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REVIEW OF HYBRID SOLAR DRYERS

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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 hybrid solar dryers. Drying proceeded successfully even under unfavorable weather conditions in the hybrid mode of operation these are the most cost effective type of dryers and are easy to fabricate and use. In this review paper, we reviewed different types of hybrid solar dryers and different design modifications applied to them in order to increase their effectiveness.

KEYWORDS: Direct Type Solar Dryer, Natural Solar Dryer, Hybrid Solar Dryer.

REVIEW OF HYBRID SOLAR DRYERS

Michael W. Bassey developed hybrid crop dryer using solar energy and saw dust. The dryer design uses direct solar energy and a heat exchanger through which steam, produced by a "hole-through-sawdust" burner, and circulates. Results of tests, for no load and using okra (Hibiscus esculentus L.), show that the dryer, operating between 40 and 70 *C, can dry twice faster than the traditional method.

DESIGN OF HYBRID DRYER

The general features of the dryer, consisting of a burner and cabinet dryer are shown in Fig. 1. Designed using reported work , the burner (100x56x25 cm^3) had primary and secondary loaders with 20 and 8 burner holes respectively, spaced 10 cm between centers. Four galvanized iron evaporator pipes (110cm long, 1.27 cm diameter) connected to 6.5 cm header pipes, were mounted directly over the burner holes.

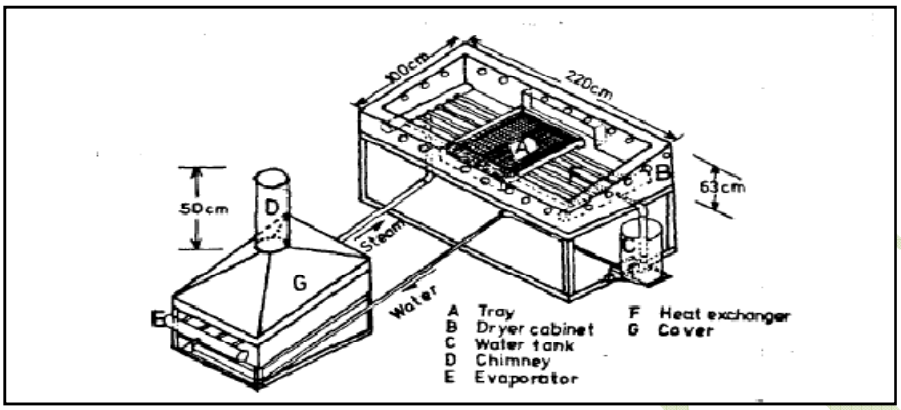


Fig. Diagram showing general features of drying

This hybrid dryer produces a better quality product and can, depending on the heat source, reduce the drying time by up to 50 percent compared to traditional drying.

A. G.Ferreira et al. developed a hybrid solar-electrical dryer was built, composed of a solar chamber (in which the air is heated) and of a drying chamber (Fig.). The solar chamber is inclined at 30° from horizontal, opened at its edges, with 1.50 m of length, 1.20 m of width and 0.20 m of internal height. The walls of the solar collector were built with galvanized steel plates, painted in black, thermally insulated with wool glass and covered with galvanized steel plates painted in gray. The solar chamber is covered with glass.
The drying chamber has 0.90 m of length, 1.20m of width and 0.96 m of height. It was built using galvanized steel plates, thermally insulated with wool glass and covered with galvanized steel plates painted in gray. To complement solar heating, an auxiliary heating system was installed on the bottom of the drying chamber. The auxiliary heating system is composed of 20 incandescent lamps of 100 W each. To allow the drying air exit, a 0.20 m diameter chimney (with an exhauster) was installed on the top of the dryer. Eight trays (0.74 m x 0.52 m) were put inside the drying chamber, corresponding to an area of 3.08 m^2. The products can be introduced and removed trough two doors, located on the back of the dryer. A thermostat was installed in the chimney to control the airflow temperature in the device outlet.

Fig: Hybrid solar-electrical dryer

Experimental runs for drying of banana slices were performed. Banana slices were exposed to natural sun drying in the hybrid dryer and in an artificial dryer and the drying curves obtained were compared. Results showed that the time required by the samples to reach the desired final moisture content was lower in the

hybrid dryer when compared with natural sun drying and with the artificial dryer, to similar outlet air temperatures. Incandescent lamps used as an auxiliary energy system in the hybrid dryer provided a faster drying; however, the thermal losses were more significant and the products did not dry homogeneously. The products in the trays closer to the lamp presented a faster rate of drying. When compared with artificial dryers, the proposed dryer is technically and economically viable. It represents a suitable alternative to dry agricultural products.

Reyes A et al developed a hybrid solar dryer for drying tomato. Tomato pieces were dehydrated in a hybrid solar dryer provided with a 3 m2 solar panel and electric resistances. At the outlet of the tray dryer 80 or 90% of the air was recycled and the air temperature was adjusted 50 or 60ºC. At the outlet of the solar panel the air temperature raised between 5 and 18°C above the ambient temperature. Temperature and sample size significantly affected critical moisture content. The color parameters of dehydrated tomato indicate a notorious redness. Rehydration was achieved in less than 50 minutes. Drying kinetics was adequately adjusted with three empirical models. Sorption isotherms adjusted soundly well with the Guggenheim-Anderson-de Boer and Peleg models. The solar energy input resulted in 6.6-12.5% energy saving.

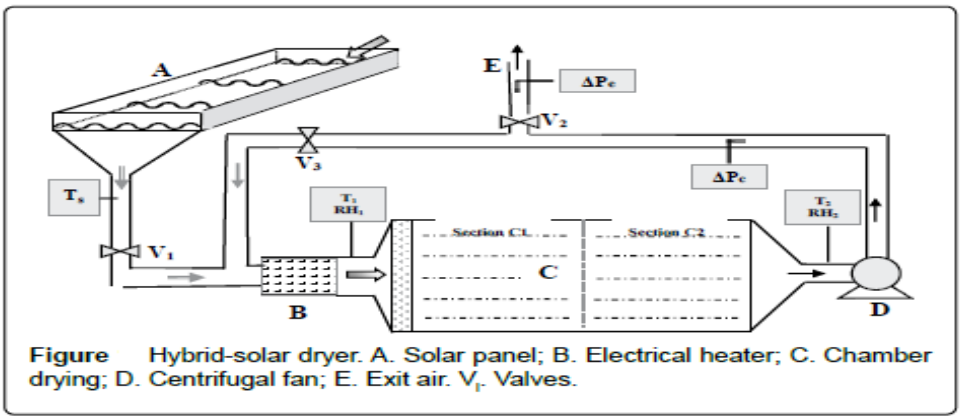


Figure Hybrid-solar dryer. A. Solar panel; B. Electrical heater; C. Chamber drying; D. Centrifugal fan; E. Exit air. V_i. Valves.

Okoroigwe E. C. et all have designed solar and biomass dryer for developing countries. A small scale demonstration model consisting of a combined solar and biomass cabinet dryer with 3 equally spaced drying trays was designed, constructed and evaluated. The results, obtained using fresh yam chips as test material over a four day test period, were satisfactory and useful for optimization purposes. Maximum tray temperature of 53°C was obtained in combination with solar and biomass heating sources even though the ambient temperature for the test period was between 24 and 30°C. An optimal drying rate of 0.0142 kg/hr was achieved with the combined solar and biomass dryer, compared to the lower drying rate of 0.00732 kg/h for the solar drying and 0.0032 kg/h for the biomass drying. This study proved that the efficiency of agricultural dryers could be increased through the use of a combination of solar and biomass heating sources, compared to conventional dryers with only solar or only biomass heating sources. It implies that improvements in the design and construction of the various components of the system would lead to more efficient dryers for use in small and medium business enterprises for sustainable development of developing countries. Using combined solar and biomass dryers have the potential to increase the productivity and resultant economic viability of small and medium-scale enterprises producing and processing agricultural produce in developing countries. African countries, with large quantities of natural resources, like forests and solar radiation, could make the most use of these types of dryers.

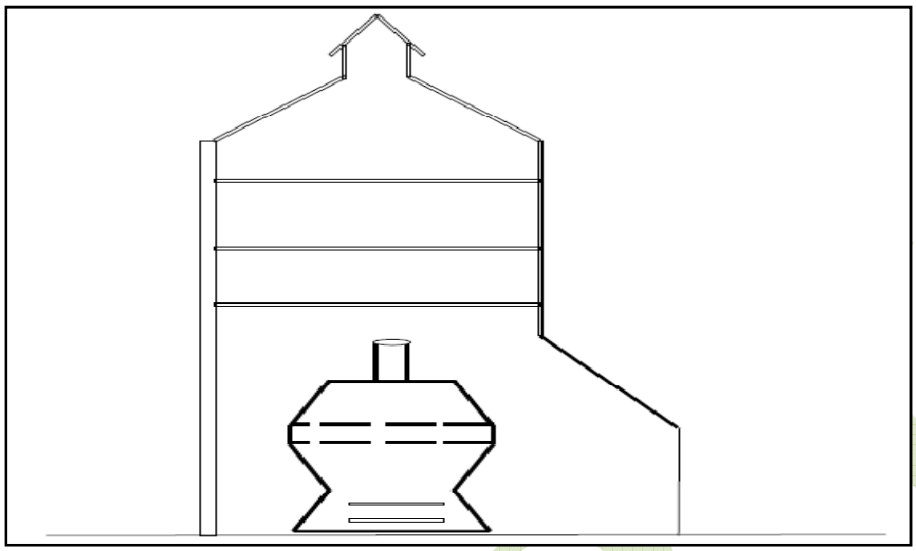


Fig. Dimensionless sketch of combined Solar Biomass dryer

Using combined solar and biomass dryers have the potential to increase the productivity and resultant economic viability of small and medium-scale enterprises producing and processing agricultural product in developing countries.

Sajith K. G. C. Muraleedharan has done study on drying of alma using solar hybrid dryer. In this work, Indian gooseberry or amla fruit which is the richest source of vitamin C among fruits were dried using a hybrid photovoltaic thermal (PV/T) dryer. An experimental hybrid solar dryer associated with a photovoltaic (PV) system was developed for the purpose. The experimental hybrid system consisting of a double pass arrangement produces both electric and thermal energy simultaneously. Drying process of amla samples using the hybrid system has been compared with open sun drying. The developed hybrid PV/T drying system produces better quality products in shorter time by the efficient use of solar energy.

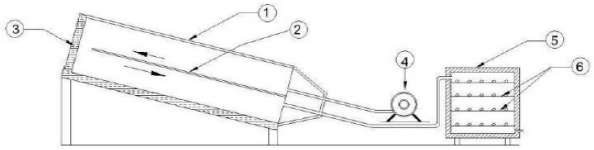


FIGURE . EXPERIMENTAL SET UP
(4) Top glass cover (2) Photovoltaic panel (3) Insulation Blower (5) Solar dryer (6) Trays

In this study, the performance of a hybrid photovoltaic thermal (PV/T) drying system which produces both thermal and electric energy simultaneously using a solar panel of rating 100 W was investigated. The thermal energy produced was used for the controlled drying of amla. By using this hybrid system, better drying performance was obtained compared with open sun drying. The closed nature of the system prevents many typical short-comings of open sun drying such as microbial contamination and exposure to humid environment.

B.M.A. Amer et all have done performance evaluation on hybrid solar dryer for banana. A hybrid solar dryer was designed and constructed using direct solar energy and a heat exchanger. The dryer consists of solar collector, reflector, heat exchanger cum heat storage unit and drying chamber. The drying chamber was located

under the collector. The dryer was operated during normal sunny days as a solar dryer, and during cloudy day as a hybrid solar dryer. Drying was also carried out at night with stored heat energy in water which was collected during the time of sun-shine and with electric heaters located at water tank. The efficiency of the solar dryer was raised by recycling about 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 40 _C above the ambient temperature. The solar dryer was tested for drying of ripe banana slices. 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.
The colour, aroma and texture of the solar dried products were better than the sun drying products.

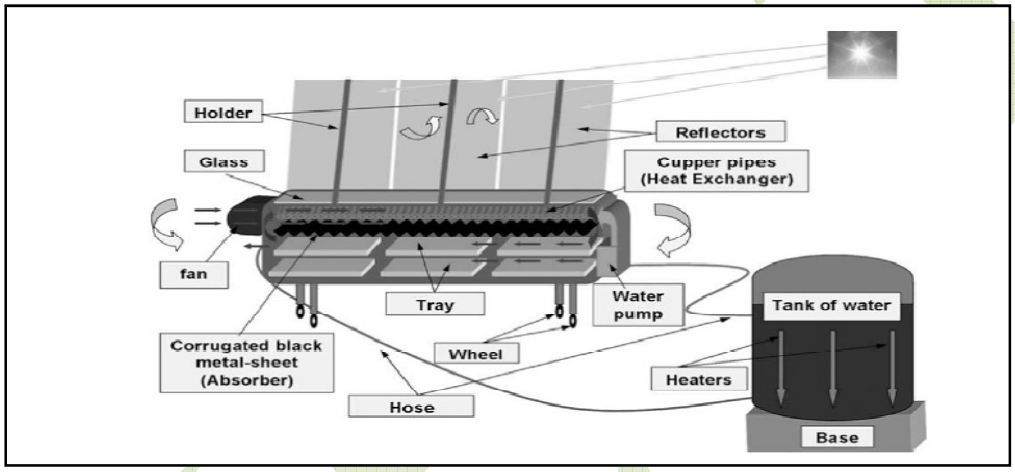
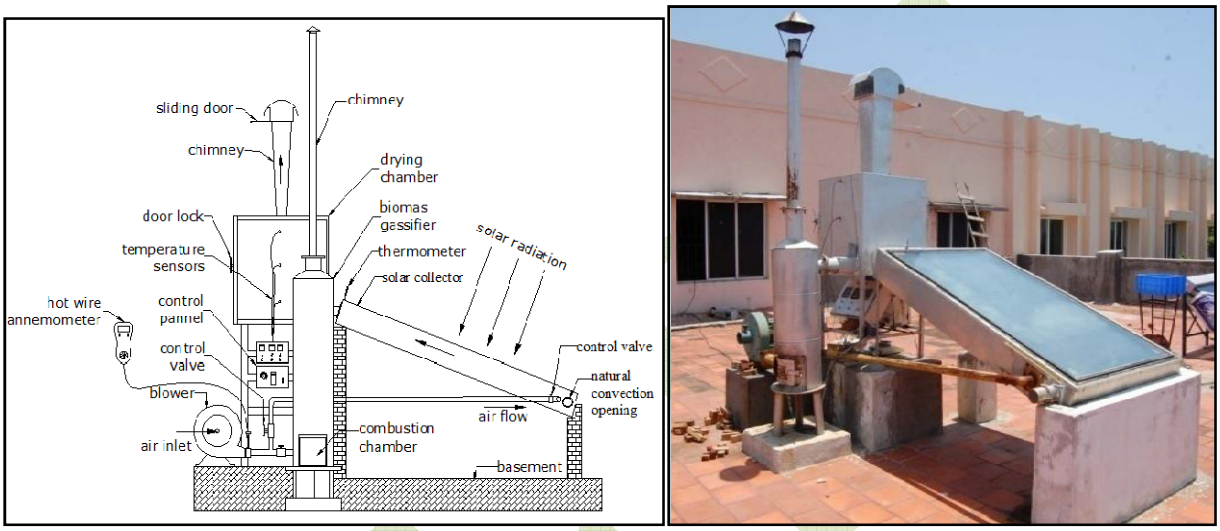


Fig. Schematic diagram of solar hybrid dryer

The efficiency of the solar dryer could be raised by recycling about 65% the drying air again in the solar dryer. It was found that the best condition for collecting the solar energy during the day by the solar dryer is using the solar reflectors with holders to move it according to the sun angles during the day, and by turning the dryer also according to the sun angles. Under Mid-European summer conditions it can raise up the air temperature between 30 and 40 _C above the ambient temperature. The solar dryer was tested for drying of ripe banana slices. 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). The dryer can also be used with an auxiliary heat source with the dryer when adverse weather conditions exist. Using the water tank with the solar dryer, about 15 _C can be stored in water during the time of sun-shine. During the night, the system transfers the stored heat from the water to the air inside the solar dryer and controls the air temperature through the drying process at night. The colour, aroma and texture of the solar dried products were better than the sun drying products.
Drying of Cashew nut to remove test is one of the most energy-intensive processes of cashew nut process industry. For this reason Dhanushkodi **Saravanan et all** designed and fabricated a hybrid dryer consisting of a solar flat plate collector, a biomass heater and a drying chamber. 40 kg of Cashew nut with initial moisture of 9 % is used in the experiment. The performance test of the dryer is carried out in two modes of operation: hybrid-forced convection and hybrid-natural convection. Drying time and drying efficiency during these two modes of operation are estimated and compared with the sun drying. The system is capable of attaining drying temperature between 50º and 70ºC. In the hybrid forced drying, the required moisture content of 3% is

achieved within 7 hours and the average system efficiency is estimated as 5.08%. In the hybrid natural drying, the required moisture content is obtained in 9 hours and the average system efficiency is 3.17%. The fuel consumption during the drying process is 0.5 kg/hr and 0.75 kg/hr for forced mode and natural mode, respectively. The drying process in the hybrid forced mode of operation is twice faster than the sun drying. The dryer can be operated in any climatic conditions: as a solar dryer on normal sunny days, as a biomass dryer at night time and as a hybrid dryer on cloudy days. Based on the experimental study, it is concluded that the developed hybrid dryer is suitable for small scale cashew nut farmers in rural areas of developing countries.



The solar biomass hybrid dryer has been fabricated for the purpose of drying 40kg of cashew nut per batch. The average collector efficiency of the system in the hybrid forced mode is 75.6%. Temperature between 5575ºC and 75ºC can be obtained depending on the weather conditions and fuel used. This is a practical technology which can be used for dying of cashew as well as of other agricultural products. This system could reduce drying time by half when compared to the open sun drying and it produces a high quality cashew nut (W240). Improvements in the performances of dryer could be achieved through further modification which include (1) providing the parabolic reflector on both sides of the collector, (2) increasing the absorptivity of the absorber plate by replacing copper plate with aluminum one, (4) increasing air flow rates, and (5) providing PVT operated electrical heating coil. It can be concluded that the developed dryer is more suitable for cashew nut farmers in rural areas of developing countries.

CONCLUSION

This review paper is focused on hybrid solar dryers. A comprehensive study of how hybrid 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 hybrid dryers are also discussed. The Hybrid dryers are the most cost effective type of dryers and are easy to fabricate and use. Hybrid solar dryers do not use any auxiliary equipment and protects the products from external contamination and it can use in unfavorable weather condition and also it is used in night time. These are the simplest form of dryers and are easy to fabricate, use and cost-effective.

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