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Recent Trends of Hybrid Solar Dryer

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ABSTRACT

In most of the countries trends are agricultural product drying under the open sun. This type of drying method degrade the quality of product due external impurities are settle down on product, require lots of land for drying and decrease the drying rate. 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. The use of solar energy for, heating, distillation, cooking, drying, refrigeration and air conditioning and power generation is increasing day by day because of a high consumption rate of fossil fuels, round the globe and systems are there which performs on solar energy to fulfill the demand of, cooking, distillation, water heating, etc. Solar energy based drying techniques offer better return on investment to farmers. The drying process in the hybrid forced mode of operation is twice faster than the sun drying. Basically, there are three types of solar dryers; direct solar dryers, indirect solar dryers and mixed-mode dryers. This 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 paper, we viewed different types of hybrid solar dryers and different design modifications applied to them in order to increase their effectiveness.

Keyword: biomass heating source, drying process, indirect solar dryer, investment, mixed-mode dryer

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INTRODUCTION

The use of solar energy is continuously progressive because of an efficient and cost free source on the earth. Globally, solar energy contributes to all the necessary heating and cooling tasks such as, cooking, crop drying, water heating, space heating, timber seasoning, power generation, refrigeration, air conditioning, etc. The qualities of this free fuel from the sun are, pollution free fuel, available in good amount at almost locations on the earth, abandon source of energy, reduced greenhouse gas emissions, recovery of despoiled land, less requirement for transmission lines within the power grid, progress in the quality of water resources, etc.

Most tropical regions high levels of solar radiation throughout the year, much of this radiation are absorbed by frequent rain and persistent cloud cover. Due to inadequate preservation techniques available to farmers in developing countries, large quantities of agricultural output with high moisture contents are lost annually due to decomposition by microorganisms. This results in reduction of the net agricultural output and subsequent reduction in the gross domestic product (GDP) of the developing countries.

The most common method of dehydration is by open air sun drying but this often results in food contamination and nutritional deterioration. Food dehydration technology employs direct and/or indirect mixed mode systems with natural or forced distribution of heated air. A hybrid solar-electrical dryer was built, composed of a solar chamber (in which the air is heated) and of a drying chamber. 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 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. A portion of the incident solar radiation passes through the glass cover and reaches the absorber in the solar chamber. Ambient temperature air inlets and is heated by convection, raising its temperature while it flows towards the drying chamber. If necessary, the auxiliary heating system heats the air in the entrance of the drying chamber. The drying air passes through the drying trays, removing humidity from the products, and leaves the dryer trough the elbow shaped chimney. The artificial movement of the air is promoted by an exhauster placed inside the chimney.

The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time, normally regarded as the "safe storage period". Drying is a dual process of

(i) Heat transfer to the product from the heating source
(ii) Mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air

Several attempts have been made to determine the efficiency of 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 [1], studied a dish type solar dryer for drying grapes [2], designed and tested a low-cost solar bamboo dryer for drying chilies at MANIT, Bhopal [3], designed and evaluated the performance of a new hybrid solar dryer for banana drying. The tropics are characterized by hot damp climates. If the relative humidity of ambient air is too high to facilitate drying in the field, such air would obviously be of limited value for drying the harvested crop [4].

CLASSIFICATION OF DRYING SYSTEM

All drying systems can be classified primarily according to their operating temperature ranges into two main groups of high temperature dryers and low temperature dryers. However, dryers are more commonly classified broadly according to their heating sources into fossil fuel dryers (more commonly known as conventional dryers) and solar-energy dryers. Strictly, all practically-realized designs of high temperature dryers are fossil fuel powered, while the low temperature dryers are either fossil fuel or solar-energy based systems.

High Temperature Dryers

High temperature dryers are necessary when very fast drying is desired. They are usually employed when the products require a short exposure to the drying air. Their operating temperatures are such that, if the drying air remains in contact with the product until equilibrium moisture content is reached, serious over drying will occur. Thus, the products are only dried to the required moisture contents and later cooled. High temperature dryers are usually classified into batch dryers and continuous-flow dryers. In batch dryers, the products are dried in a bin and subsequently moved to storage. Thus, they are usually known as batch-in-bin dryers. Continuous-flow dryers are heated columns through which the product flows under gravity and is exposed to heated air while descending. Because of the temperature ranges prevalent in high temperature dryers, most known designs are electricity or fossil-fuel powered. Only a very few practically-realized designs of high temperature drying systems are solar-energy heated [5–11].

Low Temperature Dryers

In low temperature drying systems, the moisture content of the product is usually brought in equilibrium with the drying air by constant ventilation. Thus, they do tolerate intermittent or variable heat input. Low temperature drying enables crops to be dried in bulk and is most suited also for long term storage systems. Thus, they are usually known as bulk or storage dryers. Their ability to accommodate intermittent heat input makes low temperature drying most appropriate for solar-energy applications. Thus, some conventional dryers and most practically-realized designs of solar-energy dryers are of the low temperature type.

CLASSIFICATION OF SOLAR-ENERGY DRYING SYSTEM

Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms, they can be classified into two major groups:

- Active solar-energy drying systems (most types of which are often termed hybrid solar dryers)
- Passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems)

Three distinct sub-classes of either the active or passive solar drying systems can be identified (which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat are (Figure 1):

- Integral-type solar dryers
- Distributed-type solar dryers
- Mixed-mode solar dryers.

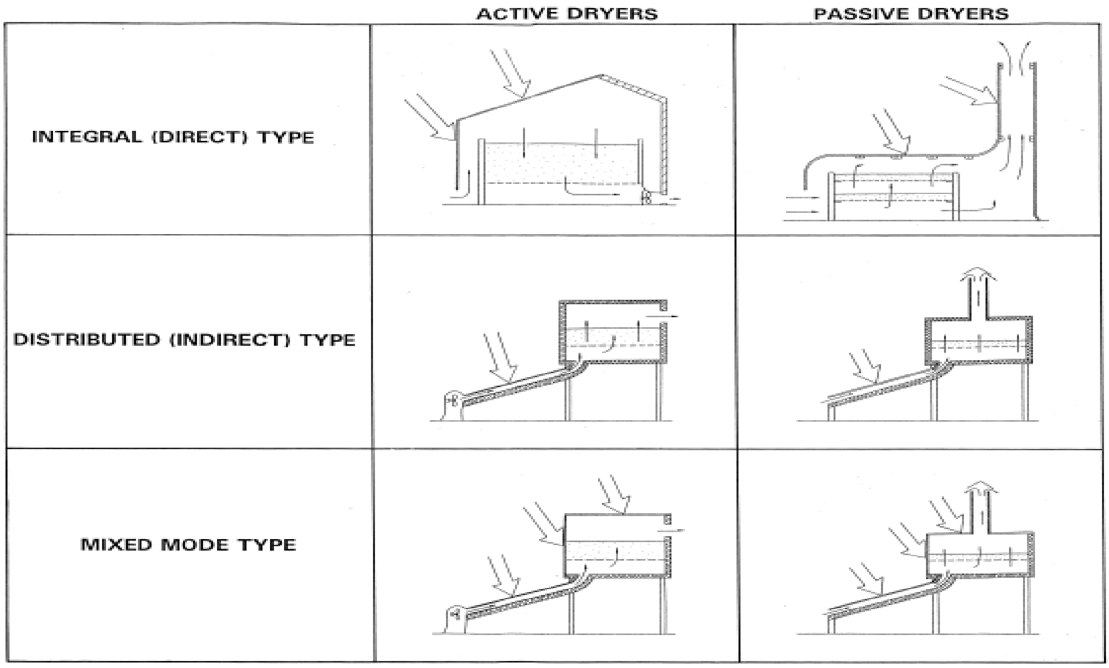

Fig. 1. *Type of solar energy dryer.*

Integral-Type Solar Dryers

In integral-type natural-circulation solar-energy dryers (often termed direct solar dryers), the crop is placed in a drying chamber with transparent walls that allow the insulation necessary for the drying process to be transmitted. Thus, solar radiation impinges directly on the product. The heat extracts the moisture from the crop and concomitantly lowers the relative humidity of the resident air, thereby increasing its moisture carrying capability (Figure 2).

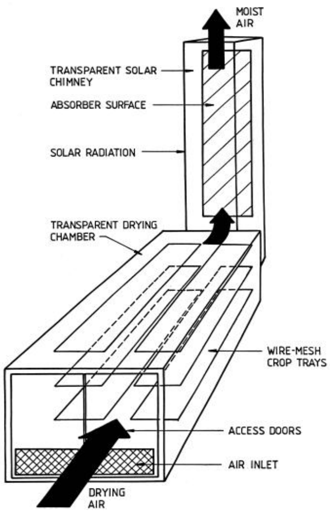

Fig. 2. *Integral type solar dryer.*

Distributed-Type Solar Dryers

These are often termed indirect passive solar dryers. Here, the crop is located in trays or shelves inside an opaque drying chamber and heated by circulating air, warmed during its flow through a low pressure drop thermos phonic solar collector. Because solar radiation is not incident directly on the crop, caramelization and localized heat damage do not occur. These dryers are also recommended generally for some perishables and fruits for which their vitamin content are reduced considerably by direct exposure to sunlight and for color retention in some highly pigmented commodities that are also very adversely affected by direct exposure to the sun. Distributed solar dryers have higher operating temperatures than direct dryers or sun drying and can produce higher quality products.

A typical distributed natural-circulation solar-energy dryer (Figure 3) would be comprised of the following basic units:

- An air-heating solar-energy collector
- Appropriately insulated ducting
- Drying chamber
- Chimney

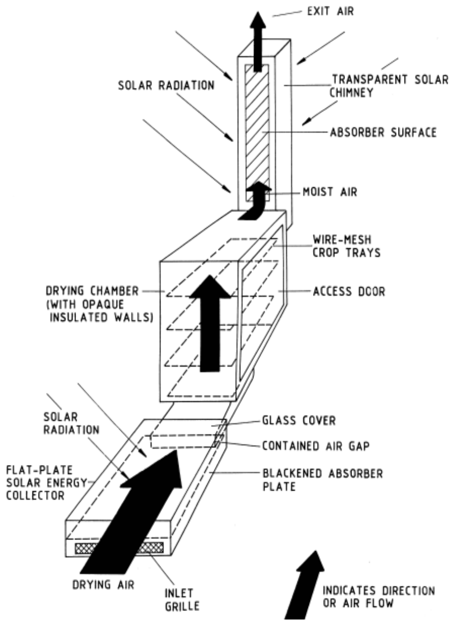

Fig. 3. *Distributed-type solar dryer.*

Mixed-Mode Solar Dryers

These dryers combine the features of the integral (direct) type and the distributed (indirect) type natural-circulation solar-energy dryers. Here the combined action of solar radiation incident directly on the product to be dried and pre-heated in a solar air heater furnishes the necessary heat required for the drying process. The unit consists of a solar air heater, a cabinet for the rice bed and a chimney which provides a tall column of warm air to increase buoyancy. The air heater's absorber consists of a thick layer of burnt rice husks covered by a clear plastic sheet on an inclined bamboo framework. The drying chamber is a shallow wooden box with a base made of bamboo mat with a fairly open structure to allow for an easy flow of the drying air. It is covered with a nylon netting to prevent the rice grains from falling through. A clear plastic sheet covering the rice bed allows the direct heating of the rice (by direct absorption of solar radiation) while protecting it against rain. The chimney consists of a bamboo framework clad with dark plastic sheet (which absorbs solar radiation, thus keeping the chimney inside warm) (Figure 4).

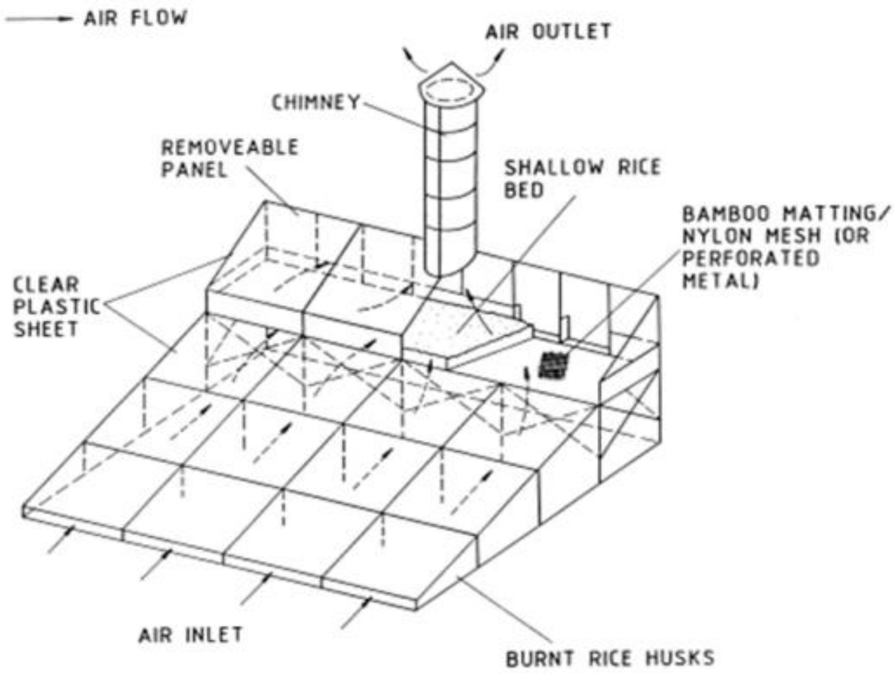

Fig. 3. *Mixed-mode solar dryers.*

PROCEDURE TO DRYING AGRICULTURE OBJECT

The main parameters affecting the performance of the dryer were measured. A pyranometer was used to measure the global radiation incident on the dryer. This device has a response time lower than 1 second, operational temperature from -30°C to 70°C and uncertainty of 5%. Incoterm thermocouples were used to measure ambient temperature and the drying air temperature inside the dryer. In the range of operation from -20°C to 150°C, the uncertainties of the sensors are 1.2°C. The velocity of drying air was measured with a 0.050 m diameter propeller anemometer (Homis), with a global uncertainty of 6%. Weight loss of the product during the drying period was measured with a digital analytical balance, with uncertainty of 0.3 g. Uncertainties of the measurement devices were obtained to a 95% level of confidence. A metrological analysis was performed to minimize measurement errors. All these data were measured three times to reduce measurement uncertainties.

The first experiment was performed without any products inside the dryer, to evaluate the dryer's ability to control the characteristics of the outlet airflow and to evaluate the optimum operational condition of the dryer. Ambient conditions (global solar radiation incident on the dryer and ambient temperature) and global thermal characteristics of the airflow (velocity and temperature) were measured with the auxiliary energy system operating. The second experiment was intended to determine a global balance of energy in the dryer and to evaluate its economic feasibility. The incident global solar radiation (G), the ambient temperature and the outlet airflow velocity and temperature were measured without any products inside the dryer and the auxiliary energy system turned off. The solar energy incident on the device (E_s) was determined by

$$S = \int (G.A)\, dt \qquad (1)$$

in which A represents the collector area of the dryer.

The fraction of the solar energy used to raise the airflow temperature (E_c) was determined based on the mass airflow (m), on the airflow specific heat at constant pressure (C_p) and the ambient (T_{amb}) and outlet (T_{out}) airflow temperatures.

$$E_c = \int m\, C_p\, (T_{out} – T_{amb})\, dt \qquad (2)$$

The global absorbed energy required by the air to achieve 50˚C (E_t) was determined by

$$E_t = \int m\, C_p(50\ ˚C – T_{amb})dt \qquad (3)$$

It is important to notice that 50˚C is the temperature defined for the drying airflow in the experiments.

The collector efficiency can be defined by

$$\eta = \frac{Ec}{Es} \qquad (4)$$

Finally, the economy obtained by the dryer, when compared with an artificial dryer without any thermal losses, can be determined by

$$\eta = \frac{Ec}{Et} \qquad (5)$$

The technical viability of the device was determined in the third experiment. Slices of object were dried in three distinct situations and the results were compared. The objects were put into three immersion baths. After this, the objects were hand peeled, cut into 5 mm thick slices and divided into four samples. The first sample was used to determine the initial moisture content. It was put into an oven with controlled temperature, humidity and time. After a defined period of time, the initial moisture content (in wet basis) was determined. The second sample was inserted into an electrical dryer (forced circulation oven). The third into the hybrid dryer and the fourth sample was directly exposed to the sun. In both dryers, the air temperature was fixed in 50˚C. It was observed in previous analysis that the volume flow provided by the electrical dryer was not suitable to the proposed drying. Therefore, it was installed a more powerful fan in the hybrid dryer, increasing its volume flow. To minimize errors, all the samples were subdivided into three sub samples. The drying curves were obtained for all the samples until the desired moisture content of 20% (wet basis) was achieved [12, 13].

ADVANTAGES OF HYBRID SOLAR DRYING SYSTEM

- It is quite simple and less expensive.
- It protects the product from UV rays.
- It less damage from temperature extremes.
- It has ability to operate without sun and reduces the chance of food loss.
- It allows better control of drying.
- Its fuel mode may be up to 40x faster in hybrid solar dryer.

DISADVANTAGES OF HYBRID SOLAR DRYING SYSTEM

- More complex and expensive than direct sun.
- It may cause fuel dependence in case of hybrid solar dryer
- UV radiation can damage food in direct dryer and mixed mode solar dryer

BENEFIT SOLAR DRYING SYSTEM

- Dried foods are tasty, nutritious, the nutritional value and flavor of food is only minimally affected by drying

- Dried foods are high in fiber and carbohydrates and low in fat, making them healthy food choices
- Vitamin A is retained during drying
- Storage space is minimal, easy-to-store
- Transportation costs are reduced; dried Products weigh only about 1/6 of the fresh food product
- The energy input is less than what is needed to freeze or can
- easy-to-prepare; solar food drying is a very simple skill
- Longer storage of dried products outside the fridge!
- It is an absolute safe technology. No high voltage is used; no risk of high Temperature not any harm could be generated by the dryer.
- The food is safe, although it could be contaminated before drying. Because of the pasteurization-effect due to “high” temperature in the dryer.

CONCLUSION

We have presented a comprehensive review of the various designs, details of construction and operational principles of the wide variety of practically-realized designs of solar-energy drying systems. We have also evolved a systematic classification of solar-energy dryers. This classification illustrates clearly how these solar dryer designs can be grouped systematically according to their operating temperature ranges, heating sources and heating modes, operational modes or structural modes.

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. 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.

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