Prospect & Future of Solar Dryer: Perspective Bangladesh

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***Abstract*—Energy is one of the main concerns for the growing future of any nation. Energy is by far the largest merchandise in the world and an enormous amount of energy is extracted, distributed, converted and consumed in our global society daily. The per capita energy consumption of Bangladesh is one of the lowest amongst the sub continent. Despite only 32% population has access to the National grid, The Government of Bangladesh a noble vision to provide electricity for all by the year 2020.Target of meeting 5% of total electricity demand from RE by 2010 and 10% by the year 2020 .In crisis conditions energy usage should be appropriate and meticulous. Our technology for energy harvest, conversion and efficient application is still lacking behind with that of developed world. We should give emphasis for the development of indigenous technology. Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east longitude, which is an ideal location for solar energy utilization. Daily solar radiation varies between 4 and 6.5 kWh/m2.In this regard, solar dryer for domestic as well industrial usage could be an effective alternative of saving conventional energy. Utilization of solar thermal energy through solar dryer is relatively in a nascent state in our country. The objective of this paper is the design & performance analysis of different types of solar dryer & its prospect in Bangladesh.**

***Index Terms*—Natural Convection Solar Dryer, Forced Convection Solar Dryer, Solar dryer Design & Performance analysis, Solar panel performance improvement, Potential & Limitation.**

I. Design and Performance Study of Solar Dryer

The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel. Now the solar dryer designed and developed for and used in tropics and subtropics are discussed under two headings.

A. Natural Convection Solar Drying

Natural convection solar drying has advantages over forced convection solar drying is that it requires lower investment though it is difficult to control drying temperature and the drying rate may be limited. Due to low cost and simple operation and maintenance, natural convection solar drier appears to be the obvious option and popular choice for drying of agricultural products. It is the oldest type of solar dryer and consists of a solar collector with a transparent cover on the top and a drying unit with an opaque cover on the top. These are connected in series .Natural convection solar dryers do not require power from the electrical grid or fossil fuels. Hence the obvious option for drying would be the natural convection solar dryers. Several designs are available and these are (i) cabinet type solar drier suitable for drying fruits and vegetables (Sharma et.al, 1995), (ii) indirect natural convection solar drier for paddy drying (Oosthuizen, 1995) and mixed mode AIT drier for drying paddy(Excell, 1978). These dryers have been widely tested in the tropical and subtropical countries. [1]

[1] Cabinet type solar dryer

Cabinet type solar drier suitable for drying fruits and vegetables (Sharma et.al, 1995).Direct-solar cabinet-type driers are used to dry small quantities of food or vegetables, and provide moderate drying temperatures (37-58°C) and airflow rates. Both the 1 m^2 and 2 m^2 model dryers have been tested for fish and banana drying. The 1 m^2 model can dry about 15- 20 kg of fresh fish over a period of two or three days while the 2 m^2 model can dry double this quantity.

The dryer consists of four main parts: a base frame, drying chamber, drying trays, and loading door. The rectangular base frame has six supporting legs on which rest a drying chamber. A solar collector, supported by another three legs, is attached to the drying chamber. The drying chamber of the 1 m^2 model measures 1 m length x 1 m width x 0.75 m height, and contains 4 trays of 1m x 0.495 m to provide a total drying area of 2 m^2. The drying chamber of the 2 m^2 model measures 1 m length x 2 m width x 0.75 m height, and contains 8 trays of 1m x 0.495 m to provide a total drying area of 4 m^2.The base frame is built with softwood. Within the frame, a mat made from papyrus is laid and covered over with black plastic sheet to form the base of the drying chamber. Along the back of the frame, a ventilation slot is made to form the air inlet vent to let the air enter the collector and the chamber. The roof of the collector is parallel to the roof of the chamber. The vent is covered plastic mosquito mesh to keep out insects. The dryer has a solar collector attached at the other side of the drying chamber. The solar collector heats the ambient air, which then passes through the products to be dried (loaded on trays) by natural convection.

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Fig. 1. Base frame of solar cabinet dryer – 1 m^2 model.

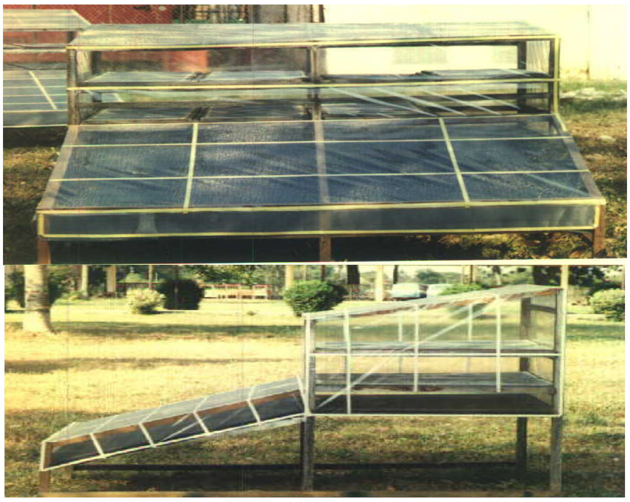

Fig. 2. Completed solar cabinet dryer – 2 m^2 models.

The drying chamber is built with hardwood for strength and durability. The front of the chamber has two hinged doors to provide access for loading and unloading the drying trays, on which the products to be dried are spread. Wooden rails are provided in the cabinet frame, on which the trays slide through. The tray has a hardwood frame, and plastic mosquito mesh is stapled to it. An air outlet vent is provided at the top front side, for exit of the warm moist air through natural convection; the vent is covered with mesh to keep the insects and flies out. Both the 1 m2 and 2 m2 model dryers have been tested for fish and banana drying. The 1 m2 model can dry about 15-20 kg of fresh fish over a period of two or three days while the 2 m^2 model can dry double this quantity. [2]

[2] Solar Box Dryer

The solar box dryer has been designed to be suitable for household drying of agricultural products. The dryer can dry about 4-5 kg of fish, fruits and vegetables in a single batch, at a drying air temperature of about 40-50°C. The dryer design was based on thermal performance and product quality optimization.

The dryer consists of a rectangular inner box made of GI sheet, with an open top. It is insulated at the outside with a layer of glass wool at the bottom and sides, and clad with GI sheet. A 3 mm thick window glass is used as cover glazing. The glass is fixed at the top of the box, and is hinged to the box at the left edge. This facilitates opening and closing of the cover glass, allowing access inside the box for loading and unloading the products spread on trays.

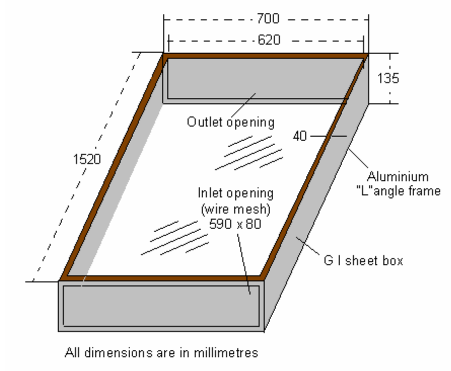

Fig. 3. Isometric view of the box dryer.

Fig. 4. Fully assembled box dryer.

The dryer box is fixed on a mild steel stand with a tilt of 20° (suitable for Cambodian latitude), and placed facing south, to maximize the incident solar radiation. [2]

[3] Mixed-mode solar dryer

The mixed-mode solar dryer consists of a separate solar collector and a drying unit, both having a transparent cover on the top. Solar radiation is received in the collector as well as in the dryer box. The dryer is shown in Fig. 5 and the solar collector consists of a matt-black substance spread on the ground and provided with transparent top and side covers. The dryer was initially designed with a bed of burnt rice husk as the absorber and clear UV stabilized polyethylene plastic sheet as transparent cover. However, these materials could be substituted with locally available materials such as charcoal, black plastic or black-painted metal sheets, dark-colored pebbles, etc. [1]

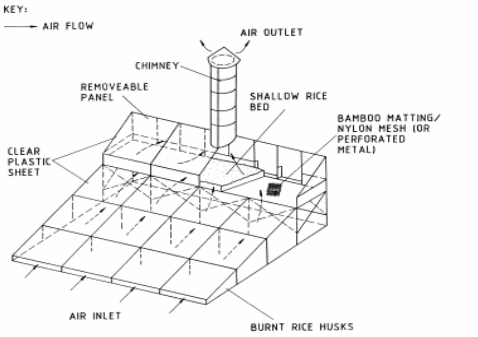

Fig. 5. AIT-dryer.

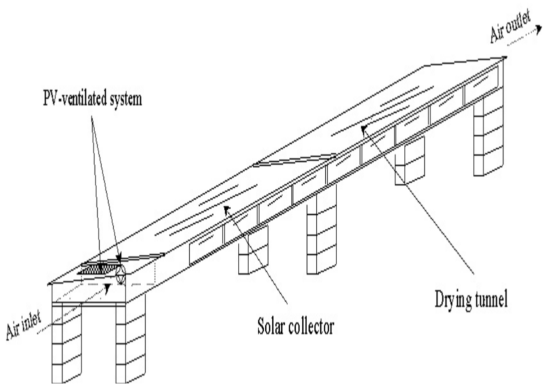

Fig. 6. Pictorial view of the solar tunnel dryer under construction.

B. Forced Convection Solar Drying

1) Solar tunnel dryer

Solar tunnel dryer was developed at the University of Hohenheim, Germany in the early eighties for small scale production of dried fruits, vegetables, spices, fish etc. This type of dryer has been widely tested and attained economic viability. A low cost version of this drier has been designed at Bangladesh Agricultural University, Mymensingh, Bangladesh and the pictorial view of the dryer under construction The design of the solar tunnel dryer has been further improved and tested by Janjai (2004) at Silpakorn University at Nakhon Pathom in Thailand. The dryer still consists of two parts, namely the solar collector part and the drying part similar to the original version. Instead of using PE plastic sheet, the roof of the new design dryer is made of polycarbonate plates fixed with the side walls of the dryer. The plate has an inclination angle of 5° for the drainage of rain. As loading of products to be dried cannot be done from the top of the dryer, rectangular windows were made at the side wall of the drying part for loading and unloading products. Back insulation was made of high density foam sandwitched between two galvanized metal sheets. A 15 watt-solar cell module was used to power a dc fan for ventilating the dryer. The collector part and the drying part have the area of 1.2×4 m^2 and 1.2×5 m^2, respectively. The schematic diagram of this dryer is shown in Fig.6.In the solar collector the drying temperature is heated up to 60 ^{0}C which is the optimum drying temperature for most fruits. The standard size of the drier is 20 m^2 m with 20 m^2 of drying area. The capacity of the drier is mainly influenced by the size, shape and moisture content of the fruits/fish to be dried. The loading capacity ranges from 120 to 150 kg of fresh fruits/fish. [1]

Performance of solar tunnel dryer

a. The solar tunnel drying required 3 days to dry mango samples from 78.87% to 13.47% as compared to 78.87% to 22.48% in 3 days. [1]

b. The solar tunnel drying required 3 days to dry pineapple samples from 87.32% to 14.13% as compared to 87.32% to 21.52% in 3 days.[1]

c. The moisture content of mushroom reached from 89.41% to 6.14% in 8 hours in the solar tunnel drier and it took 8 hours to dry it from 89.41% to 15% in the traditional method under similar conditions.[1]

d. The moisture contents of chilli at three different locations starting from top to bottom inside the dryer reached to 16.70 % (w.b.), 07.13 % (w.b.) and 01.58 % (w.b.) respectively from 76.96 % (w.b.) in 27 hours of drying in three days while the moisture content of a similar sample in the traditional method after the same period of drying was 53.78 % (w.b.). [1]

e. The moisture content coffee reached to 8.3% from 58.36% (w .b.) in 6 days of drying in the solar tunnel drier while it took 6 days to bring down the moisture content in a similar sample to 26.65% in traditional sun drying method. [1]

f. Drying in the solar tunnel drier required 3 days to dry silver jew fish from 71.56% to 14.75% as compared to 71.56% to 23.63% in 3 days in traditional sun drying. [9]

g. A walk in type semi cylindrical solar tunnel dryer for drying 1500 handmade papers per batch has been commissioned at M/s Cellulosic Waste Recycling Education Project, Vidhya Bhawan Society, Udaipur, Rajasthan, India. A solar tunnel dryer with 122.95 m2 solar collector area was sufficient for drying handmade paper from 53.85% to 9.96% moisture content (dry basis) in 4–5 h. [8]

2) Greenhouse solar dryer

A pv-ventilated greenhouse solar dryer was developed at Silpakorn University (Janjai, 2004).The dryer essentially consists of a parabolic shape greenhouse with a black concrete floor with an area of 5.5×8.0 m^2 (Fig. 9.) and the pictorial view of the dryer is shown in Fig. 10. The parabolic shape can withstand well the tropical rain and storm. The roof of the dryer is covered with polycarbonate plates. The floor of the dryer is made of concrete mixed with black powder paint to serve as a basement of the dryer as well as solar radiation absorber. The loading capacity of the pv ventilated greenhouse solar dryer is 100-150 kg of fresh chillies. Drying in the pv ventilated greenhouse results in considerable reduction in drying time (50%) and the quality of the dry products is high quality dried products in terms of color and texture. The payback period of the dryer is estimated to be about 3.36 years. Several units of this type of dryer have been constructed in Thailand and are being used for drying of chili, banana and green tea [1, 3]

Performance of a PV-ventilated Greenhouse Dryer for Drying Bananas

To investigate its performance, the dryer was used to dry two batches of bananas. Results from the investigation showed that 50 kg of fresh bananas with the initial moisture content of 70 % can be dried in 3 days. With the same weather conditions, natural sun drying required 5 days of drying time. The air temperature inside the dryer at noon time of a clear day was 60-70 o C. [3]

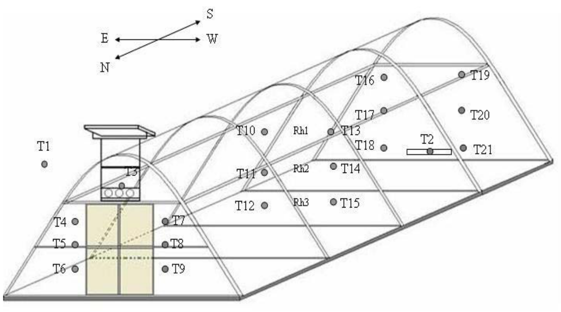

Fig. 7. Schematic diagram of the greenhouse type.

Fig. 8. Pictorial view of the greenhouse solar dryer solar dryer with polycarbonate sheet.

3) Roof-integrated solar dryer

The roof-integrated solar dryer consists of a roof-integrated solar collector and a drying bin with an electric motor operated fan to provide the required air flow. The bin is connected to the middle of the collector through a T- type air duct connection. The roof-integrated collector consists of two arrays of collector: one facing the south and other facing the north with a total area of 108 m^2. These arrays of these collectors also serve as the roof of the building. The roof-integrated collector is essentially an insulated black painted roof serving as an absorber which is covered with a polycarbonate cover. [1]

Performance of a Roof –Integrated solar dryer

Field level tests of drying of 200 kg of rosella flower and chilli at Suan Phoeng Educational Park, Ratchaburi, Thailand demonstrated that drying in roof integrated solar dryer results significant reduction in drying time compared to the traditional sun drying method and the dry product is a quality dry product compared to the quality dry products in the markets. This dryer was used to dry rosella flower from a moisture content of 90% (w.b.) and chilli from moisture content of 80% (w.b.) to a moisture content of 18% (w.b.) within 3 days. The payback period of the roof integrated solar dryer is about 5 years. [1] Roof-integrated solar dryer is costly in terms of capital cost. But the operating cost is extremely low and it is also environment friendly.

II. Potential & Limitations

Field level tests in Bangladesh and Thailand have demonstrated the potentialities of solar tunnel dryer, greenhouse type solar dryer and roof integrated solar dryer for production of quality dried fruits, vegetables, spices, medicinal plants and fish. Different products to be dried have different maximum permissible drying air temperatures. The drying air temperature for a product must not exceed the maximum permissible drying air temperature. The maximum permissible temperature for production of quality dried pineapple, mango, jackfruit and chili is 65 °C and that of fish is 52 °C. But for herbal and medicinal plants a maximum temperature of 100°C is recommended for glycoside species, 65°C for mucilage species and 35 to 45°C for essential-oil species. This drying air temperature can be achieved by simply adjusting collector length (in solar tunnel dryer) or air flow rate by changing the number of fans in operation.

III. Performance Improvement of Solar Panel

Solar panels convert light energy from the sun into electrical energy. Normally energy from the sun is received in the form of light and heat. The light energy received has different wavelengths. Photo cells can produce output only for a particular range of frequencies of light.

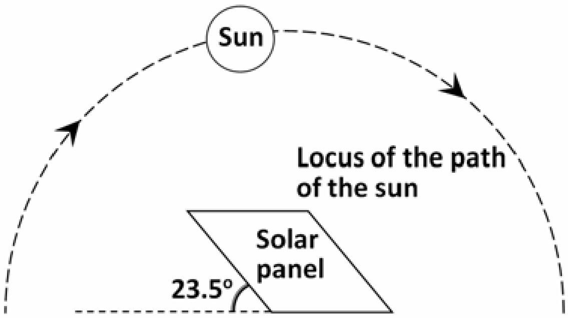

Fig. 9. Sun-Earth geometry.

The extraterrestrial solar spectrum at mean sun-earth distance can be categorized as follows [4]:

Ultraviolet region (λ< 0.38 mm,

Visible region (0.38 < λ < 0.78 mm)

Infrared region (λ> 0.78mm) percentage of solar radiationare respectively 7%, 47.3%. & 45.7%

Bangladesh on an average receives 4 to 6.5 kWh per square meter of solar energy every day. Solar cells have an average efficiency of 10%, which means it can convert 0.4 to 0.65 kWh per square meter of solar energy into electrical energy [5]. Unless high efficiency solar cells are invented, the only way to enhance the performance of a solar cell is to increase the intensity of light energy falling on the solar panels. Sun tracking is one of the popular methods of enhancing performance of a solar panel.

IV. Efficiency Increase Through Solar Tracking

Any solar system performance depends on how much solar irradiation it can collect. For collecting the maximum amount solar radiation, all types of solar collectors must be directed towards the sun so that all the sun's rays fall normally on the optical system, which can increase the efficiency of the system. Energy collection is increased for a given system if it is oriented in such a manner that the surface normal at the centre coincides with the solar beam all the time. This will be possible only if the system is rotated continuously according to the position of the sun, i.e. the tracking is done with sun movement. Energy collection will be reduced if no tracking is done. Conventionally, the solar collectors are fixed in positions to utilize the sun's incident energy. Since the sun is continuously altering its position because of earths' rotation and its revolution around the sun, the ray's incident on the collectors cannot be in the optimum direction. This can lead to an insufficient collection system. In order to overcome this problem some systems are developed to trap this energy by continuously changing the orientation of the collector so that the direction of propagation of beam radiation is always perpendicular to the collector surface. These systems are known as "Sun tracking systems or Sun trackers". Commercially, single axis and two axis tracking mechanisms are available.

An investigation has shown that modifying the two axis solar tracking system & calculating the inclination angle System around 3.23% and 9.46% gain can be increased compared to the conventional 23.5^{o} inclination and horizontally placed PV system. If two-axis tracking has been adopted the PV panel would achieve 15.8% increase than the 23.5^{0} inclined PV panel in received solar irradiation. This can be achieved if the proposed system can track the sun throughout the day and consequently the PV panel will always be perpendicular to the incident sun light. But in Bangladesh the use of solar PV systems are mainly confined in Solar Home Systems and two axis tracking is not feasible for most of the PV systems in Bangladesh. Solar PV systems in Bangladesh should maintain different inclination planes for different months and therefore achieving greater efficiency without any increase in cost. Sun appears at the same zenith angle twice a year.

V. Conclusion

In all the cases the use of solar dryer leads to considerable reduction of drying time in comparison to sun drying and the quality of the product dried in the solar drier was of quality dried products as compared to sun dried products and they are appropriate for production of quality dried fruits, vegetables, spices, herbs and medicinal plants, and fish.

Solar dryers are simple in construction and can be constructed using locally available materials by the local craftsman. They may vary in construction depending upon their loading capacity. The solar drier can be operated by a photovoltaic module independent of electrical grid. The photovoltaic driven solar driers must be optimized for efficient operation.

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