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Review on Solar Dryer for Grains, Vegetables and Fruits.

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Abstract

In this paper a review of the solar dryer is presented. The world population is more than 6 billion and about 20-25 percent people does not have enough food to eat. It has been estimated that world as a whole more than 25-30 percent food grains and 30-50 percent vegetables, fruits etc. are lost before it reaches to the consumers. To overcoming spoiling problems of vegetables, food grains and fruit; 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 flavor. A solar dryer is an enclosed unit, which is used to dry agricultural products. It is also required to keep the food safe from damage, birds, insects and unexpected rainfall. Solar dryers, also known as dehydrators, have been used throughout the ages to preserve grains, vegetables and fruits by removing moisture. Solar dryers can be made locally of any size and capacity and solar dryers are economical if cash crops are dried. The various design of the solar dryer is reported in the literature thus far is presented.

1. Introduction

Grains vegetables and fruits are agricultural products that are known for their rich vitamins, high concentration of moisture and low fats. These are seasonal crops and are mostly available during the production season. The demand for vegetables by the growing population has not been met despite the increase. This is as a result of wastes that result from biological and biochemical activities taking place in the fresh product and unfavorable storage conditions, inefficient handling, transportation, inadequate post harvest infrastructure and poor market outlets. Sun drying is still the most common method used to preserve agricultural products like grains and vegetables in most tropical and subtropical countries. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. Sun drying is only possible in areas where, in an average year, the weather allows foods to be dried immediately after harvest. However, being unprotected from rain, wind and dust, damage by birds, insects and other animals, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried products may have adverse economic effects on domestics and international markets. Direct exposure to sunlight reduces the quality (colour and vitamin content) of some fruits and vegetables Moreover, since sun drying depends on uncontrolled factors; production of uniform and standard products is not expected. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer which comprises of collector, a drying chamber and sometimes a chimney (Madhlopa *et al.*, 2002). The conditions in tropical countries make the use of solar energy for drying food practically attractive and environmentally sound. Dryers have been developed and used to dry agricultural products in order to improve shelf life, product variety and large volume reduction Most of these either use an expensive source of energy such as electricity (El-Shiatry *et al.*, 1991) or a combination of solar energy and some other form of energy (Sesay and Stenning, 1996). Most projects of these natures have not been adopted by the small farmers, either because the final design and data collection procedures are frequently inappropriate or the cost has remained inaccessible.

1.1. Types of solar drying system.

1.1.1 Direct type dryers: In direct or natural convection type dryers, the agricultural product is placed in shallow layers in a blackened enclosure with a transparent cover. The solar radiations are directly absorbed by the product itself. The food product is heated up and the moisture from the product evaporates and goes out by the natural convection/circulation.

1.1.2 Indirect type dryers: In these dryers the food product is placed in a drying chamber. The air is heated in solar air heaters and then blown through the drying chamber. In some of the designs, dryers receive direct solar radiations and also heated air from solar air heaters. In these dryers manipulation of temperature, humidity and drying rate is possible to some extent.

1.1.3 Forced circulation type dryers: In these dryers, hot air is continuously blown over the food product. The food products itself is loaded or unload continuously or periodically. These kind of dryers are comparatively thermodynamically efficient, faster and can be used for drying large agricultural product. These dryers can be of Cross-flow type, concurrent flow type or counter-flow type.

1.2. Advantages of Solar drying system.

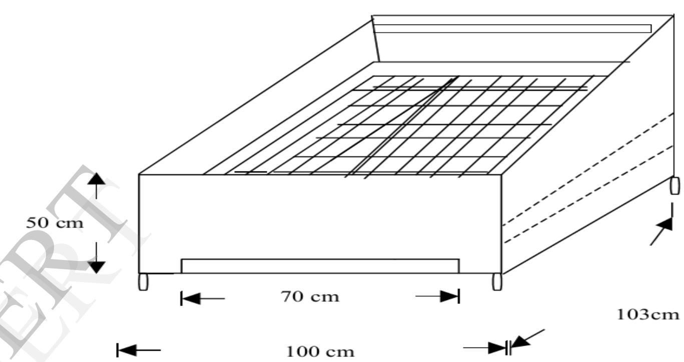
The higher the temperature, movement of air, and lower humidity, increases the rate of drying. Dryers are waterproof so the product is protected against flies, rain and dust; product can be left in the dryer overnight or during rain. The quality of the product is better in terms of nutrients, hygiene and colour, It permits early harvesting and reduces the field losses of the products, It permits better planning of harvesting season, It reduces spoilage in storage drastically, It permits the farmer to sell his product at better price during early period of harvesting season, Quality of the product gets enhanced significantly and hence farmer gets more money for his product, and Transportation is easy with dried product.

1.3. Disadvantages of solar drying system.

The main disadvantage of the solar dryer is the limited time of solar isolation during the day, long drying times, and contamination of product, natural drying, and energy requirement, initial investment cost is very high.

2. Literature Review.

2.1. Amin Omda Mohamed Akoy et al. [1] reported on a natural convection solar dryer of a box- type (cabinet) was designed and constructed. The constructed dryer consisted of drying chamber and solar collector combined in one unit as shown in Figure.1.and they concluded the designed dryer with a solar collector area of 16.8 m² is expected to dry 195.2 kg fresh mango (100kg of sliced mango) from initial moisture 81.4% to 10% final moisture in two days under ambient conditions during harvesting period from April to June.

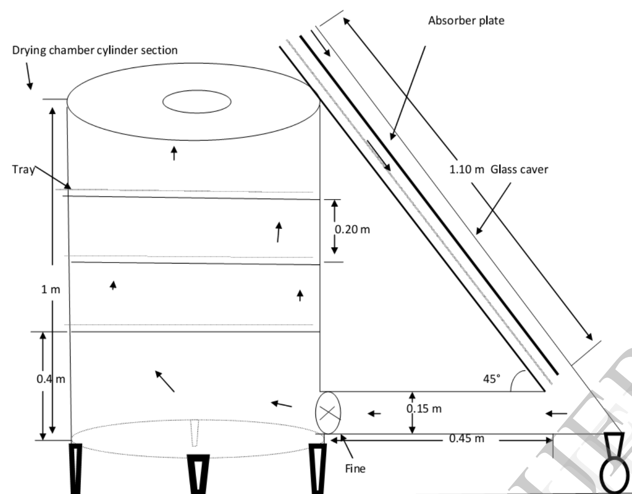


“Figure.1.Isometric view of constructed solar dryer.”

A prototype of the dryer with 1.03m² solar collector area was constructed to be used in experimental drying tests. The average ambient conditions are 30ºC air temperature and 15% relative humidity and air flow rate 0.0903 kg/s with daily global solar radiation incident on horizontal surface of about 232 W/m² for drying time 10 hours per day.

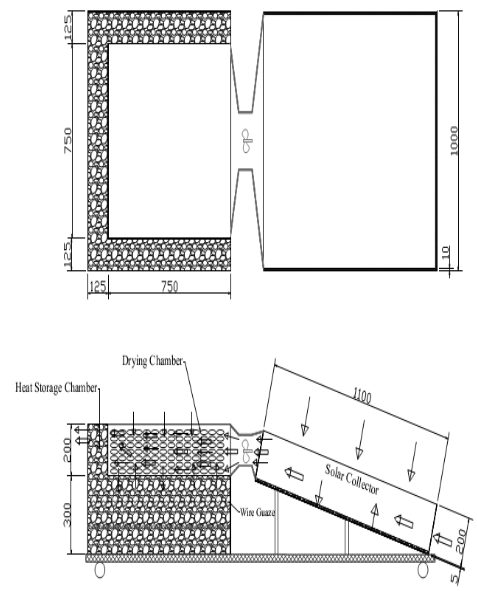
2.2. Ahmed Abed Gatea [2] developed a solar drying system of a cylindrical section and analysis of the performance of the thermal drying system as shown in figure.2 The system consists of a solar collector flat plate with length of 1.10 m and width of 1.10 m drying chamber cylindrical section and a fan was built and designed for the purpose of drying 70 kg of bean crop. The performance of the solar air collector using three air flow rates has been tested. The highest temperature

(71.4°C) of the outlet solar collector has been obtained at 11 am. At radiation intensity 750 W/m² for air flow rate of 0.0401 kg/s was obtained and minimum temperature (40.0°C) was obtained when air flow rate was 0.0675 kg/s at radiation intensity 460 W/m² was obtained. The maximum value of average thermal efficiency 25.64% of the solar air collector obtained at air flow rate of 0.0675 kg/s, and minimum average thermal efficiency is 18.63% at air flow rate of 0.0405 kg/s.The initial moisture content of beans was 70% and final 14% when the air flow rate was 0.0405 kg/s 18% d.b at air flow rate of 0.0540 kg/s and 20% d.b at air flow rate of 0.0765 kg/s.



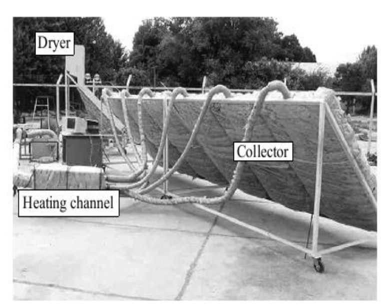
"Figure.2.Sectional view of the solar drying system,a cylindrical section."

2.3.A.O. Fagunwa et.al [3] persons had developed a solar dryer with thermal energy storage for intermittent drying of cocoa beans as shown in figure.3. Drying mechanism was based on a combination of convective heating and direct radiation, with a provision for controlling the rate of air flow through the beans. The solar collector area is basically a top open wooden box, 1100 x 1000 x 200 mm made from 10mm thick plywood. The experimental model dehydrated cocoa beans from 53.4 to 3.6% moisture content (w.b) in a 72 hours inter-mittent drying process against ambient temperature and relative humidity in the range 25-30°C and 58-98%, respectively. Free convective drying attained equilibrium moisture content of 3.56% (w.b); whilst, 9.09% and 7.11% (w.b) were obtained with the forced convective drying, with 1.02 and 1.32 m3/min airflow rates, respectively.



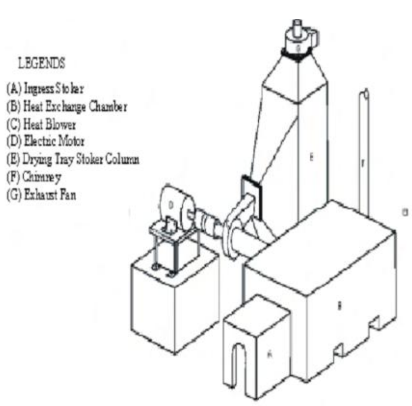
"Figure.3 A Schematic illustration showing plan view and elevation of the experimental solar dryer, air flow and heat flow."

2.4.A Zomorodian*, D. Zare, H. Ghasemkhani presented optimization and evaluation of a semi-continuous solar dryer for cereals (Rice, etc.) as shown in figure 4.



"Figure.4.A new semi-continuous active mixed-mode type drying system (six solar air heaters, heating channel, air ducts, fan and dryer)"

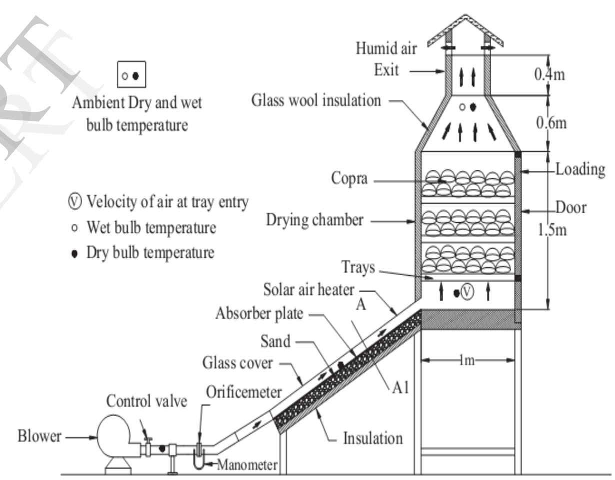
The rough rice solar dryer was a cross flow and an active mixed-mode type with a new and an efficient timer assisted semi-continuous discharging system. The Drying rig was designed and fabricated which consists of six ordinary solar air heaters, an auxiliary electric heating channel, a drying chamber with an electrically rotary discharging valve and an air distributing system. The area of each collector was 2 m² (totally 12 m²) and they were installed on a light frame tilted 45° towards the south. The experiments were conducted on sunny days between 11 am 2 pm (Sep.2001 with average incident solar radiation of 865 W/m², nearly constant relative humidity and average ambient air temperature of 25ºC). One of the objectives in this research was to evaluate the effect of air mass flow rate and time interval of crop discharge, on the rate of crop drying by the dryer. Therefore three levels of air mass flow rate of 0.0048, 0.0066 and 0.011 kg/ m²/s and two levels of interval time of 15 and 30 min successive discharge for rotary valve were adopted. Drying air temperature of 55ºC was maintained throughout the experiments. The maximum efficiency of the collectors was 37.13%.The maximum capacity of the dryer was about 132 kg rough rice with 27% initial down to 13% final moisture content in three hours drying time. The maximum overall drying system efficiency was 21.24% on 0.011 kg/ m²/s and interval discharge time of 15 min, whereas the maximum drying capacity was on 0.011 kg/ m²/s with 30 min interval discharge time with overall drying system efficiency of 18.23%



."Figure.5.The perspective view of fruit and vegetable dryer."

J.C. Ehiem et.al [5] also designed and developed an industrial fruit and vegetable dryer to reduce vegetable wastage and improve storage conditions as shown in figure.5.The dryer which has a mean drying capacity Of 258.64 kg of tomatoes per batch with a thermal efficiency of 84 % and drying rate of 40 g/hr, at relative humidity of 35% and drying temperature 50ºC improved the drying time of vegetables and is recommended to industrial users. The device has a mean thermal efficiency of 82% with average capacity of 258.64 kg/batch. The average drying rate of the device is 40 g/h.The size, air flow rate and drying time have highly significant effect on gram weight of the tomato slices being dried. For all the tomato sizes and at all air flow rate levels, weight of the tomato decreased with increase in drying time. Also for all the sizes at all drying time levels, gram weight decreased with increase in air flow rate.

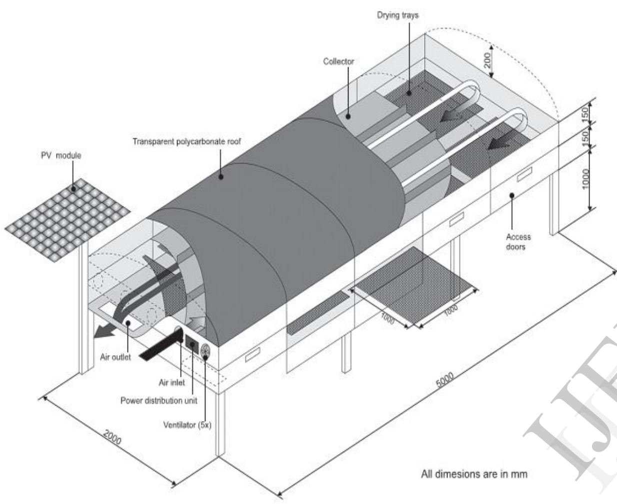
2.6. M. Mohanraj and P. Chandrasekhar built forced convection solar dryer and tested for the drying copra under Indian climate conditions as shown in figure.6.



"Figure.6: Schematic view of the solar dryer used for copra drying."

At that time a maximum solar intensity of 932 W/ m² was observed. The average relative humidity about 68% and The average drying air temperature at the inlet of the drier was 43ºC The maximum drying air temperature recorded was 63ºC. At the outlet of the drying chamber, a high relative humidity of about 90% was recorded during the initial stages of drying but this gradually reduced to about 34% at the end of drying. The average moisture content of the coconut was reduced from about 51.8% to 7.8% and 9.7% in the bottom and the top tray, respectively, after 82 h. The moisture reduction during the first and the second day of drying was found to be about 33% and 20%, respectively. Finally, they concluded that forced convection solar drier is more suitable for producing high-quality copra for small holders. About 75% of high-quality copra could be produced. The average thermal efficiency of the solar air heater was found about 24%.

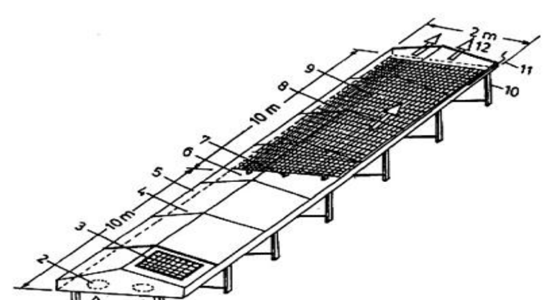
2.7.J. Banout et.al [7] designed Doubled Pass Solar Dryer (DPSD) for drying red chilli in central vietanam as shown in figure.7. and compared with cabinet dryer (CD) and traditional open sun drying.



" Figure.7:Description of double pass solar dryer."

They found that average drying temperatures were 60ºC, 52ºC and 35.8ºC and corresponding relative humidity 34%, 45% and 62% for DPSD, CD and open-air sun drying, respectively. The overall drying efficiency of DPSD is 20% which is typical for forced convection solar dryer. The moisture content of fresh red chilli was almost similar during all drying tests where as the initial values were 9.18kg/kg,9.17kg/kg and 9.30kg/kg (db) for DPSD, CD and open-air sun drying, respectively. Where the final moisture content in case of DPSD 0.05kg/kg was reached after 23 h, 0.09kg/kg after 29h for CD and 0.18kg/kg after 36 h in case of open sun drying (excluding nights).The performances of a new designed DPSD have been compared with those of a typical CD and a traditional open-air sun drying for drying of red chilli. The DPSD resulted in the shortest drying time to meet desired moisture content of chilli (10% w.b.), which corresponds to the highest drying rate comparing to other methods. The DPSD shows higher performance as well in all measured efficiencies, of which the overall drying efficiency was more than two times higher in case of DPSD compared to CD Although the construction cost of DPSD was higher than in CD, the drying costs per one kilogram of chilli were by 39% lower in case of DPSD as compared to CD. However taking in to the consideration the life of both driers the payback period of DPSD is preferable. Hence, Double-pass solar drier was found to be technically and economically suitable for drying of red chillies under the specific conditions in central Vietnam.

2.8.M.A. Hossaina and B.K. Bala were used a mixed mode type forced convection solar tunnel drier to dry hot red and green chillies under the tropical weather conditions of Bangladesh as shown in figure 8.which consists (1.air inlet 2.fan;3.solar module;4.solar collector;5.side metal frame;6.outlet of the Collector 7.wooden support; 8.plastic net; 9.roof structure for supporting the plastic cover; 10.base structure for supporting The dryer;11.rolling bar; 12,outlet of the drying tunnel.)The drier had a loading capacity of 80 kg of fresh chillies.

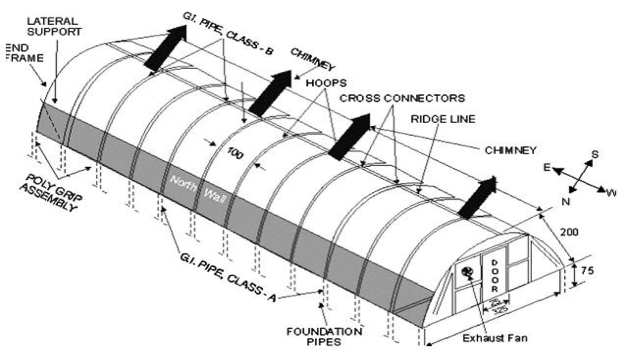


"Figure.8. Solar tunnel dryer."

Moisture content of red chilli was reduced from 2.85to 0.05 kg/kg(db) in 20 h in solar tunnel drier and it took 32 h to reduce the moisture content to 0.09 and 0.40 kg/kg (db) in improved and conventional sun drying methods, respectively. In case of green chilli, about 0.06 kg/kg(db) moisture content was obtained from an initial moisture content of 7.6 kg/kg(db) in 22 h in solar tunnel drier and 35 h to reach the moisture content to 0.10 and 0.70 kg/kg(db) in improved and conventional sun drying methods, respectively. Average air temperature rise in drier was about 21.62 ºC.

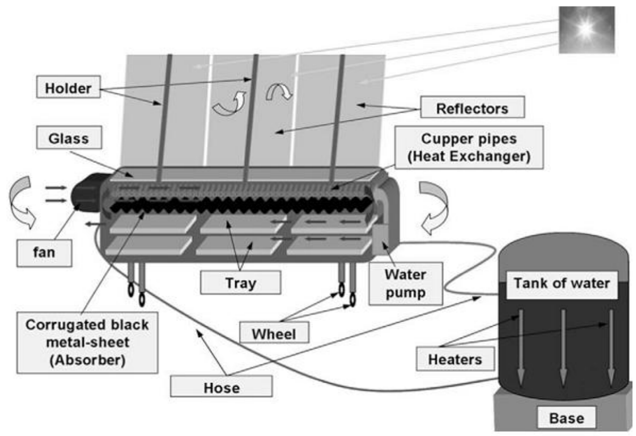
2.9.N.S. Rathore and N.L. Panwar used experiment studies on hemi cylindrical walk-in type solar tunnel dryer for grape drying as shown in figure 9.

“Figure.9: Schematic of natural convection solar dryer.”



The dryer was designed for drying grapes on large scale. Maximum allowable temperature inside the drying was 65ºC with average solar radiation 2.3 MJ/ m²/h and 10 h duration per day for drying 320 kg grapes. Specific Heat of air 1.012 kj/kg/ºC and finally they had reduced moisture content from 85% to 16% in 7 days by using tunnel dryer with 30% dryer efficiency.

2.10.B.M.A. Amer et.al[10] developed a hybrid solar dryer was designed and constructed using direct solar energy and a heat exchanger as shown in fig.10.



“Figure.10.Schematic diagram of solar hybrid dryer.”

The efficiency of the solar dryer was raised by recycling up to 65% of the drying air in the solar dryer and exhausting a small amount of it outside the dryer. Under Mid-European summer conditions it can raise up the air temperature from 30 to 40ºC above the ambient temperature. The capacity of the dryer was to dry about 30 kg of banana slices in 8 h in sunny day from an initial moisture content of 82% to the final moisture content of 18% (wb).In the same time it reduced to only 62% (wb) moisture content in open sun drying method.

Conclusion

In this paper, a review of the research paper is state that, use of solar dryer led to considerable reduction in drying time in comparison to that of conventional sun drying, and the product dried using this dryer were of better quality as compare to their conventional sun dried. The efficiency of solar drying system is affected by the properties of drying materials.e.g.moisture content, size, shape, and geometry as well as ambient conditions which includes solar radiation and temperature, relative humidity, velocity and atmospheric pressure of ambient air.

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