DIRECT TYPE NATURAL CONVECTION SOLAR DRYER: A REVIEW

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ABSTRACT

In many countries, agricultural products are dried under the open sun. However, this way of drying degrades the quality of the dried products due to interference from external impurities and uneven drying rates. Numerous types of solar dryers have been designed and developed in various parts of the world, yielding varying degrees of technical performance. Basically, there are three types of solar dryers; direct solar dryers, indirect solar dryers and mixed-mode dryers. This review paper is focused on the natural convection direct type solar dryers. These are the most cost effective type of solar dryers and are easy to fabricate and use. Direct type natural convection solar dryers do not use any auxiliary equipment and protects the products from external contamination. In this review paper, we reviewed different types of direct natural convection solar dryers and different design modifications applied to them in order to increase their effectiveness.

Keywords: Direct Type Solar Dryer, Natural Solar Dryer.

I INTRODUCTION

With the fossil fuels becoming more expensive day by day and getting depleted, demand for solar energy is increasing drastically. The potential of using solar energy in agricultural sector is also increasing. Solar assisted drying is most promising application of solar energy especially in under developed and developing countries. Traditionally all the agricultural crops were dried in the sun, however, this drying has many disadvantages. Direct sun drying requires large open space area, and very much dependent on the availability of sunshine, susceptible to contamination with foreign materials such as litters, dusts and are exposed to, insects, birds and rodents. Hence, most agricultural produce that is intended to be stored must be dried first.A major barrier to the use of solar drying technology and equipments is their cost. Farmers find these dryers costly and are insecure about using them. However, now, due to advent in solar drying technology, many low cost, easy to operate dryers are being fabricated which are highly efficient. There are various types of dryers developed like direct type solar dryers, indirect solar dryers and mixed-mode dryers. The classification of solar dryers and different drying modes is shown in the fig. 1[8].

In this review paper, we focus on direct type natural convection solar dryers. These are the simplest form of solar dryers. This type of dryer does not use any auxiliary equipment and is cheap as compared to other types of solar dryers.

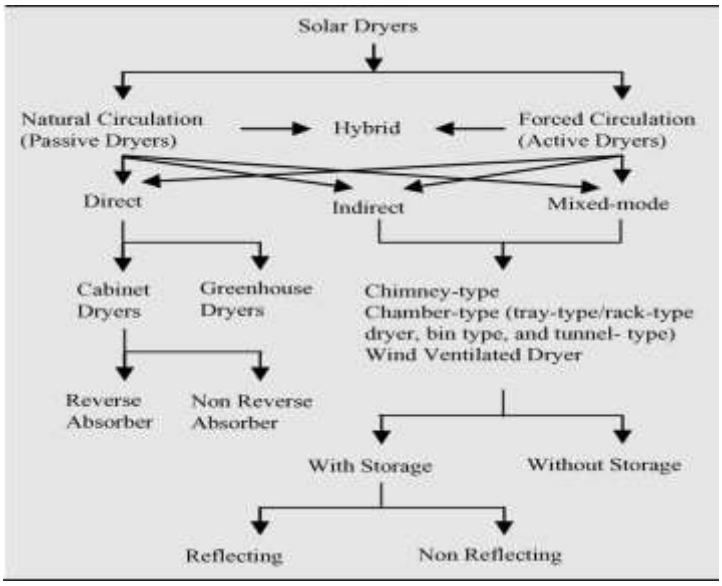

Fig. 1: Classification of solar dryers and drying modes [8].

II DIRECT TYPE NATURAL CIRCULATION SOLAR DRYERS

In natural circulation solar dryers, the products that are to be dryer are stored in the hot box units or in the drying cabin. Heating method is direct, indirect or a combination of the two (mixed type) which depends on the final product quality and time requirement. Heating takes place by natural convection, solar radiation through the transparent cover as shown in fig 2 [8] or through a solar air heater. The natural circulation type solar dryers are inexpensive in constructions, easy to install and operate. Natural convection solar dryers are also called passive mode solar dryers.

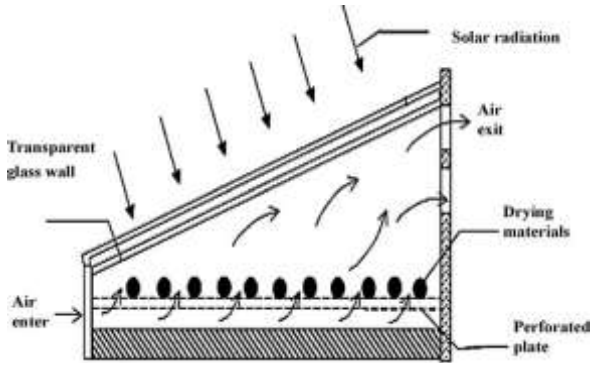

Fig. 2: General structure of a direct type natural convection food solar dryer [8].

III SOLAR DRYER EVALUATION

In order to compare different types of dryers and their various enhancement models, it is necessary to evaluate the performance based on certain parameters. M. Augustus Leon, S. Kumar and S.C. Bhattacharya [9] reported certain parameters that are generally measured to evaluate the performance of the dryers. These parameters could be categorized as:

- Physical features of the dryer:
  - -Type, size, shape.
  - -Drying capacity/loading density.
  - -Tray area and number of trays.
  - -Loading/unloading convenience.
- Thermal performance:
  - -Drying time/drying rate.
  - -Drying air temperature and relative humidity.
  - -Airflow rate.
  - -Dryer efficiency.
- Quality of dried product:
  - -Sensory quality (colour, flavor, taste, texture, aroma)
  - -Nutritional attributes.
  - -Rehydration capacity.
- Cost of dryer and payback period.

IV REVIEW OF DIRECT TYPE NATURAL CONVECTION SOLAR DRYERS

Sodha et al. [1] developed a theoretical and experimental study of the solar cabinet dryer (fig. 3). The experimental results showed that, on atypical summer day fruit mango flesh, with 95% initial moisture content dries up to 13% final moisture content in 12 sunshine hours. It was also concluded that the cabinet type driers were very useful for domestic applications for drying of fruits and vegetables (i.e. high moisture content products) in developing and underdeveloped countries.

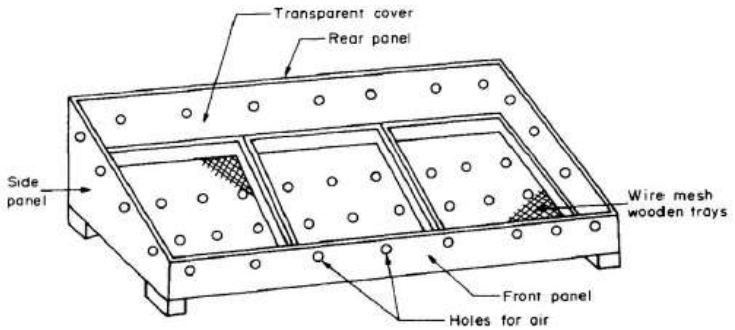

Fig. 3: Experimental setup of a cabinet type drier [1].

Ezekwe [2] reported a modification of the typical designed cabinet dryer (fig.4) which was equipped with a wooden plenum. This plenum was used to guide the inlet air into the dryer. A long plywood chimney was also provided to enhance the natural circulation. This dryer was reported to have accelerated the drying rate by about five times over the open sun drying.

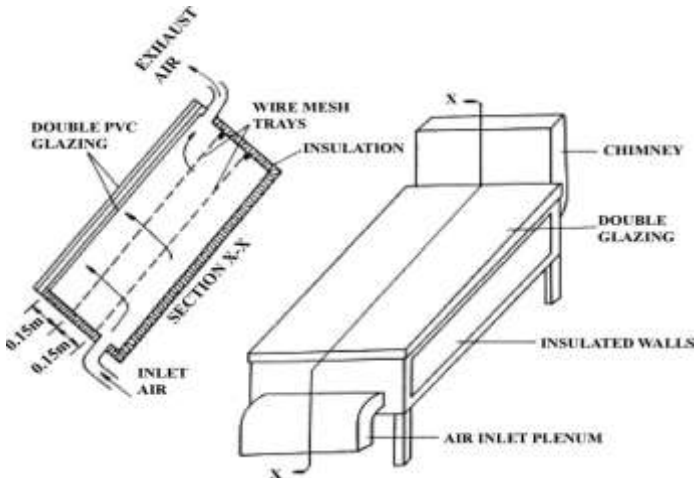

Fig. 4: Natural convection solar dryer modified by Ezekwe [2]

Diemuodeke E. Ogheneruona et al. [3] designed and fabricated a direct natural convection solar dryer for drying tapioca. Through experimentation, the initial and final moisture content were found to be 79 % and 10 % wet basis, respectively. The average ambient conditions recorded were 32ºC and 74 % relative humidity with daily global solar radiation of 13 MJ/m^2/day. They developed a prototype of the dryer with minimum collector area of 1.08 m^2 and performed drying tests under various loading conditions.

EL- Amin Omda Mohamed Akoy et al. [4] developed a natural convection solar dryer (Cabinet Type) to dry mango slices (fig. 5). The dryer specifications are also shown in the figure. The designed dryer had a collector area of 16.8m^2. They dried 195.2 kg of fresh mangoes from 81.4% to 10% wet basis. They dried mangoes in two days under ambient conditions during harvesting period of April to June.

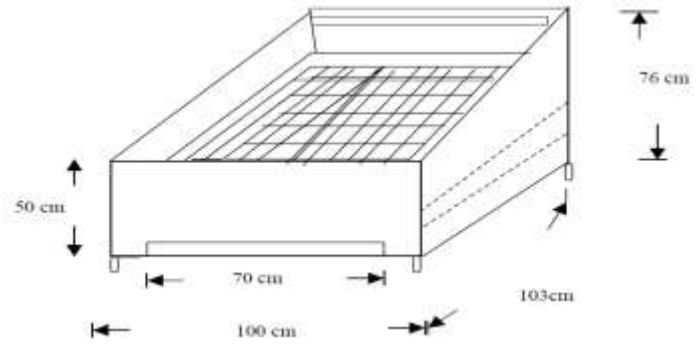

Fig. 5: Natural convection cabinet type solar dryer [4]

Singh et al. [5] developed a natural convection solar dryer (fig. 6). The dryer is a portable solar dryer with multi-shelf-design and intermediate heating. It has four main components, multi-tray rack, movable glazing, shading plate and trays. The multi-rack is inclined depending upon the latitude of the location. The movable glazing consists of a movable frame and a UV stabilized plastics sheet. The dryer is portable and of low cost to make it economically viable. It can be used in cottage industries in remote places.

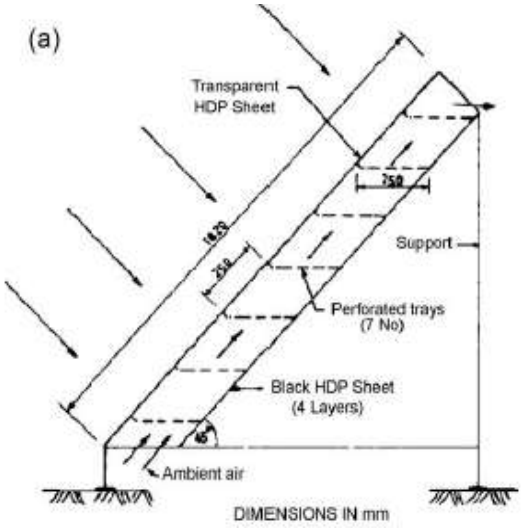

Fig. 6: Natural convection multi-shelf portable solar dryer [5].

H. Yobouet Andoh et al. [6] designed a natural convection direct type solar dryer (Fig. 7). They constructed the dryer using local materials and then tested it experimentally to dry foodstuffs (cassava, bananas, and mango). They analysed the behaviour of the dryer and the study mainly relates to the kinetics and establishment of drying heat balances.

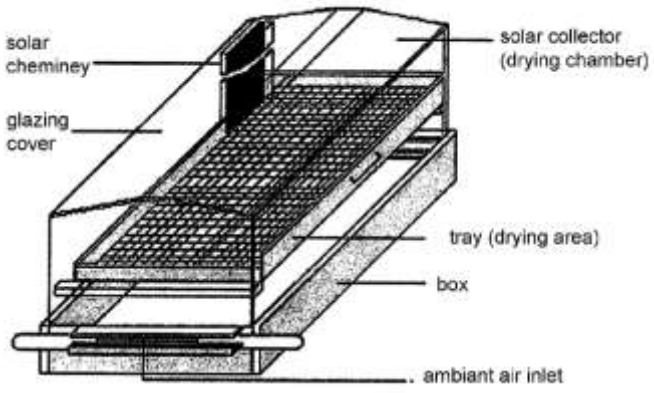

Fig. 7: Schematic of solar dryer with natural convective heat flow [6]

They studied the influence of significant parameters governing heat and mass transfers, such as drying air mass flow, solar incident radiation, and effectiveness in order to evaluate thermal performances of the dryer. They represented the experimental data in the form M (t) = Miexp (-kt) for representation of drying process. Through this drying process, they concluded that the moisture content of cassava and sweet banana was reduced from 80% to the safety threshold value of 13% in 19 and 22 h, respectively. They concluded that the drying rate increases with drying air temperature and drying air mass flow and also highlighted the influence of various parameters on the drying process and to establish empirical correlations describing their characteristics.

Ben Akachukwu et al. [7] developed a small scale direct mode natural convection solar dryer for drying tomato, okra and carrot using locally available and affordable materials. They sliced these crops and loaded them in the dryer at the same time. They compared the results with that of open sun drying and observed that sliced samples of tomato, carrot and okra dried with solar dryers, achieved 54.55, 52.88 and 50.98 percent gain in drying time respectively. They observed that tomato; carrot and okra dried in solar dryers attained 21.80%, 21.18% and 24.95% system drying efficiencies respectively as compared to open sun drying efficiencies of 10.59%, 12.71% and 15.19% for the same.

V CONCLUSION

This review paper is focused on direct type natural convection solar dryers. A comprehensive study of how natural convection solar dryers fare compared to other dryers, various design modifications and enhancement techniques applied to them is done. In this paper, various new improvements to the convectional natural convection dryers are also discussed. The natural convection direct type dryers are the most cost effective type of solar dryers and are easy to fabricate and use. Direct type natural convection solar dryers do not use any auxiliary equipment and protects the products from external contamination. These are the simplest form of dryers and are easy to fabricate, use and cost effective.

To further improve the efficiency of these dryers, various enhancement techniques and design modifications need to be applied to them such as desiccant materials, heat storage units, etc.

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