



Article Title: A Review on Solar Dehydration System with Energy Storing Material

A Review on Solar Dehydration System with Energy Storing Material

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ABSTRACT

Solar energy is one of the most important renewable energy which is freely available energy from the sun. As this energy is freely available there is growth for solar industries on global level. But the main challenge faced by the solar industries is the efficiency of the solar application. Solar Dehydration system or dryer is one the new emerging application in solar field. This system is used to remove moisture content from various agricultural products over conventional sun drying method. Use of axillary heating source is must to use solar dryer after the sunset. Therefore we can use phase change materials (PCM) to store the heat energy which can be used after sunset. For any solar application the overall performance or efficiency is approximately equal to 15-18%. Therefore to increase the efficiency by maximum utilization of the solar energy we can adopt the latest technologies like internet of things (IoT) software solution. To enhance the efficiency we can use the new technologies like internet of things (IoT), artificial intelligence (AI), machine learning (ML), etc. Smart sensors are used to monitor the different parameters like temperature, humidity, etc. which will help to get the data when the system is mounted at remote location and the data can be viewed at any location by the user.

Keywords: Solar Dryer or dehydration system, Phase Change Material (PCM), Internet of Things (IoT), Sensors.

1 Introduction

Now a days we are more dependent on fossil fuels for heat and power. We are using them much rapidly than they are being produced and the time comes when these energy sources will run out. As these energy has also some disadvantages like waste disposal problem, environmental hazardous, limited quantity leads to think about renewable energy sources which can able to help the fill the gap. We may call renewable energy as “green” or “clean” energy as it produces very little pollution to the atmosphere.

The process of solar dehydration is an efficient way of utilizing solar energy in the drying process. In the solar dehydration process, the products are dried in an enclosed space or in a drying cabinet at an elevated temperature [3]. The main objective of solar drying is to supply more heat to the products than it is available under the normal sun drying condition. In the solar dryer, the product is dried at the high temperature and low relative humidity compared to the open sun drying for the same solar radiation intensity [5]. The high temperature increases the



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vapour pressure of the moisture content of the product sufficiently and also reduces the drying air relative humidity resulting in high drying rate and the moisture carrying capacity of the drying air [33].

The daily and seasonal fluctuations in the solar radiation, rainy days, and night period affect the drying operation in the solar dryer and thus its reliability. In the solar drying process also, sometimes products spoil due to unavailability of the solar radiation for several consecutive days and get affected by microbial organisms during the drying process itself. Besides, the high temperature during the peak - sunshine hours causes hardening, shrinkage, and burning of the surface of the products in the solar dryer. The hybridization of the solar dryer, where the conventional energy sources like electrical heater, biogas burner, LPG, etc. or thermal energy storages are integrated into the dryer unit, eliminates these problems. [1, 4, 8, 9]

Infrared radiation can be used for grape drying purpose. It is unique process and distinctly different from conventional or natural drying. The infrared radiations accelerate drying process with a better control to achieve uniform drying, reduced drying time and ultimately improved product quality. Besides, it requires less floor space and compact system are the additional advantages. [7, 10, 25].

Solar Dehydration System [28]

Solar dryers or dehydration system are available during a range of size and style and are used for drying of varied agricultural products. Various sorts of Dryers are available within the market as per requirement of farmers. Primarily all the drying systems are classified on the idea of their operating temperature ranges that's heat solar dryer and coldness Solar dryer.

Following criteria's are required for the classification of solar dryer:-

- 1) Air movement mode
- 2) Insulation exposure
- 3) Air flow direction
- 4) Dryer arrangement
- 5) Solar contribution
- 6) Type of fruit to be dried



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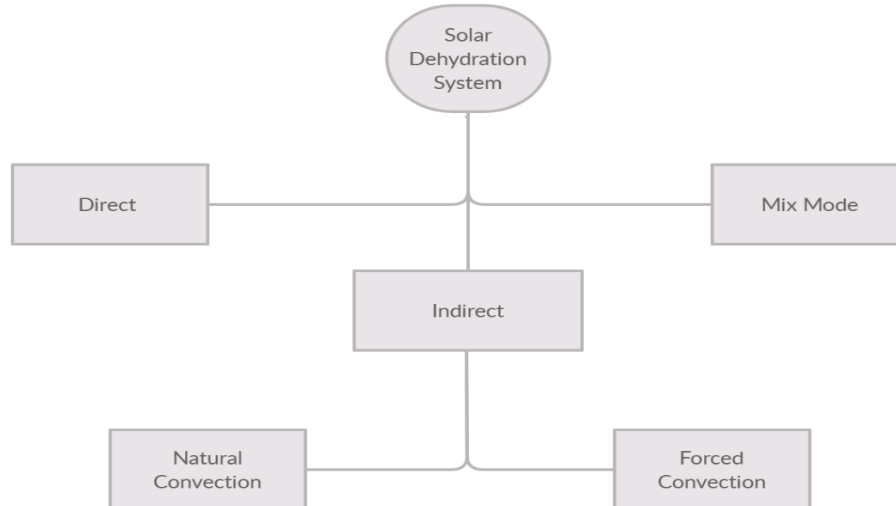


Figure: 1. Types of Solar Dehydration System (11, 15, 19)

1.1 Direct Solar Dryer

It is a type of dryer in which solar radiation is directly absorbed by the product to be dried. It is also called as natural convection cabinet dryer since the solar radiation is directly fall on the product, the quality of product is reduced. This dryer comprises of a drying chamber that is covered by a transparent cover made of glass or plastic.

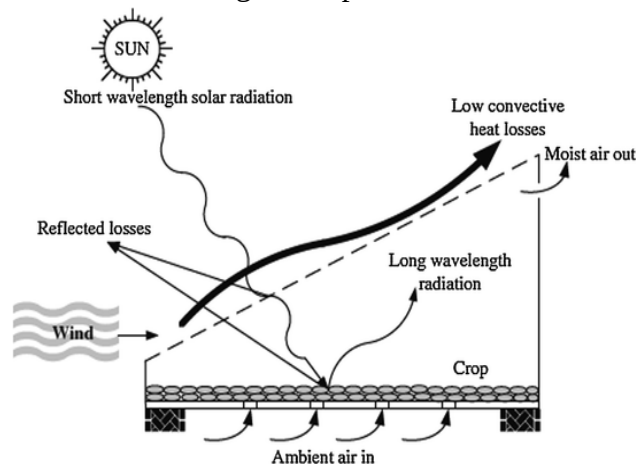


Figure: 2 Direct Solar Dryer

1.2 Indirect Solar Dryer

The solar radiation gained by the system is used to heat the air which flows through the agricultural or meat product to be dried in this dryer. In this type of dryer quality of product improved though drying rate increased. Heated air is blown through the drying chamber by means of natural or forced convection or by both. At the top of drying chamber vents are



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provide through which moisture is removed. In indirect type of solar drying systems a better control over drying is achieved. Fig. shows principle of indirect solar drying. Indirect solar dryer is also called as conventional dryer.

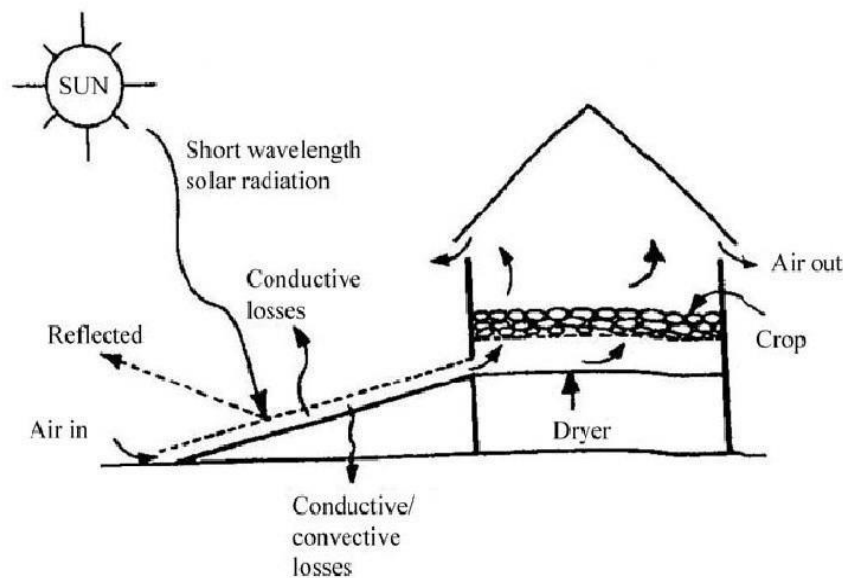


Figure: 3 *Indirect Solar Dryer or Conventional Dryer*

Indirect solar dryers are further classified as [41]

- a) Active Indirect Solar Dryer- This type of dryer works on natural convection only.
- b) Passive Indirect Solar Dryer- This type of dryer works on both natural and forced convection system for air movement through collector and drying chamber.

1.3 Mixed Mode Solar Dryer

In the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a drying chamber, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or roof. It is a combination of direct and indirect solar dryer. It's a passive type of solar dryer. In this dryer direct and indirect solar drying done simultaneously. Outcome of mix mode is very high and this is more effective type of solar dryer.



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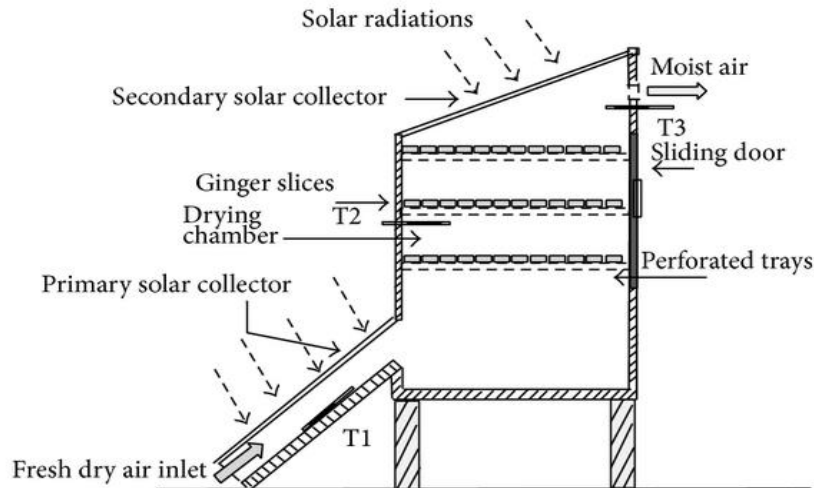


Figure: 4 Mixed Mode Solar Dryer

2 Solar Dehydration System with Energy Storing Material

Energy storage is a key issue to be taken into consideration to allow alternate energy sources, typically renewable sources, to match energy supply with demand [4]. There are various number of storage technologies that are capable of storing energy in different forms including kinetic energy, chemical solutions, magnetic fields, or other novel approaches.[8]

Different Energy Storage system can be coupled with existing solar dehydration system to enhance efficiency and to utilize maximum sun's energy so that the dryer can be used after the sunset or even at the night time.

These Different Energy storage System are listed below

- a) Thermal Energy Storage
- b) Phase change Materials (PCM)
- c) Biomass heater
- d) Auxiliary heating source like heater, etc.
- e) LPG as heating element

There are three types of Thermal energy storage systems are Sensible heat storage, Latent heat storage; and Thermo-chemical storage. In sensible heat storage (SHS) the amount of energy is stored by the material is by raising the temperature of a solid or liquid is called sensible heat storage. Which can use the heat capacity and change in temperature of the material during the process of charging or discharging [30, 6, 8]. Latent heat storage (LHS) uses the phase change of the materials. The heat is absorbed or released when the storage material undergoes a change of one phase from solid to other liquid phase, liquid to gas at more or less constant temperature. The materials used for the latent heat storage are called phase change materials (PCM).



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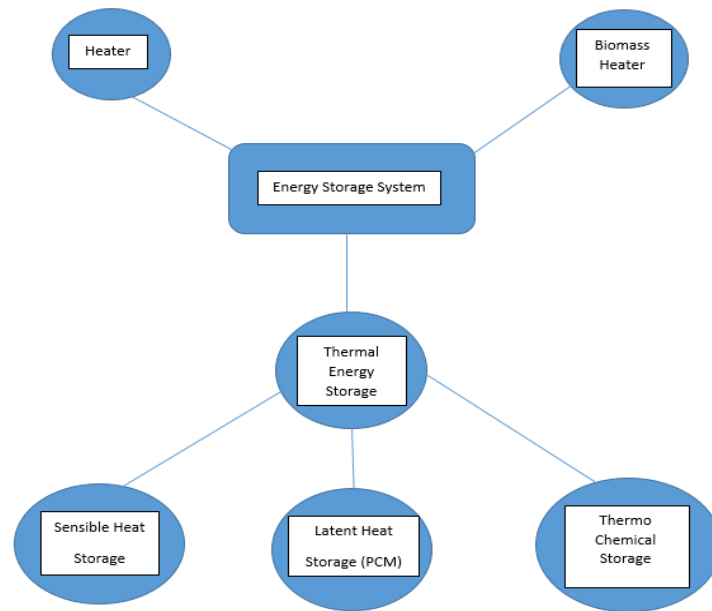


Figure: 5 Energy storage system [4, 8, 30, 33]

3 Phase Change Materials (PCM)

A usual problem in solar drying and various other industrial processes is that the existing gap between the amount of thermal energy availability and its time of usage. This situation creates the necessity for an efficient method by which excess heat can be stored for later use. Latent heat thermal energy storage (LHTES) is one among the foremost efficient ways of storing thermal energy through which the disparity between energy production or availability and consumption can be corrected, thus avoiding wastage and increasing the process efficiency. [15]

The following phase change material (PCM) properties to be used for latent heat storage were highlighted as desirable [8]

1. High value of the heat of fusion and specific heat per unit volume and weight,
2. Melting point which matches the application,
3. Low vapour pressure (1 bar) at the operational temperature,
4. Chemical stability and non-corrosiveness,
5. PCM should not be hazardous, highly inflammable or poisonous,
6. PCM should have a reproducible crystallisation without degradation,
7. PCM should have a small super cooling degree and high rate of crystal growth,
8. PCM should have a small volume variation during solidification,
9. High thermal conductivity,
10. PCM should be of abundant supply and at a low cost



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4 Internet of Things (IoT) in Solar Dryer

The internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, etc. that are provided with unique identification number and which has ability to transfer data over a network without human to human interaction.[42]

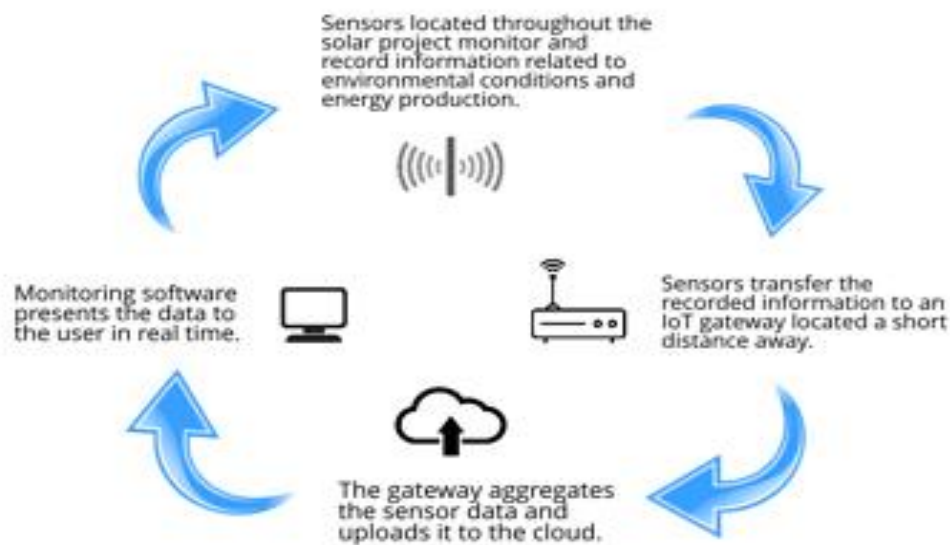


Figure: 6 Working of IoT system

Different kinds of sensors used in the solar dehydration system so as to get the data over a network to the user are as follows:

- Humidity sensor –Humidity sensors senses the humidity of the drying environment
- Temperature sensor –It will sense the inlet and outlet temperature of the product and air.
- Moisture sensor-It will sense the final and initial moisture and hence one can compare with the pre-desired moisture level.
- Colour sensor- It will give you colour coordinates that will help in sorting by colour.
- Proximity sensor- Use for metal detection, if accidentally came from the farm, from wearing and tearing of the equipment used in processes, or from any other sources.

5 Wi-Fi Module

It is used as a way of communication between two devices. The data recorded is sent to the Ethernet or controlling network because of this user will get the necessary information at one place.



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Various sensors like thermocouple, airflow meter, humidity sensor are installed inside the cabin to monitor and control the various conditions like temperature and airflow in the cabin. A central computer Arduino or raspberry is used to maintain the temperature. The real time data can be sent and monitored using a smartphone remotely using IOT (Internet of things).

6 Conclusion

- Solar dryers are closed chamber which are capable of removing moisture from a product naturally.
- An optimal design of solar dryer converting the input into effective output is under recent study by many researchers.
- Conversion rate and time taken to dry food product by a solar dryer depends on area occupied by it.
- Performance of solar dryer can also be increased by integrating its input with output of various thermal devices like A/C, solar air heater, etc.
- Artificial intelligence based performance predictions of solar dryers are identified as trending research gap.
- Introduction of IOT in to the field of solar dryers is expected to have increased performance in comparison to manual mode of operation.

References

1. C V Papade; M A Boda, Year: 2014, "Design & Development of Indirect Type Solar Dryer with Energy Storing Material", International Journal of Innovative Research in Advanced Engineering (IJIRAE), Vol: 1, no: 12, pp. 2349-2163.
2. L R Dhumne; V H Bipte; Prof. Y M Jibhkate, Year: 2015, "Solar Dryers for drying Agricultural products", International Journal of Engineering Research-Online, pp. 2321-7758.
3. Qianjun Mao; Ning Liu; Li Peng, Year: 2018, "Recent Investigations of Phase Change Materials Use in Solar Thermal Energy Storage System", Hindawi Advances in Materials Science and Engineering, Vol: 2018.
4. Shripad Chopade; Sagar Kauthalkar; Pushpendra Kumar Sharma, Year: 2013, "Solar Heat Energy Storage in Phase Change Materials", International Journal of Engineering Research and Applications (IJERA), Vol: 3, no: 4, pp. 2248-9622
5. K.N Babu; P. Kumar; D Yamuna, Year: 2012, "A Research on Development of a Fixed Solar Dryer with a Practical Research", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol: 8, no: 9S2, pp. 2278-3075.



Article Title: A Review on Solar Dehydration System with Energy Storing Material

6. S S Rokade; Dr. J S Bagi; M M Wagh, Year: 2018, "A Review of Solar Air Dryer Based on the Phase Change Material as Thermal Storage", International Journal for Research in Engineering Application & Management (IJREAM), Vol: 04, no: 04, pp. 2454-9150
7. S S Joshi; S V Joshi, Year: 2013, "Grape Dryer Using Infrared Radiation: An Experimental Study", J. Food Sci. Technol. Nepal, Vol. 8, no: 18-22, pp. 1816-0727
8. Murat Kenisarin; Khamid Mahkamov, Year: 2006, "Solar energy storage using phase change materials", Renewable and Sustainable Energy Reviews, Vol: 11, pp. 1913–1965.
9. S M Shalaby; M A Bek; A A El-Sebaili, Year: 2014, "Solar dryers with PCM as energy storage medium: A review", Renewable and Sustainable Energy Reviews, Vol: 33, pp. 110–116.
10. Kathiravan Krishnamurthy; H K Khurana, Soojin Jun; Joseph Irudayaraj; Ali Demirci, Year: 2008, "Infrared Heating in Food Processing: An Overview", COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY, Vol: 7.
11. M. Boda; C. Papade, Year: 2016, "Analysis of Solar Dryer using Tono Therm M-65 Phase Change Material", International conference on Communication and Signal Processing, pp. 1951-6851.
12. M A Boda; N M Dhore; M D Jadhav; A K Jamadar; K D Kapse, Year: 2016, "Design and Development of Solar Dryer of Convergent Nozzle type Flat Plate Collector", REST Journal on Emerging trends in Modelling and Manufacturing, pp. 2455-4537.
13. Prof. A.I. Ambesange; Prof. S K Kusekar, Year: 2017, "Analysis of Flow through Solar Dryer Duct Using CFD", International Journal of Engineering Development and Research (IJEDR), pp. 2321-9939.
14. Kaivalya V; Premkumar S, Year: 2018, "Study on Solar Dryer Coupled with Flat Plate Collector", International Journal of Engineering Research and Technology (IJERT), Vol: 6, no: 15, pp. 2278-0181.
15. V V Bhagwat; V P Patil; K K Bhosale; S P Kambale, Year: 2017, "Experimental Analysis of a Solar Air Dryer with Thermal Energy Storage Unit (PCM)", International Advanced Research Journal in Science Engineering and Technology (IARJSET), pp. 2394-1588.
16. Vigneshwaran.T; Aravindh.A; Jayaraj.R; Balachandar.B; Arumugam.P b, Year: 2015, "Design of Mixed Mode Solar Dryer", International Journal of Engineering Research & Technology, Vol: 3, no: 22, pp. 2278-0181.
17. K M Arjunraja; T. Gopalakrishnan; M. Hariharan; P. Kishore, Year: 2018, "Design and Fabrication of Solar Air Dryer", International Journal of Engineering Research & Technology (IJERT), Vol: 6, no: 04, pp. 2278-0181.
18. V M Shinde; R R Chavan; V V Bhagwat, Year: 2017, "Experimental Analysis of a Solar Dehydration with Phase Changing Material", International Journal of Engineering Research & Technology (IJERT), Vol: 6, no: 3, pp. 2278-0181.



Article Title: A Review on Solar Dehydration System with Energy Storing Material

19. Prof. P M Gupta; A S Das, R C Barai; S C Pusadkar; V G Pawar, Year: 2017, "Design and Construction of Solar Dryer for Drying Agricultural Products", International Research Journal of Engineering and Technology (IRJET), Vol: 4, no: 3, pp. 2395-0072.
20. P N Burade; R M Dongare; S Thomas; S Tamgadge; Dr. N. K. Mandavgade, Year: 2017, "Application of Solar In Food Dryer-A Literature Review", International Journal of Innovations in Engineering and Science, Vol: 2, no: 11, pp. 2456-3463.
21. B. K. Bala; Nipa Debnath, Year: 2012, "Review Article Solar Drying Technology: Potentials and Developments ", Journal of Fundamentals of Renewable Energy and Applications, Vol: 2.
22. O. Kilanko; T.A. Ilori; R.O. Leramo; P.O. Babalola; S.E. Eluwa ; F.A. Onyenma; N.I. Ameh; P.N. Onwordi ; A.K. Aworinde;, M.A. Fajobi, Year: 2019, "Design and Performance Evaluation of a Solar Dryer", International Conference on Engineering for Sustainable World.
23. Wengang Hao; Shuonan Liu; Baoqi Mi; Yanhua Lai, Year: 2020, "Mathematical Modeling and Performance Analysis of a New Hybrid Solar Dryer of Lemon Slices for Controlling Drying Temperature", MDPI Energies.
24. S S Halewadimath; Prajwal Subbhapurmath; Naveen Havaladar; Karthik Hunashikatti; Siddharth Gokhale, Year: 2015, "Experimental Analysis Of Solar Air Dryer For Agricultural Products", International Research Journal of Engineering and Technology (IRJET), Vol: 2, no: 3, pp. 2395-0072.
25. Mithat Akgün; Levent Kandemir; Burhan Öztürk, Year: 2016, "Effect of Led Drying on Drying Behavior of Prunus domestica L. Fruit", Indian Journal of Pharmaceutical Education and Research, Vol: 52, no: 4.
26. A H Patel; Prof. S A Shah; Prof. Hitesh Bhargav, Year: 2013, "Review on Solar Dryer for Grains, Vegetables and Fruits", International Journal of Engineering Research & Technology (IJERT), Vol: 2, no: 1, pp. 2278-0181.
27. S.K. Amedorme; J. Apodi; and K. Agbezudor, Year: 2013, "Design and Construction of Forced Convection Indirect Solar Dryer for Drying Moringa Leaves", Scholars Journal of Engineering and Technology (SJET), Vol: 1, no: 3, pp. 2321-435X.
28. U Toshniwal; S.R Karale, Year: 2013, "A review paper on Solar Dryer", International Journal of Engineering Research and Applications (IJERA), Vol: 3, no: 2, pp. 2248-9622.
29. S M Shamiq; P Sudhakar; M Cheralathan, Year: 2014, "Experimental study of a solar dryer with different flow patterns of air in the drying chamber", International conference on Advances in Mechanical Engineering.



Article Title: A Review on Solar Dehydration System with Energy Storing Material

30. V V Pakhare, S P Salve, Year: 2016, "Design and Development of Solar Dryer Cabinet with Thermal Energy Storage for Drying Chilies", International Journal of Current Engineering and Technology special, no: 5, pp. 2347 – 5161.
31. W P Missana; Eugene Park; Thomas T. Kivevele, Year: 2020, "Thermal Performance Analysis of Solar Dryer Integrated with Heat Energy Storage System and a Low-Cost Parabolic Solar Dish Concentrator for Food Preservation", Hindawi Journal of Energy, Vol: 2020.
32. K.Nagendra Babu; P.Sudheer Kumar; Yamuna, Year: 2019, "A Research on Development of a Fixed Solar Dryer with a Practical Research", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol: 8, no: 9, pp. 2278-3075.
33. M N Musembia; K S Kiptoob; Nakajo Yuichic, Year: 2016, "Design and Analysis of Solar Dryer for Mid-Latitude Region", International Conference on Power and Energy Systems Engineering.
34. G Sadeghi; O Taheri; F Mobadersani, Year: 2012, "New Technologies of Solar Drying Systems for Agricultural and Marine Products", Middle-East Drying Conference.
35. H P Bhavsar; Dr. C M Patel, Year: 2020, "Performance Evaluation of Various types of Solar Dryer and Drying Technologies", International Journal of Advanced Science and Technology, Vol: 29, no: 9, pp. 2005-4238.
36. Arjoo; Yadvika, Y.K; Yadav, Year: 2017, "Performance Evaluation of a Solar Tunnel Dryer for Around the Year Use", Current Agriculture Research Journal, Vol. 5, pp. 2347-4688.
37. Ragul Kumar N; Muthukkannan Natarajan; Ayyappan S; Karunaraja Natarajan, Year: 2020, "Analysis of Solar Tunnel Dryer Performance with Red Chili drying in two intervals", Research Journal of Chemistry and Environment, Special Issue on Renewable Energy and Sustainable Environment.
38. V N Hegde; V S Hosur; S K Rathod; P A Harsoor; K B Narayana, Year: 2015, "Design, fabrication and performance evaluation of solar dryer for banana", Energy, Sustainability and Society.
39. Kumbhar B.A; Mote P.S; Dr. Vibhute A.S., Year: 2018, "Temperature Conditioning for Solar Dryer", International Research Journal of Engineering and Technology (IRJET), Vol: 05, no: 03, pp. 2395-0072.
40. Mr. V H Deokar; Dr. R S Bindu, Year: 2020, "Real-time controlling and monitoring of solar drying and Water pumping system using IoT", Mukta Shabd Journal, Vol: IX, no: V, pp. 2347-3150.
41. A Tiwari, Year: 2016, "A Review on Solar Drying of Agricultural Produce", J Food Process Technol, an open access journal, Vol: 7, no: 9, pp. 2157-7110.
42. V H Deokar; Dr. R S Bindu, Year: 2020, "Real-time controlling and monitoring of solar drying and Water pumping system using IoT", Mukta Shabd Journal, Vol: IX, no: V, pp. 2347-3150.