International Engineering Journal For Research & Development

Vol.4
Issue 7

E-ISSN NO:-2349-0721

Impact factor : 6.03

ADVANCES IN HYBRID DRYERS: REVIEW IN TECHNOLOGICAL DEVELOPMENT

Prof. Saurabh S. Bhange
Asst. Professor
PRMIT&R,
Badnera-Amravati.
saurabhbhange@gmail.com

Mr. Rahul Mohite
Student, Final Year,
PRMIT&R,
Badnera-Amravati.
mohiterahul047@gmail.com

Mr. Shubham Khursange
Student, Final Year,
PRMIT&R,
Badnera-Amravati.
shubhamkhursange2828@gmail.com

Mr. Siddhesh Wasu
Student, Final Year,
PRMIT&R,
Badnera-Amravati.
siddheshwasu04@gmail.com

Abstract-

Drying of the food is one of the oldest & finest methods of food preservation. Food dehydration finds its roots in the history of mankind, even the cavemen found the dehydration as the best alternative for food storage. To overcome the shortcomings of open sun drying various dryer designs had been proposed so far. From the conventional method of open-air drying to hybrid dryers, many technological changes are introduced in the drying mechanisms. This paper provides information about various designs of those solar dryers which are already developed for helping the reader to develop new and modified dryer structures. For this purpose, many designs are discussed in this paper.

Keywords— Food Drying, Solar Energy, Solar Dryer, Hybrid Dryer.

I. INTRODUCTION

One of the biggest challenges faced by the human race today is to feed the ever-growing population. The food which is served to the plates of ultimate consumer takes around 3 – 10 months of time from the harvesting stage to edible food. Storage of the grains for this period requires removal of moisture from it. Drying of food grains under the sun in the open is the conventional & widely used method. But this method has a number of drawbacks like contamination of grains because of rain, moisture, dust, etc. Also birds, pesticides and rodents also spoil the grains.[1]

Drying of food grains helps in moisture removal or dehydration of food. Enhanced quality of product, increased shelf life is the advantages of drying the crops. [2] Two types of moisture (in the form of water) present in the food items are the chemically bound water & the physically held water. Only physically held water can be removed during the process of drying. [3] The heat removal rate during drying process can be significantly improved with the help of heat received from the sun, by means of using solar dryer. But the efficiency of solar dryers is not very high because the diffuse nature of solar radiation, which restricts the use of solar dryers. [4] Any attempt to increase efficiency by using concentrators or reflectors increases construction cost astronomically. However, it has been discovered that most agricultural products dry efficiently at temperatures attainable using simple solar dryer. [5]

The primary idea of solar drying was introduced by Everitt & Stanley in 1976 to overcome the problem of open sun drying. The first solar dryer consists of a box shaped housing having a transparent sunlight cover. The intention behind this concept was to provide a new & improved design to overcome the various difficulties adverted in open sun drying. During the course of time, many developments in the design of solar dryers were seen which are utilizing natural circulation & forced circulation heating of the air with burning of biomass & fossil fuels to attain higher temperatures. [6] Onigbogi I.O.(2012) designed a small scale solar dryer for drying maize and plantain. Factors considered in selecting the engineering materials for the fabrication of the equipment were: i. Cost of the fabrication. ii. Mechanical properties of materials (e.g. stress, creep, fatigue etc). iii. Corrosion resistance. iv. Ease of fabrication (e.g. forming, nailing, bending, cutting etc) v. Service requirement. His design shown significant growth in the temperature inside drying chamber and drastic reduction in humidity. [7]

Solar drying of agricultural commodities in boxed structures by forced convection is better to approach of reducing post-harvest losses and the inferiority of dried commodities related to conventional open sun-drying strategies. In several rural locations in most developing countries, grid-connected electricity and provides alternative non-renewable sources of energy are inaccessible, unreliable or too costly. In such conditions, solar dryers seem more and more to be engaging as business propositions.[8]

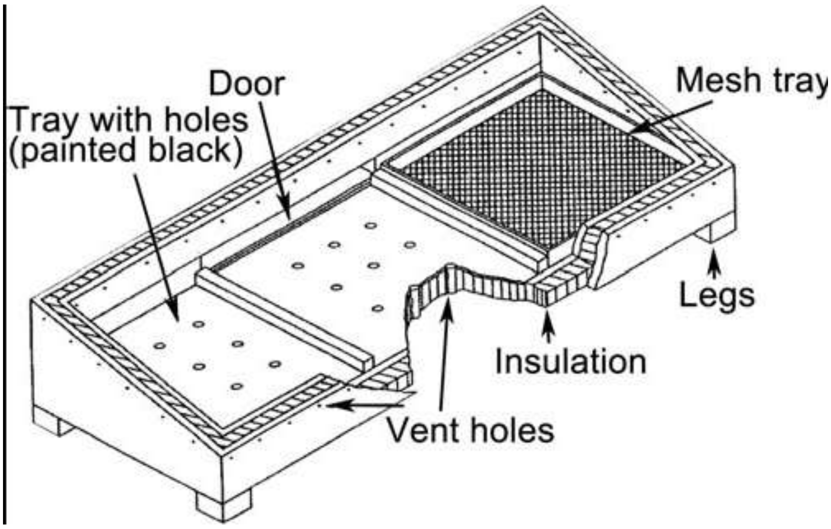
TABLE 1: THE DESCRIPTION OF INITIAL AND FINAL MOISTURE CONTENT AND MAXIMUM ALLOWABLE TEMPERATURE FOR DRYING FOR SOME CROPS [9]

Crop	Initial moisture content (%web.)	Final moisture content (% web.)	Maximum allowable Temp. (◦C)
Paddy, raw	22-24	11	50
Paddy, parboiled	30-35	13	50
Maize	35	15	60
Wheat	20	16	45
Corn	24	14	50
Rice	24	11	50
Pulses	20-22	9-10	40-60
Oil seed	20-25	7-9	40-60
Green Peas	80	5	65
Cauliflower	80	5	65
Carrot	70	5	75
Green beans	70	5	75
Onion	80	4	55
Garlic	80	4	55
Cabbage	80	4	55
Sweet Potato	75	7	75
Potatoes	75	7	75
Chilies	80	5	65
Apricot	85	18	65
Apples	80	24	70
Grapes	80	15-20	70
Bananas	80	15	70
Guavas	80	7	65
Okra	80	20	65
Pineapple	80	10	65
Tomatoes	96	10	60
Brinjal	95	6	60

II. DESIGN OF SOLAR DRYER

Solar drying is used for the drying and preservation of food produce. These three designs ascend in complexity.
Three designs
i. Basic solar dryer design: a wooden box with a hinged transparent lid, black inside, with an insulated base. Produce is put on a mesh tray or rack above the floor. Air is allowed to flow into the chamber through holes at the front and leave through vents at the top and back.

FIG. 1 SCHEMATIC DIAGRAM OF A BOX DESIGN SOLAR DRYER



ii. Box/barn design: An insulated compartment with a glass cover permits warm air to be drawn in at the bottom, absorbing moisture from produce as it travels via the stack effect to leave near the top. The size (which may be small up to barn-sized) and shape depend upon the products / amount to be dried. The inside is painted black to absorb the sun's heat. It tilts perpendicular to the midday sun, but at an angle greater than 15° to allow rainwater to run off, and must be situated away from shadows.

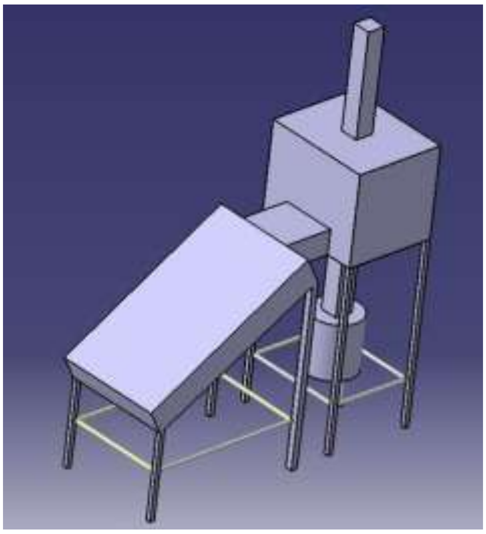
iii. Indirect solar dryer design: air enters through holes at the front of the base. It is drawn by convection. This is created by two glass-covered solar collectors: one just above ground level and one higher up. They both help to draw the air into a vertical cupboard where mesh racks are situated to hold the produce. The air is drawn all around the produce through the mesh. It leaves through a flue at the top. The flue may be painted black to absorb the sun's heat and increase the stack effect. The taller the flue, the more the draw. The produce is not in direct sunlight. [10]

III. DEVELOPMENTS IN SOLAR DRYERS

Hamdani in 2018 has developed **hybrid solar-biomass dryer for drying fish**. A cross-flow type heat exchanger for an air heater that utilizes biomass fuel also mounted to the dryer. There were 25 kg of fish used as raw material and dried utilizing specific devices using several methods. In the beginning, drying was conducted using solar energy, from 09:00 to 16:00, and continued with hot-air produced from biomass combustion from 16:00 to 06:00 and maintained at 40–50 °C. The test revealed that after reaching 22–23 h of the drying process, the overall weight of the fish did not change much, and the final weight is 12.5 kg. [11] The major problems with multiple trays cabinet dryer is uneven drying of the products being dried on different trays. S. Abubakar (2018) developed **Mixed-mode solar crop dryers with and without thermal storage materials** and tested under the same meteorological conditions of Zaria, Nigeria. The dimensions of the d r y e r s were: 0.65 m, 0.3 0 m2 , 0.9 m, 0.7 m, 1.64 m and 0.43 m for collector length, collector area, the height of the drying chamber, chimney height, length of the drying chamber and width of the drying chamber respectively. As per the experimental results, the efficiency of the dryer with the storage materials is enhanced by about 13 % due to the thermal storage used. [12]

M. Chandrasekar (2018) developed **a solar dryer integrated with condenser unit** of split air conditioner (A/C) for enhancing drying rate. For this purpose, an integrated solar dryer that uses hot air from split A/C condenser was fabricated in house and the drying behavior of sultana grapes was investigated in the present work. Drying experiments were carried out in the locality of Tiruchirappalli (78.6^{o}E & 10.8^{o}N), Tamil Nadu, India during summer months of April and May 2016. The use of split A/C condenser outlet cooling air reduced the drying time of grapes by 16.7% compared with open sun drying method. A possibility of 13% increase in solar dryer efficiency was demonstrated due to the integration of solar dryer with A/C condenser unit compared to the conventional indirect solar dryer. From the experimental results, it was found that the exponential model is capable of describing the drying characteristics of seedless grapes. Predicted values of moisture ratio were good. [13] Bhange S. (2019) developed a **natural convection solar dryer combined with heat from burning of biomass**. Figure 2 shows CAD model of hybrid solar dryer developed in the project. In the hybrid dryer, the heated air passes through a separate solar collector which consists of absorber plate and transparent cover to the drying chamber & solar collectors are reinforced with heat from burning biomass kept in a combustion chamber placed right below the drying chamber for raising the temperature inside it. The results obtained shows that the temperature inside the drying chamber is higher than the ambient temperature. [14]

FIG. 2. CAD MODEL OF HYBRID SOLAR DRYER



D.V.N. Lakshmi (2018) developed **a mixed mode forced convection solar dryer integrated with thermal energy storage** for drying of black turmeric (Curcuma caesia). In the present work, performance analysis of mixed mode solar dryer with thermal energy storage has been carried out for drying of 15 kg sliced black turmeric. The experimental results were further analysed to find the best suitable thin layer drying kinetic model for both sun and solar dried samples. It was observed that Two Term model and Page model were found to fit for solar dried and sun dried samples, respectively. The amount of time saved by using mixed mode solar dryer was 60.7% compared to open sun drying. The overall efficiency 46% of the solar dryer was found to be 12.0%. The quality analyses in terms of colour, antioxidant activity, and total phenolic content and total flavonoids were carried out as per ASTM (American society for testing and methods) standards for fresh and the samples dried in the open sun and in a mixed mode solar dryer. [15]

IV. TEMPERATURE RISE & MOISTURE REDUCTION ACHIEVED WITH VARIOUS TYPES OF DRYERS

TABLE 2: COMPARATIVE TABLE SHOWING HIGHEST TEMP. ACHIVED & MAX. MOISTURE REDUCTION IN VARIOUS TYPES OF DRYERS

Commodity	Type of Dryer used	Highest Temperature achieved	Moisture % Reduction
Banana[16]	Hybrid Solar Dryer	30 and 40^0C above the ambient temperature	64%
Maize[7]	Passive Solar Dryer	30^0C above the ambient temperature	43.2%
Plantain[7]			40.6%
Mango [17]	Passive Solar Dryer	40^0C above the ambient temperature	71.4%
Grapes [18]	Mixed-mode solar dryer with forced convection	Up to 22^0C above the ambient temperature	85.4%
Chili and Ear-Lobe Mushroom [19]	Solar-biomass hybrid dryer	Up to10^0C	60-80%
Tomato [20]	PV-assisted solar dryer	30 and 40^0C above the ambient temperature	9.1–64.6%
Apple [21]	Indirect natural convection updraft solar dryer	Up to 20^0C	77.88%
Fish [22]	Mixed mode tent-type solar dryer	Up to 30^0C	82%
Banana [23]	Indirect Type Solar Dryer	Up to 30^0C	71.86%
Yam [24]	Mixed mode solar dryer	Up to 10^0C	80%
Black Turmeric (Curcuma caesia) [15]	Mixed mode forced convection solar dryer integrated with thermal energy storage	Maximum up to 10.3°C	64.9%

V. CONCLUSION

It is to be observed that various researchers & scholars have developed various models of solar dryers and they used them for various applications. It is observed that the better efficiencies in term of higher moisture removal rate & higher temperature achievement, is improved with the introduction of force convection method or using other auxiliary sources such as, biomass can be achieved. Also the findings from this paper suggest that different commodities of food grain have different requirement of dryer design. So, it can be said that there is a scope to find an optimal design of dryer for majority of the commodities.

REFERENCES

Janjai S, Khamvongsa V, Bala BK. Development, design & performance of a pv ventilated greenhouse dryer. Int. Energy J. 2007; 8:249-58

Bernwal P, Tiwari GN. Grape drying by using hybrid photovoltaic thermal (PV/T) greenhouse dryer: an experimental study. Solar energy 2008; 82:1131-44

Ikejiofor I. D., "Pasive solar cabinet dryer for drying agricultural products", Workshop proceedings on the Physics & Technology of Solar Energy Conversion 1985, pp. 157-165.

Othieno H., "Design factors of small scale thermo-siphon solar crop dryers, Workshop proceedings on the Physics & Technology of Solar Energy Conversion 1985, pp. 135-143.

Fath H.E.S., "Thermal performance of simple design solar air heater with built-in thermal energy storage system" Energy Conversion & Management, Vol. 36, No. 10, 1995. Pp. 989-997.

Ekechukwu O, Norton B. Review of solar energy drying systems II : an overview of solar drying technology. Energy converse management 1999; 40: 615-55.

Onigbogi I.O, Sobowale, S. S and Ezekoma, O.S. Design, Construction and Evaluation of a Small Scale Solar Dryer. Journal of Engineering and Applied Science. Volume 4, June 2012.

C.L. Hii, S.V. Jangam, S.P. Ong and A.S. Mujumdar, Solar drying: Fundamentals, applications and innovations 2012. ISBN: 978-981-07-3336-0.

Om Prakash and Anil Kumar. Historical Review and Recent Trends in Solar Drying Systems. International Journal of Green Energy 2012. ISSN: 1543-5075 print / 1543-5083 online DOI: 10.1080/15435075.2012.727113.

David Thorpe.Solar Energy Pocket Reference 2018. ISBN: 978-1-138-50120-1.

Hamdani, T.A. Rizal, Zulfri Muhammad. Case Studies in Thermal Engineering 12 (2018). pp. 489–496

S. Abubakar, S. Umaru, M.U. Kaisan, U.A. Umar, B. Ashok, K. Nanthagopal. Development and Performance Comparison of Mixed-Mode Solar Crop Dryers with and without Thermal Storage. Renewable Energy: An International J. Volume 128, Part A, December 2018, Pages 285-298

M. Chandrasekar, T. Senthilkumar, B. Kumaragurubaran, J. Peter Fernandes. Experimental investigation on a solar dryer integrated with condenser unit of split air conditioner (A/C) for enhancing drying rate. Volume 122, July 2018, pp. 375-381.

P. B. Jawanjal, S. S. Bhange, S. G. Bahaley. An Experimental Investigation of a Biomass-Solar Integrated Dryer. ISSN (Online): 2581-5792. pp. 399-402.

D.V.N. Lakshmi, P. Muthukumar, Apurba Layek, Prakash Kumar Nayak. Drying kinetics and quality analysis of black turmeric (Curcuma caesia) drying in a mixed mode forced convection solar dryer integrated with thermal energy storage. Renewable Energy. Volume 120, May 2018, Pages 23-34.

B.M.A. Amer a, M.A. Hossain b, K. Gottschalk. Design and performance evaluation of a new hybrid solar dryer for banana. Energy Conversion and Management 51 (2010) 813–820.

EL- Amin Omda Mohamed Akoy, Mohamed Ayoub Ismail, El-Fadil Adam Ahmed and W. Luecke. Design and Construction of A Solar Dryer for Mango Slices. November 2015.

Chandrakumar B Pardhi, Jiwanlal L Bhagoria. Development and performance evaluation of mixed-mode solar dryer with forced convection. International Journal of Energy and Environmental Engineering 2013.

Gauhar A. Mastekbayeva, Chandika P. Bhatta, M. Augustus Leon and S. Kumar. Experimental studies on a hybrid dryer.

Hadi Samimi-Akhijahani, Akbar Arabhosseini. Accelerating drying process of tomato slices in a PV-assisted solar dryer using a sun tracking system. Renewable Energy: An International Journal 2018.

Maundu Nicholas Musembi, Kosgei Sam Kiptoo, Nakajo Yuichi. Design and Analysis of Solar Dryer for Mid-Latitude Region. Energy Procedia 100 (2016) 98 – 110. 3rd International Conference on Power and Energy Systems Engineering, CPESE 2016, 8-12 September 2016, Kitakyushu, Japan.

Pranav Mehta, Shilpa Samaddar, Pankaj Patel, Bhupendra Markam, Subarna Maiti. Design and performance analysis of a mixed mode tent-type solar dryer for fish-drying in coastal areas. Solar Energy 170 (2018). pp 671–681.

Abhay Lingayat, Chandramohan V.P., V.R.K. Raju. Design, Development and Performance of Indirect Type Solar Dryer for Banana Drying. Energy Procedia 109 (2017) 409 – 416.International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR 2016, 10-12 November 2016, Bhubaneswar, India.

S. Abubakar, S. Umaru, M.U. Kaisan, U.A. Umar, B. Ashok, K. Nanthagopal. Development and Performance Comparison of Mixed-Mode Solar Crop Dryerswith and without Thermal Storage. Renewable Energy: An International Journal 2017.