drawn:

- Forced convection dryers are best suited for high moisture content crops whereas natural convection is best for low moisture content crops.
- PV/T integrated greenhouse can be frequently used in villages without any fear of electricity grid as electricity is produced and utilized by itself.
- Creating greenhouse effect by greenhouse structures to dry the agricultural produce gave the best quality of dried products as compared to open sun drying.
- Greenhouse structures with thermal energy storage and opaque north wall was found to be best modification to reduce heat loss as well as to increase the temperature inside greenhouse structure.

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