Renewable and Sustainable Energy Reviews 82 (2018) 3250–3262

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Recent developments in greenhouse solar drying: A review

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ARTICLE INFO

Keywords:
Active greenhouse
Passive greenhouse
Drying
Solar energy
Solar dryer

ABSTRACT

The world is moving towards the reduction of dependency on fossil fuels. Various innovations are undergoing to make the use of sources of renewable energy like wind, solar, tidal etc. Among these sources, solar energy is available in enormous quantity and best option that may be used for space heating and generation of electric energy. For drying agricultural and non-agricultural products, solar energy can be used directly or indirectly. But in open sun drying the products are affected by external calamities such as rain, insects and animals. To overcome the shortcomings of open sun drying various greenhouse solar dryer had been proposed so far. Some of recent researches have been discussed in the paper. This paper provides the data of already developed greenhouses so the reader can develop new and modified the greenhouse structure. To accomplish this, various researches of recent years have been studied and presented in this review.

1. Introduction

Increasing population is the major problem of the entire world. Increase in the population increases the consumption of food. To fulfill this demand either that amount of food must be produced on a regular basis or produced food can be stored after some processing. Therefore, continuous production is not possible but food can be stored for a certain period by drying it.

Drying is the phenomenon of reducing moisture up to a safe limit. Solar drying is the ancient method that is practiced everywhere for crop preservation. Solar drying is an effective method of utilizing energy of sun [1]. Drying of agricultural products leads to counteract the activity of various microscopic organisms. The crop after drying can be stored for a longer time without any fear of getting deteriorated [2]. The dried crop has various advantages like enhanced product quality, longer safe storage time and low post-harvest losses [3]. Heat transfer in the form of conduction, convection, thermal and radiation plays a vital role in solar drying process [4].

In open or natural sun drying, the crops are laid simply on the floor or mat in the full sunny days. As the crops being exposed directly to the sun, it gets contaminated from dirt and pest infestation and also lost by birds and beast. Researchers developed various drying techniques like spray, mechanical, electrical, solar drying etc. Such drying techniques are using around the world for drying of agricultural and non-agricultural products. Among these dryers, greenhouse solar dryer has various advantages over other types which make it a good alternative [1]. These dryers not only reduce the consumption of fossil fuels for drying purpose, but also provide the best quality, color and taste of the dried products [5]. The modern solar drying equipment uses optimum energy and time and occupies less area for producing better quality dried products with almost zero energy cost [6]. The working of greenhouse solar dryer is based on the principle of greenhouse effect. It allows incoming short wavelength solar radiations from the sun and traps the long wavelength solar radiations. Greenhouse dryers are used for crop cultivation, poultry, aquaculture, soil solarisation, and crop drying [7].

Greenhouse basically operates either in passive (natural convection) or active mode (forced convection) [8]. Fig. 1 shows the classification of greenhouse solar dryer on the basis of our literature review. In the passive mode of greenhouse dryer, ventilator or chimney is provided at the chimney for the natural circulation of air entering inside the dryer. While in case of the active dryer, exhaust fan is provided for moving humid air outside the dryer.

Various modifications and researches have been done to improve the greenhouse dryer's performance. Some of the modifications implemented on active and passive greenhouse solar dryers in literature are:

- PV integrated greenhouse solar dryer [1,8,9,11,15,17,20–22,24,26,31,34,36].
- Used opaque northern wall to insulate it and prevent heat loss [12,13,16,18,22,32].
- Used thermal storage materials such as sand, rock-bed, black painted concrete floor and PVC sheet. So that greenhouse can be used during off sun-shine period [1,12,28,34,37].
- Inclined and reflecting north wall to collect maximum radiations [10].

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http://dx.doi.org/10.1016/j.rser.2017.10.020
Received 14 April 2017; Received in revised form 6 September 2017; Accepted 26 October 2017
Available online 31 October 2017
1364-0321/

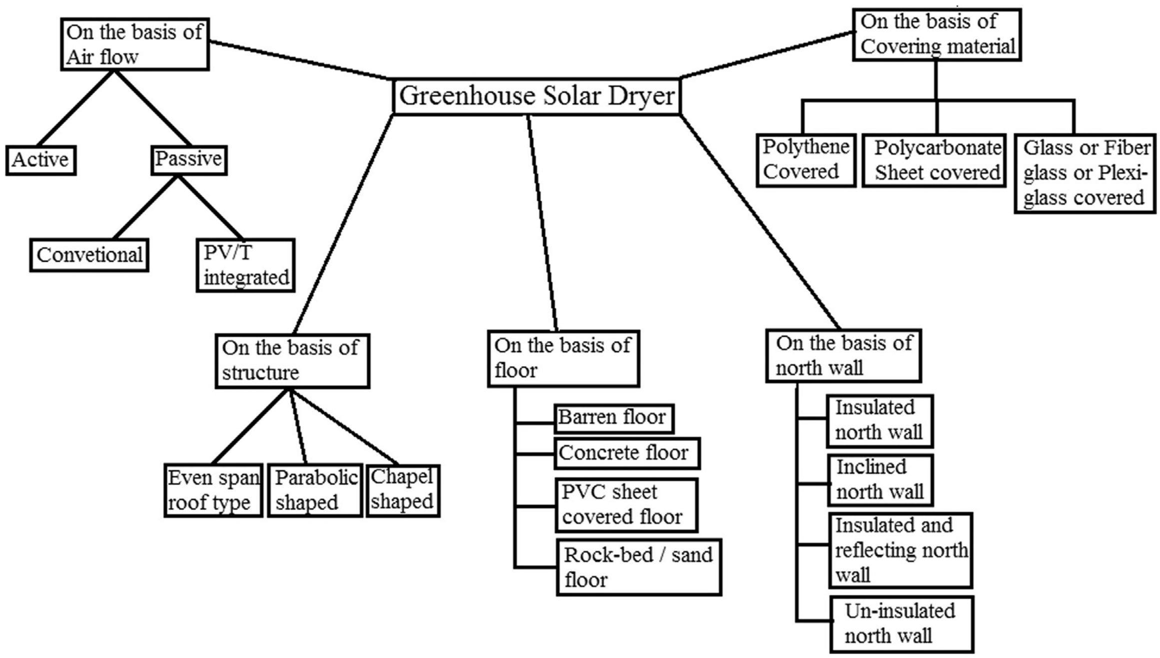

Fig. 1. Classification of greenhouse solar dryer on the basis of our literature review.

Fig. 2. The developed greenhouse solar dryer.

- Using greenhouse coupled with solar air heater to achieve faster drying [30,39].
- Provided additional area enhancing panels to increase drying area [35].

2. Researches on greenhouse based solar dryer

Janjai et al. [1] developed parabolic shaped PV ventilated greenhouse solar dryer with a black concrete floor. The Dryer was installed at Solar Energy Research Laboratory, Silpakorn University at Nakhon Pathom, Thailand. Fig. 2 shows the developed greenhouse dryer. The dryer floor area was 44 m^2 and was enveloped with polycarbonate sheets. A 53 W rating solar panel was provided to run the 3 DC fans. Dryer was loaded with 150 kg of fresh chillies to investigate its performance. The result shows that the chillies had been dried from 80% moisture content to 10% (wet basis). The drying period varies from 2 to $3\frac{1}{2}$ days while in open sun drying it takes 6 days.

Kumar and Tiwari [2] investigated the convective mass transfer coefficient with respect to change in mass of onion flakes in a greenhouse dryer installed at IIT Delhi, India. Three different weights 300 g, 600 g and 900 g of onion flakes were dried continuously for 33 h both in open sun and in the greenhouse. Experimental setup for drying onion under open sun drying, natural and forced convection mode is shown in Fig. 3. The even span roof type greenhouse dryer had a floor area of 1.2 × 0.78 m^2 and was enveloped with UV film. The result shows that, for different modes of drying convective mass transfer of onion flakes

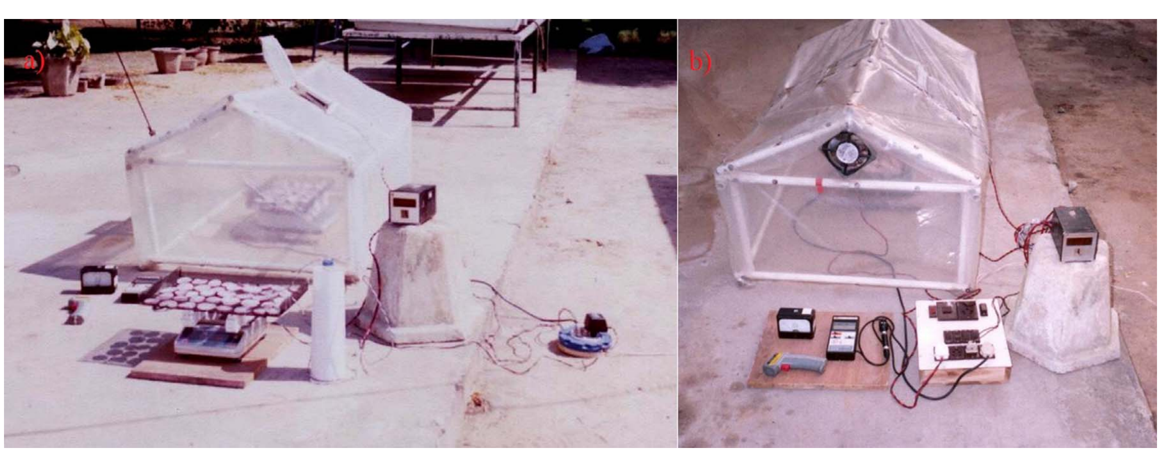

Fig. 3. Experimental setup for onion drying in (a) natural and (b) forced convection mode.