Impact Factor Value 3.441 e-ISSN: 2456-3463
International Journal of Innovations in Engineering and Science, Vol. 2, No.11, 2017
www.ijies.net

Application of Solar In Food Dryer-A Literature Review

Pratik N. Burade[1], Rohit M. Dongre[1], Sajin Thomas[1] ,Siddhant Tamgadge[1],Dr.N.K.Mandavgade[2]

[1]*Students, Mechanical Engineering Department, SBJITMR, Nagpur*
[2]*Associate professor Mechanical Engineering Department, SBJITMR, Nagpur*

Abstract - *Drying is a simultaneous heat and mass transfer energy intensive operation, widely used as a food preservation technique. In view of improper postharvest methods, energy constraint, and environmental impact of conventional drying methods, solar drying could be a practical, economical, and environmentally reliable alternative. Open air solar drying method is used frequently to dry the agricultural products. But this method has some disadvantages. Therefore to avoid disadvantages it is necessary to use the other solar drying methods. Different solar drying methods are direct solar drying, indirect solar drying, and mixed mode solar drying. The device used for drying process with application of solar energy called the Solar dryer. Solar dryer are also classified with mode of air circulation. In this paper, we studied the various modes of solar drying and classification of solar drying techniques.*

Keywords: Solar drying, Natural circulation, Forced circulation, food sector, medicine sector.

INTRODUCTION

Drying is an excellent way to preserve food and solar food dryers are appropriate food preservation technology for sustainable development. Drying was probably the first ever food preserving method used by man, even before cooking. It involves the removal of moisture from agricultural produce so as to provide a product that can be safely stored for longer period of time. "Sun drying" is the earliest method of drying farm produce ever known to man and it involves simply laying the agricultural products in the sun on mats, roofs or drying floors. This has several disadvantages since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic conditions like rain, wind, moist and dust, loss of produce to birds, insects and rodents (pests); totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of the produce. The process also requires large area of land takes time and highly labour intensive. With cultural and industrial development, artificial mechanical drying came into practice, but this process is highly energy intensive and expensive which ultimately increases product cost .Recently, efforts to improve "sun drying" have led to "solar drying".

In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural produce from damage by insect pests, dust and rain. In comparison to natural "sun dries", solar dryers generate higher temperatures, lower relative humidity, and lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world's food and energy crises. With drying, most agricultural produce can be preserved and this can be achieved more efficiently through the use of solar dryers.

1. **METHODS OF SOLAR DRYING –**

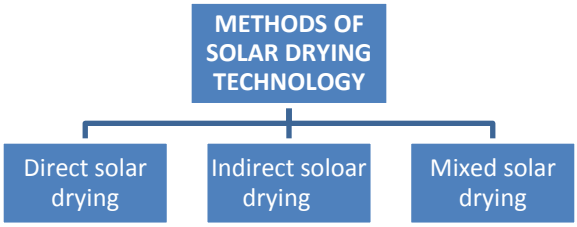


Fig 1-Methods of Solar Drying

1.1 Direct solar drying:-

Direct solar drying is a general method of drying the product by means of solar energy. In this process the energy which is obtained from sun is directly used for drying purpose. This is one of the convenient methods of drying, because energy is obtained from one of the cheaper source called as sun or renewable source of energy. It is the continuous operation of heat and mass transfer.

This technique involves the thin layer of product spread over large space to expose to solar radiation. This process for a long time until the products will dry to a required level. The surface floor made from the concrete or particular area of soil is making applicable for Outdoor direct sun drying. This type of drying method is useful for grains. Material is led on outdoor floor for a long time, usually 10-30 days. This process is going on till then when the product is dried to a required level. According to the Prof. Sanjay P. Salve (2014) drying is very important process applicable for agriculture and industrial product. Drying reduces the bacterial growth of the product and helpful for preserving the product for long period of time. But this conventional process have some disadvantages therefore in that case it is very essential to use other methods of drying such as active, passive and mixed solar drying.

1.2 Indirect solar drying:-

Indirect or convective solar drying it is more efficient than direct type of solar drying. In an indirect solar dryer, the sun's heat is first collected by the solar collectors and is then passed on to the dryer cabinet, where the drying occurs. The air heaters are connected. The basic concept of reverse flat plate collector is used to dry food products in a solar cabinet-type dryer. Here, a solar air heater is used to heat the air that enters the chamber. The heated air then turns in to warm humid air, which passes through an outlet. This kind of dryer is better than other dryers in terms of solving various equations based on energy balance. It also has better performance than other conventional cabinet type of dryers. According to the Prof. A.G.M.B. Mustayen (2014) method of drying is used to avoid direct exposing to the solar radiation. This method mainly reduces the disadvantages of direct solar drying.

1.3 Mixed mode solar drying:-

Mixed mode solar drying is one another advanced form of solar drying technique, in which both direct and indirect solar drying are performed simultaneously. This method also called as passive drier. The mixed-mode solar dryer has no moving parts, which is why it is called the passive dryer. This type of dryer acquires energy from the rays of the sun that enters through the collector lustring. The inside surface of the collector is painted black, and the sun's rays are harnessed by trapping the heat of the air that is collected inside the chamber. A previous study that examined the design and performance of this kind of solar dryer verified the accelerated drying process and its ability to dry agricultural products by quickly reaching better conditional moisture level, thus making it ideal for food preservation.

According to the A.G.M.B. Mustayen and Saad Mekhilef (2014) Based on the results, they found that the mass flow rate effect and discharge rate of crop drying are good. Moreover, this system gives satisfactory result in terms of drying efficiency and moisture content. The maximum efficiency of the system was recorded at 21.24%, and the energy consumed during the drying process was 6–8%. Final moisture content was 13% at ambient temperature (25 degree Celsius).

2. SOLAR DRYER

2.1 Natural convection solar dryer (passive mode solar dryer):-

Natural convection solar dryer is the easiest and convenient method of drying. In which a collector, a transparent sheet, and a unit for drying; it is covered by a shade on top. These parts are connected in a series, comprising a system that can obtain very satisfactory drying rates. This type of model was first introduced by Oosthuizen. This kind of solar dryer obviously plays a vital role in the drying sector because of its low cost. It has also become popular because of its simple maintenance and operation. Between a natural convection solar dryer and a forced convection dryer, the former is more suitable and is one of the oldest types of dryers available. However, the natural convection solar drying system has a limited capacity. Moreover, the drying rate is delayed and highly dependent on atmospheric conditions because of a little float for inducing air flow inside the dryer, thus reducing the quality of the drying products especially in adverse weather conditions. Later on such condition a new type of solar dryer has been designed and tested by Later Ezeike. This dryer has a very simple design and provides high efficiency in ambient atmosphere. It consists of a flat plate air collector, a drying cabin, and a dehumidification chamber. It is used in the low-isolation period because of its additional heat gain by two wall collectors in the cabinet in order to contain the desiccant,

which is a type of silica gel placed in the dehumidification chamber.

2.2 Forced convection solar drier (active mode solar dryer)

In a forced convection solar drier the energy is needed to operate the fans to convey the heated air within the solar tube towards the food tray. This helps to dehumidify the food in less time. However, many rural areas either have no electricity or have to incur high costs to generate the electricity used to run this type of dryer. Therefore, these types of dryers are not widely applicable in many developing countries. To avoid the above- mentioned disadvantages, a natural convection solar dryer may be used. This type of dryer is not dependent on electricity like a forced convection solar dryer. Its advantages include low energy cost, ideal shrinkage in the drying period, better drying capacity, minimization of mass losses, and good quality of the dried products.

Ahmad Ghazanfari (2002) develops a prototype forced circulation cabinet the drying chamber was made up of dimensions with length of 170 cm; width of 210 cm; front height of the chamber is 30 cm and the back height of 65 cm. Four trays were used of sliding type of dimensions 80 cm x 70 cm x 10 cm. It was fitted in the chamber. The final moisture content of the nuts was 6.0%. This final moisture content reached in 36 sunshine hours

3. SOURCE OF LITERATURE REVIEW

Numerous articles dealing with theory and application of solar drier have been published over several years, but topic is still under considerable development. We have examined the work related to solar drier published in referred journals. The distributions of articles in various journals.

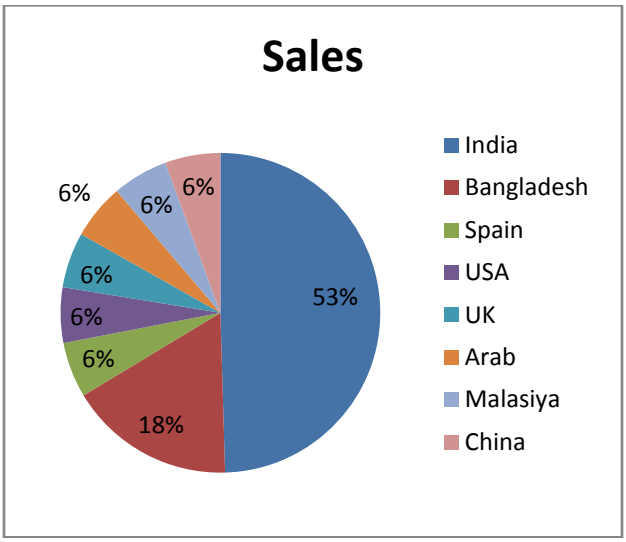
Table-1Distribution of reviewed article

Scientific research publishing
Hindwai research publishing
APRN Journal of Engineering & Applied Science
Research gate
International Journal of Research in Advent Technology
International Journal of Sustainable Energy
Drying Technology
Multistage Drying Technology

4. APPLICATION OF SOLAR DRYER IN VARIOUS FIELD

- Agriculture crop drying.
- Food processing industries for dehydration of fruits, potatoes, onions and other vegetables.
- Dairy industries for production of milk powder, casein etc.
- Seasoning of wood and timber.
- Textile industries for drying of textile material.
- Food product dryer.
- Fruits and Vegetables solar dryer.
- Solar hot air generation for industry and space heating.

5. LOCATION WISE AWARENESS IN FIELD OF SOLAR DRYER



From the above Pie chart and as per our study, the percentage of India on solar dryer is more than the other 7 mentioned countries.

According to the revised paper it is found that the authors of different countries mostly focused on the indirect and mixed type of solar drier.

6. GAPS IN LITERATURE RESEARCH

- Can be only used during day time when adequate amount of solar energy is present.
- Lack of skilled personnel for operation and maintenance.
- Less efficiency as compared with modern type of dryers.
- A backup heating system is necessary for products require continuous drying.

Table 2 - Development of literature

Sr. No.	Title of paper	Author	Year of Publish	Contribution In work
A.	Experiment of drying of fruits and vegetables with solar energy	El-Shiatry, &MA Muller	1991	The paper present drying of fruits and vegetables with solar energy.
B.	Research and develop wok on solar dryer for grape drying	Dr. Pangavhane and R. L. Sawhney	2000	The paper deals with solar dryer used in grapes drying. Natural convection solar dryer.
C.	Experiment Investigation on solar Drying of fish using solar tunnel dryer	B. K. Bala & Mr.Mandol	2001	This paper presents field level performance of the solar tunnel dryer for drying fish.
D.	Simulation of solar drying of chilli in solar tunnel drier	M.A. Hussain & B.K. Bala	2002	The paper presents drying of chilli in solar tunnel dryer. Presents modelling of a solar tunnel drier by taking the collector and mass in drying unit.
E.	Effect of air flow rate on carrot drying	A. Mulet & A. Berna	2006	In this carrot cubes is dried. Drying air flows at the rate 1000-9000 kg/m2
F.	An optimisation of corn drying in a laboratory scale	Q. Zhang and J.B. Litchfield	2007	A corn drying process in thin layer dryer in multistage drier.
G.	Prospect & Future of Solar drier	A.S.M. Mohsin & Md. Nasimul Islam Maruf	April 2011	The objective of this paper is the design and performance analysis of different types of solar dryer and its prospect in Bangladesh.
H.	A review paper on solar dryer	Ebern Fodor	Oct. 2012	The sun works " Z-flow" airflow pattern is powered by the buoyancy of the solar-heated air.
I.	Review on solar dryer for grains, vegetables and fruits	Prof. S.A. Shah & Prof. Hitesh Bhargav	Jan 2013	To overcoming spoiling of vegetables, food grains and fruits; various preserving methods are used and renewable sources are best for this purpose by which we can save energy for preservation and keeping the product in their natural flavour.
J.	A review paper on solar dryer	1)Umesh Toshnival 2)S. R. Karale	Apr. 2013	The use of solar dryer in the drying of agriculture products can significantly reduce, product wastage, food poisoning and sometimes enhance productivity of farmer.
K.	Review on development of solar drying applications	G. Pirasteh, R. Saidur & S. M. A. Rahman.	Nov.2013	They review the role of the drying system in industry and agriculture, the energy consumption capacity, and the availability of the required energy for the products to be dried.
L.	Review of solar dryer Technology	Ashish D. Chaudhary & Prof. Shaj P. Salve	Feb. 2014	Forced circulation solar drying shows better result with reduce drying time than open air solar drying and natural circulation solar drying.
M	Investigation of solar drying of ginger	A.Waheed Deshmukh &Mahesh Varma	March 2014	Potential of solar drying methods of ginger and other agriculture product is good and high advantage and relative error is 1.78%
N.	Performance of different solar dryers	A.G.M.B. Mustayen	June 2014	This paper presents a study on the design, performance and application of various types of solar dryers available taday this provides high quality dried products.
O.	Solar drying technology: A Review	Mega Sontakke & Prof. Sanjay P. Salve	April 2015	For drying the food in the various techniques of food drying such as – (1)Direct food drying. (2)Indirect food drying.
P.	Study of solar drying and its application in traditional Chinese medicine in drying.	Mingle Liu &Shangyanwan g kegong li.	April 2015	Combing flat air collector to develop practically strong solar dryer. Combining with adsorption and regeneration technology, also supplying cooling heating and other service.
Q.	Review on Indirect solar dryers	Promod C. Phadke & Pramod v. walke	May 2015	This paper is focused on indirect type solar dryers. On its various design and modification.

R.	A review paper on solar green house dryer	Nidhi and Pratiksha Verma	2016	In this paper, hothouse dryer of natural convection and forced convection are studied green house effect is used apart from solar energy effect but both works on same principle
S.	Design and Construction of Solar Dryer for Drying Agricultural Products	Prof. Pravin M. Gupta	Mar. 2017	Performance of existing solar food dryers and still be improved upon especially in the aspect of reducing the drying time and probably storage of heat energy within the system.

7. OBJECTIVE OF RESEARCH PAPER

- To study the concept of solar dryer.
- To present simplified way of application of solar dryer in various field.
- To apply the concept of solar dryer in food storage application.
- Providing backup heating system is necessary for products require continuous drying.

REFERENCES

1] *M.K. Hussain & B. K. Bala, " Simulation of solar drying of chilli in solar tunnel drier", International Journal of sustainable energy, vol. 24, pg. no. 143-153,2005.*

2*] B.K. Bala & M. R. Mandal, " Experiment Investigation solar drying of fish using solar tunnel drier", vol. no. 19, pg. no. 427-426,2001.*

3] *El. Sheatry, & MA Muller, "Experiment of drying of fruits and vegetables with solar energy", Drying Technology vol.14 pg. no. 141-148,1991.*

4] *Pangavhane & R.L. Sawhney, "Research and develop work on solar drier for grapes drying", Drying Technology, vol. 43 Pg. no. 45-61, 2002.*

5] *A. Mulet & A. Berna, "Effect of air flow rate on carrot drying", Drying Technology, vol. 5 Pg. no. 245-258, 1987.*

6] *Q. Zhang & J.B. Litchfield, " An Optimization of corn drying in a laboratory scale thin layer drier", Multi-stage drying technology, vol. 9 Pg. no. 383-395,1991.*

7] *Mingle liu & Shaungayan Wang, "Study of solar energy drying device and its application in traditional Chinese medicine in drying", Scientific Research publishing, Pg.271-280, 2015.*

8] *Megha .Sontakke & Prof.Sanjay Salve, "Solar Drying Technologies:a review",International reffered journal of engineering and science, vol.4, page no.37-43,2015.*

9] *Nidhi & Pratiksha Verma, "A review paper on solar green-house dryer",IOSR-Journal of mechanical and civil engineering,2016.*

10] *Umesh Toshinwal & S.R.Karale, "A review paper on solar dryer",Internation Journal Of Engineering Research And Application(IJERA),vol.3,page no 896-902,2013.*

11] *A. Boubekri, H. Benmoussa, and D. Mennouche, "Solar drying Kinetics of date palm fruits assuming a step-wise air temperature change," Journal of Engineering Science and Technology, vol. 4, no. 3, pp. 292–304, 2009.*

12] *A. O. M. Akoy, M. A. Ismail, F. A. Ahmed, and W. Luecke,"Design and construction of solar dryer for mango slices,"*International Renewable Energy Review, vol. 4, no. 2, pp. 1–9,2007.

13] *Ashish D. Chaudhary and Prof. Sanjay P. Salve, "A review of solar dryer technologies", International journal of research in advet technology, vol.2, 2014.*

14] *A. Waheed Deshmukh and Mahesh N. Verma, "Investigation of solar drying of ginger", Hindawi Publishing Corporation, 2014.*

15] *Pranav C. Phadke and Pramod V. Walke, "A review on indirect solar dryer", APRN Journal of Engineering and Applied Science, vol.10, Pg.8,2015.*

16] *A.G.M.B. Mustayen and S. Mekhilef, "Performance of different solar dryers: A review", Pg. no. 463-470, 2014.*

17] *G. Pirastch and R. Saidur, "A review on development of solar drying applications", ELSEVIER, Pg. no. 133-148, 2013.*

18] *A.S.M. Mohsin and Md. Nasimul Islam Maruf, "Prospect and future of solar dryer: Perspective Bangladesh", vol.3, 2011.*

19] *Fatima S. Alleyne and Rebecca R. Milezarek, " Design of solar thermal dryers for 24 hour food drying", United State Department of Agriculture, Heating Processed Food Research Unit, 2015.*

20] *Pravin M. Gupta and Amit S. Das, "Design and construction of solar dryer for drying agriculture products," International Research Journal of Engineering and Technology (IRJET), vol.4, 2017.*

20] *S. M. Henderson and S. Pabis, "Grain drying theory I: temperature effect on drying coefficient," Journal of Agricultural Engineering Research, vol. 6, pp. 169–174, 1961.*