OPTIONS FOR SOLAR DRYING SYSTEMS: PERSPECTIVE IN MALAYSIA

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ABSTRACT

Solar drying provides an alternative to the use of fossil fuel. Solar drying system is one of the most promising applications of crop drying. However, there are problems associated with the intermittent natural of solar radiation and the low intensities of solar radiation. The problems can be remedied by the use of heat storage, auxiliary energy source, control system, larger surface collector and hybrid system. However, this will result in a high capital investment. Economic indicators such as cost of maintenance, payback period, internal rate of return can be used to calculate the economic of it application.

This paper presents the experience in Malaysia on crop drying. We also present the performance of four solar assisted drying systems for crop drying using different collector types, (a) V-groove solar collector with cabinet dryer, (b) double-pass solar collector with porous media in the lower channel and a flat bed drying chamber, (c) Solar dehumidification system and (d) Photovoltaic-thermal solar drying system.

ABSTRAK

Pengering surya memberikan alternatif dari penggunaan bahan bakar fosil. Sistem pengering surya adalah salah satu aplikasi yang paling menjanjikan untuk “crop drying”. Namun, ada masalah yang terkait dengan intermiten alam dari radiasi matahari dan rendahnya intensitas radiasi matahari. Masalah dapat diatasi dengan menggunakan penyimpanan panas, sumber energi tambahan, sistem kontrol, kolektor permukaan yang lebih besar dan sistem hibrida. Namun demikian, ini akan mengakibatkan investasi modal yang tinggi. Indikator ekonomi seperti biaya pemeliharaan, “payback period”, “internal rate of return” dapat digunakan untuk menghitung keekonomian dari penerapan ini.

Makalah ini menyajikan pengalaman di Malaysia pada “crop drying”. Kami juga menyajikan kinerja dari empat sistem pengering surya untuk “crop drying” dengan menggunakan jenis kolektor yang berbeda, (a) V-groove kolektor surya dengan pengering kabinet, (b) V-groove solar collector with cabinet dryer, (c) Solar dehumidification system, dan (d) Photovoltaic-Thermal Drying System.

Kata kunci: Solar drying system, crop dring, v-groove solar colector, solar dehumidification, photovoltaic-thermal

1. SOLAR DRYING SYSTEMS

Traditionally all the agricultural crops were dried using sun drying. Consequently, it was believed that the harnessing of solar energy using the appropriate technology for the drying process could be achieved without much difficulty. However, there are not many applications of solar drying systems in Malaysia. Some universities and research institutions have tried out solar drying of various products. Small scale trial solar drying experiments have been carried out by various agencies. The Malaysian Agriculture Research and Development Institute (MARDI) has carried out solar drying activities on many commodities and products including paddy, tapioca, groundnuts, noodles, vermicelli, coffee beans, tobacco, fish crackers, mussels, anchovies, banana, and fish (Samsudin et al, 1987). So did the Solar Energy Research Institute (SERI) at Universiti Kebangsaan Malaysia (Othman, 1991). The Rubber Research Institute of Malaysia (RRIM) has carried out technical and economic analysis on solar assisted rubber smoke house. FRIM (Forest Research Institute of Malaysia) and the University of Malaya have tested a solar box dryer for drying of bamboo. Most commercial applications of solar thermal systems have shown that an attractive payback period of less than three years can be achieve to replace a conventional diesel fired dryers. Nevertheless the penetration of solar drying technology is not significant so far.

Attempts at developing industrial scale solar drying technology in Malaysia was undertaken by the ASEAN-Canada Cooperation Program. A solar assisted cocoa drier was constructed and tested in a plantation in Sabah. The facility will be used for operational and economic evaluation and eventually for training.

Table 1. The status of post harvest drying technology for Malaysian agricultural produces.

Produce	Present Drying System	Energy Source	Drying Time
Paddy	(a) Open drying (b) Fixed bed dryer (c) Moisture extraction unit	Sun Diesel Diesel/Electric	5 – 6 hours 4 –5 hours 2 –3 hours
Cocoa	(a) Sundry on cement/tray (b) Kerosene drying (c) Burner blower (d) Rotary drying	Sun Kerosene Kerosene/Diesel Diesel	6 days 35 – 40 hours 36 hours 45 –48 hours
Coffee	Sundry	Sun	14 days
Pepper	Sundry	Sun	7 days (black pepper) 3 days (white pepper)
Tobacco	Conventional curing	Rubber wood LNG	100 hours 100 hours
Tea	Drying chamber	i. Diesel	25 min at 95°C
Banana	Sundry	Sun and wood for smoking	1 day
Anchovies	(a) Sundry (b) Fixed bed dryer	Sun Diesel	7 days 5 – 7 hours
Rubber	(a) Sundry	Sun and wood for smoking	1 day

The status of post harvest drying technology for selected Malaysian agricultural produce is shown in Table 1 (Othman, 1991). The table also shows the energy sources and the required drying time. Most agricultural produces are either sun dried or dried using fossil fuel such as kerosene, diesel and LPG. However, the use of solar drier was significantly absent.

2. OPTIONS FOR SOLAR DRYING SYSTEMS

Four commercial scale solar assisted drying systems have been developed in the Solar Energy Research Park, Universiti Kebangsaan Malaysia funded by the Ministry of Science, Technology and Innovation, Malaysia (Othman et al, 2000; Othman et al, 2007 and Sopian et al, 2007)

(a) Solar Dryer with V-groove Solar Collector.

The first dryer uses collectors of V-groove absorber type and a 10 kW auxiliary heat source for continuous operation. The configuration of the system is shown in Fig. 1, and the configuration of V-groove collector is shown in Fig.2. Table 2 shows the specifications of the solar assisted drying system.

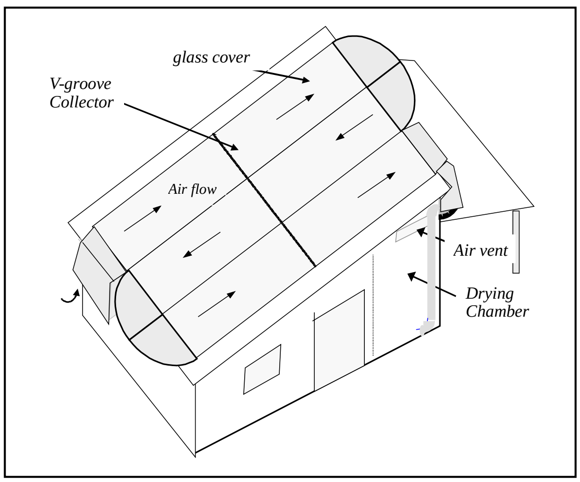

Fig. 1. Configuration of the V-groove solar drying system

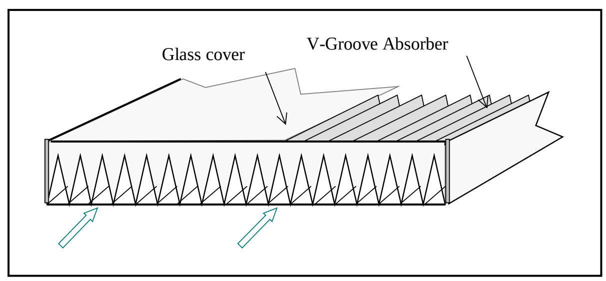

Fig. 2. Configuration of the V-groove

Air flows into the collector and carries away the heat received from the sun. The V-groove configuration enhances the heat transfer surface area and improves the performance of the system. All parts of the collector are kept in an outer case usually made of sheet metal. An average drying chamber temperature of 50 °C can be achieved with a flow rate of 15.1 m^3/min and an average solar radiation of 700 W/m^2 and ambient temperature of 27 – 30 °C. The conditions are suitable for drying of many agricultural products.

Table 2. Specifications of the V-groove solar drying system

System components	Specifications
Collector Type of absorber Absorber material Angle of groove Collector area Total collector area Top cover Insulator	 V-groove back-pass. Folded aluminium sheet SWG22: 244cm x 122 cm.. 49^{o} and height 7.8 cm. 100 cm x 460 cm per unit collector. 13.8 m^2. Glass: thickness 2.5 cm; one side tempered. Fibrerglass wool; 2.5 cm thickness, density 46.0 kgm^{-3}.
Air Circulation Two unit axial fan Ducting Air flow rate	 2700 rpm, 85 W: 230 V (AC), single phase motor. 18 cm outlet diameter: PVC pipe. 6.0 – 16.5 m^3 min^{-1}.
Drying Chamber Type Size	 Adjustable set of shelved frame. 1.0m x 3.0 m x 3.0 m.

Green tea or herbal tea, and chili have been dried using this dryer, and the analysis of drying both commodities using the solar system had been presented Sopian et. al, (2000a and 2000b). Fig. 3 shows the energy requirement for the drying process of herbal tea. The drying process started at 8:00 and ended at 18:00. The total energy required to maintain a drying chamber temperature of 50 °C is 60.2 kWh. The auxiliary energy contribution is 17.6 kWh. Hence, solar energy contributed 42.6 kWh during the process and contributes approximately 70.2 % of the overall energy requirement.

Fig. 4 shows the variations in the moisture content, auxiliary energy, solar energy and total energy used during continuous drying of chilies. The initial and final moisture content is 82.2% and 11.0 % respectively. The set temperature of the auxiliary heater is 50ºC. The drying chamber temperature varies from 48 - 52ºC. The total drying time is 58.5 hours. The total energy required used is 400.83 kWh and the solar energy contribution is 24 % of the total energy. The fan power used is only 2 % of the total energy required.

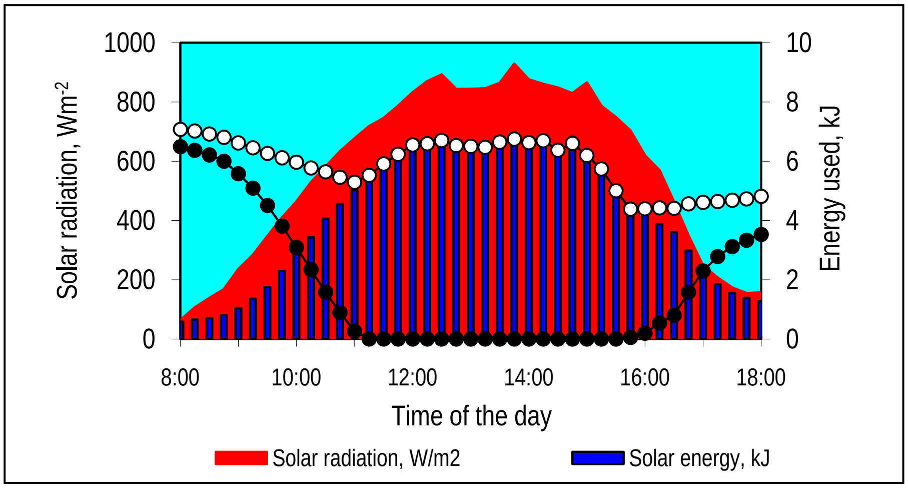

Fig. 3. The contribution of the auxiliary and solarenergy to maintain the drying chamber temperature of 50°C for the drying of herbal tea.

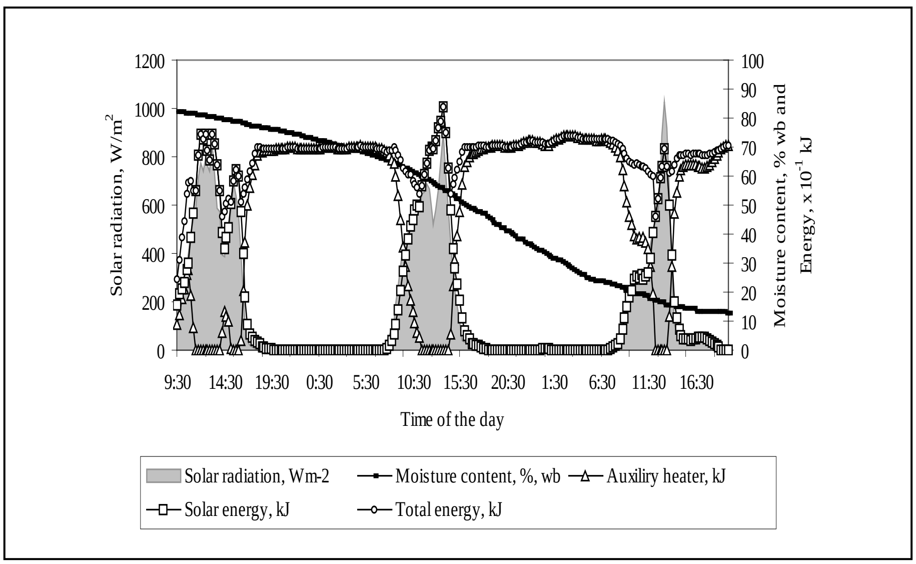

Fig. 4. Solar Dryer with Porous Medium Solar Collector

(b) Variations of the moisture contents and energy requirements for continuous drying process.

The second solar assisted drying system is design for higher temperature applications. The collector used in this system was the double-pass flat plate with porous medium in the second channel. The collector width and length are 120 cm and 240 cm respectively. The upper channel depth is 3.5 cm and the lower depth is 10.5 cm as shown in Fig. 5. The second channel is filled up with steel wool, which improves heat transfer from the collector plate to the flowing air, and also acts as a storage medium.

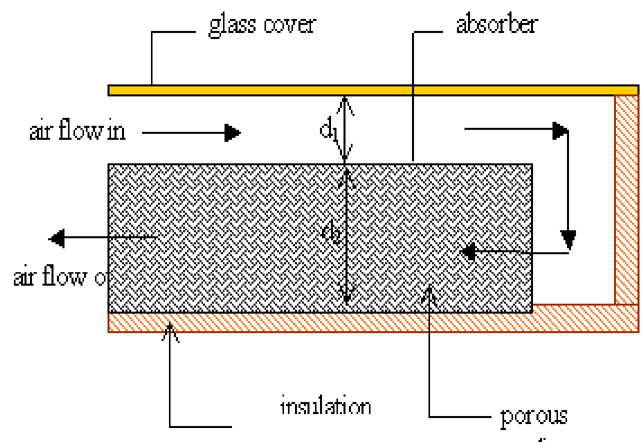

Fig. 5. The schematic of a double-pass solar collector with porous media in the second channel. (d_1 = 3.5 cm, d_2 = 10.5 cm).

The solar collector array consists of 6 solar collectors, arranged as 2 banks of 3 collectors each in series. Air enters the inlet of the upper channel in the first collector and flows in the lower channel. Next, the air flows to the second collector. The lower channel of the third collector is the air outlet from the first bank. In the second bank, air flows in the upper channel of the sixth collector and the outlet air is the lower channel of the fourth collector. The outlet air from the third collector is mixed with the air outlet from the fourth collector. The centrifugal blower is used to induce the hot air. Power rating the blower is 0.11 kW, 230 V rotating at 2520 RPM. The collector is tilted at 10^{o} from the horizon. The collector array is shown in Fig. 6.The schematic of the solar assisted drying system is shown in Fig.7.

The solar assisted-drying system using double-pass solar collector with porous medium was tested for drying shredded oil palm fronds from moisture content of about 63% to moisture content of about 15%. The drying time was 7 hours. A drying chamber temperature of above 60°C can be achieved on a typical day. Palm oil fronds have been dried using the solar dryer.

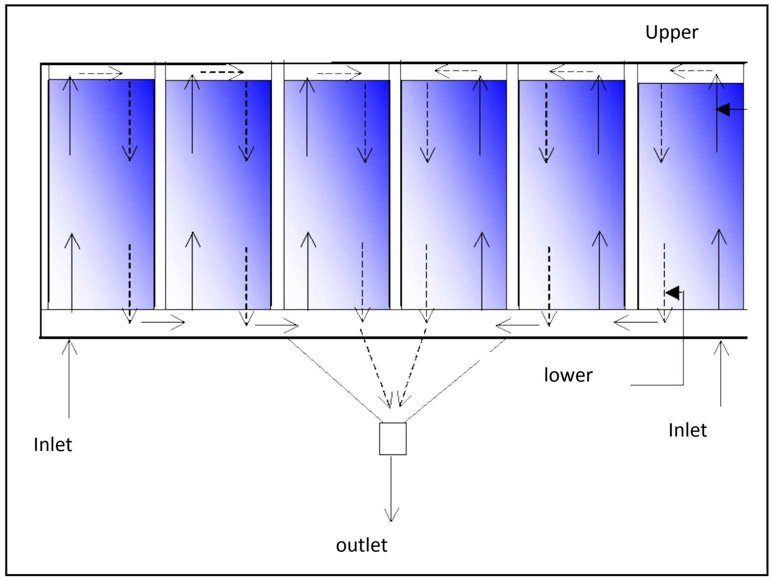

Fig. 6. The collector array for the solar drying system

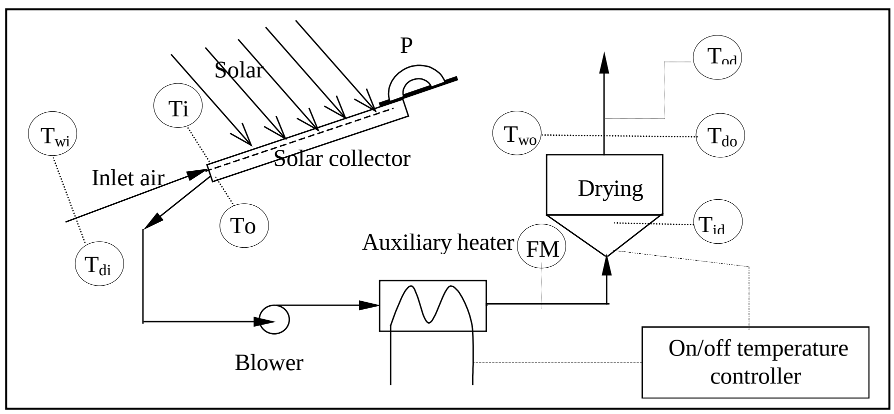

Fig. 7. Schematic of the solar assisted drying system

T_i	temp. of inlet air to collector
T_o	temp. of outlet air from collector
T_{wi}	wet bulb temp. of inlet air
T_{di}	dry bulb temp. of inlet air
T_{wo}	wet bulb temp. of outlet air
T_{do}	dry bulb temp. of outlet air
T_{id}	temp. of inlet air to dryer
T_{od}	temp. outlet air from dryer
FM	air flow meter
P	pyranometer

The waste product of oil palm are empty bunches, fibres and fronds. The fronds are chopped, dried and later ground. The ground fronds are made into pellets and exported as animal feed stocks. The present method of drying is sun drying and is subjected to many risks. The risks are spoilage both during process and subsequent storage, insect and microbial infestation, dust accumulation. All of these factors contribute to the final product quality. Therefore, solar drying is an effective and viable alternative to the present drying method. There are about 300 oil palm trees per hectare. About 20 pieces of fronds can be obtained from a single tree. The average weight of each frond is about 5 kg. Hence, about 100 kg of fronds can be obtained in a year per tree. Moreover, about 30 000 kg of fronds can be produced in one hectare in a year. The performance of the system is shown in Fig. 8.

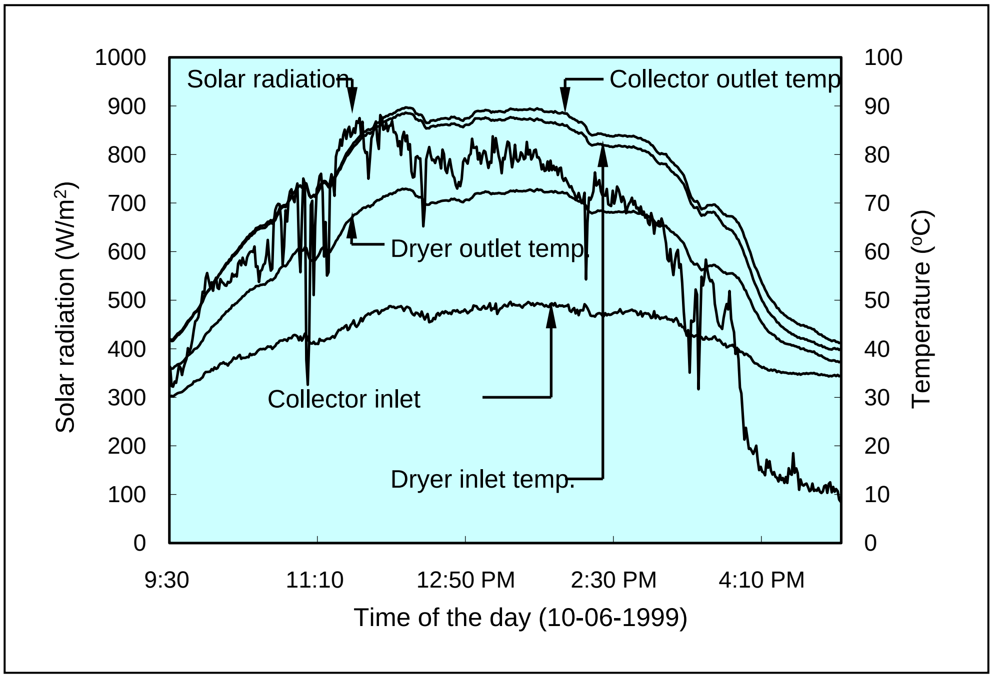

Fig. 8 Variations of the solar radiation and various temperatures (dryer inlet and outlet, collector inlet and outlet)

(c) Solar Assisted Dehumidification Drying System

As shown in Fig. 9 the system consists of a solar collector, an energy storage tank, auxiliary heater, adsorbent, water to air heat exchanger, a circulating pump for water, drying chamber, and other equipment. It is made up of essentially three processes, namely regeneration, dehumidification, and batch drying. In the regeneration process, the air outside the dryer is heated with the heat exchanger and is supplied to the adsorbent. The adsorbent is heated with this hot air, and as the result the water content rate is reduced, removing the water content. This water content is evaporated by the hot air and leaves the dryer, being contained in the air. Meanwhile, in dehumidification (adsorption) process, the air inside the dryer passes through the heat exchanger by using the blower. However, since no hot water is circulated in the heat exchanger, the air reaches the adsorbent as it is. The reached air is dehumidified with the adsorbent and supplied to the drying load as the dry air. The coefficient of performance of the solar drying system is defined as the ratio of the latent evaporation heat of the water content to be removed to the amount of heat to be supplied to the dryer.

The solar collector used in the system is a set of the evacuated glass tubes. As such the heat can be collected effectively at high temperature between 80 °C to 90 °C, and enough for the regeneration process of the adsorbent. Silica gel is used as the adsorbent which has relatively low regeneration temperature (Miller 1985). The system has been used to dry guava with initial moisture content of 80% wet basis, and final moisture content reduced to 18.7% wet basis. The drying time was about 8.5 hours with an average temperature 35°C, average flow rate of air 0.0145 kg/s, average humidity ratio 10.38 g/kg and saturated humidity ratio 16.04 g/kg. The evaporative capacity was 52.2 g/hour (Yahya et al, 2003).

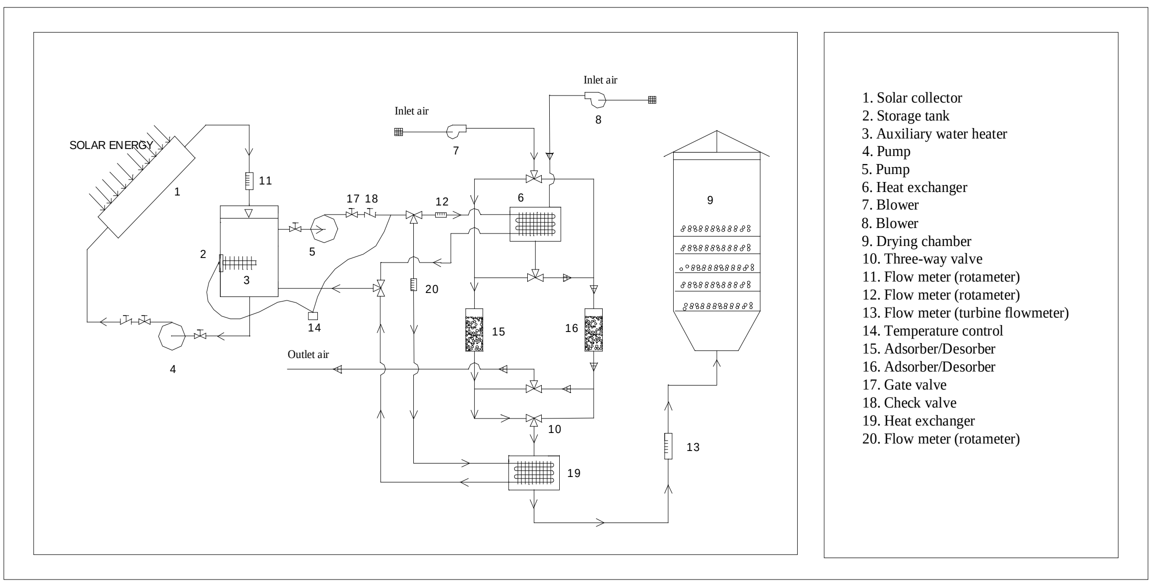

Fig. 9 The schematic of the solar assisted dehumidification drying system.

(d) Photovoltaic-Thermal Solar Drying System

A double-pass photovoltaic-thermal (PVT) collector with compound parabolic concentrator (CPC) and fins has been fabricated, and the system has been used for drying purposes. Air enters through the first channel formed by the glass cover and the photovoltaic panel and is heated directly by the sun. Next it enters the second channel formed by the back plate and the photovoltaic panel. The compound parabolic concentrators concentrate solar radiation onto the PV cells. The fins transfer the heat from the photovoltaic panel to the air where it absorbs more heat from the fins. This flow arrangement and the compound parabolic concentrators as well as the fins increase heat removal from the photovoltaic panel and enhance the efficiency of the system. The collector design concept and the collector array are shown in Fig. 10 and 11.

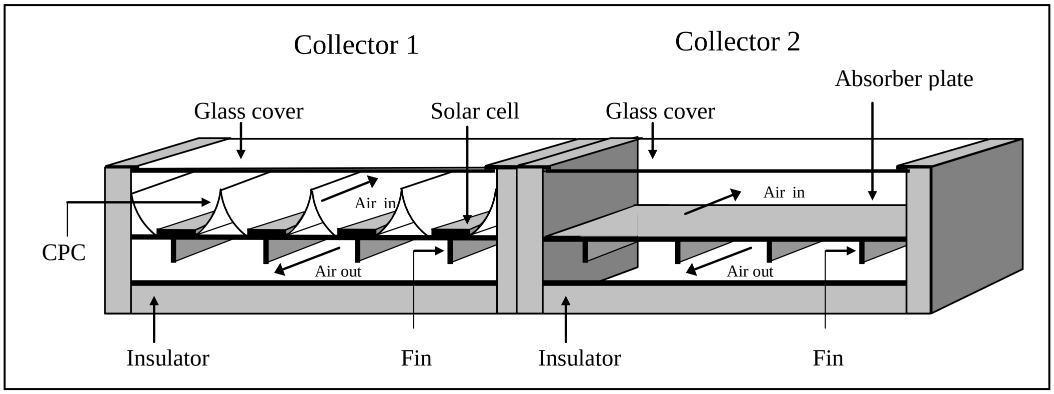

Fig. 10. The schematic diagram of photovoltaic- thermal solar collector

The collector is tilted at 14^{o} from the horizon and facing south. The array consists of two types of collectors, photovoltaic-thermal collector and flat plate solar thermal collector in series. Air enters the first collector through the upper channel formed by the glass cover, CPC and the photovoltaic panel. Next it enters the lower channel of the collector formed by the back plate and the photovoltaic panel. The hot air from the first collector then enters the second collector through the upper channel formed by the glass cover and the absorber plate followed by the lower channel of the second collector before it goes to the drying cabinet as shown in Fig. 12.

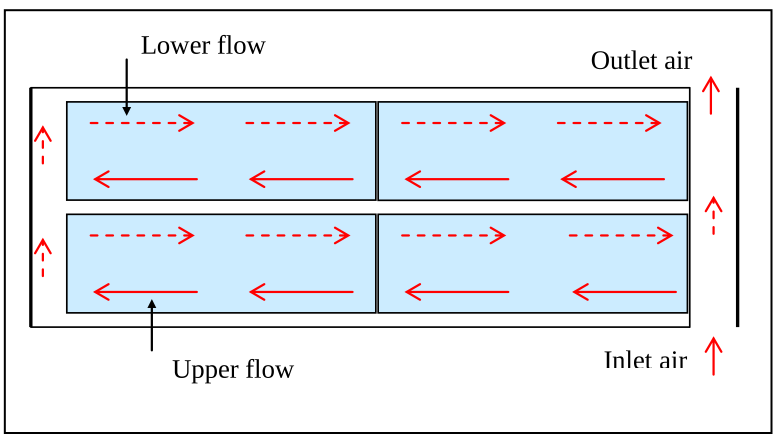

Fig. 11. The collector array for the solar drying system.

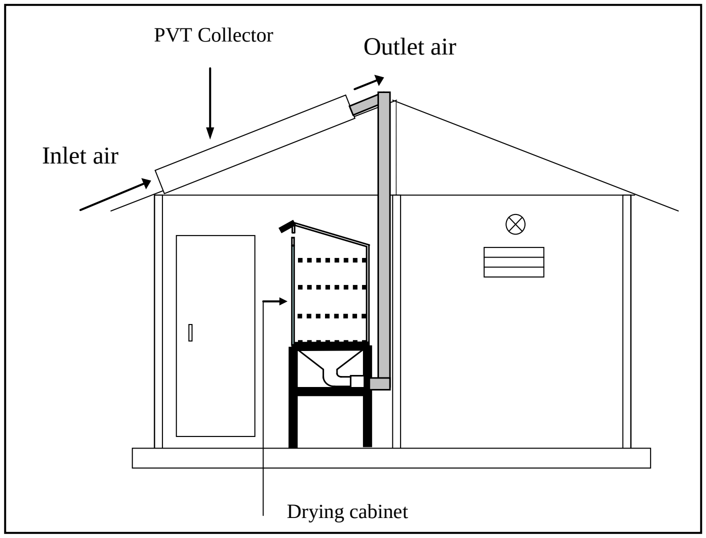

Fig. 12. Side view of PVT solar drying system

The PVT solar drying system was successfully tested under the field conditions of Universiti Kebangsaan Malaysia where high quality product is obtained. The dryer can be easy constructed with simple tools and low labor. Loading and unloading the dryer is found to be quite easy and the maintenance can be done by the farmers themselves. The performance of the solar collector to heat the drying air is assumed satisfactory. The quality attributes such as color, flavor, taste is significantly improved since it is protected from rain, dust, insects etc., in contrast to sun drying. The method of driving the fans by the solar module of PVT collector is assumed to be suitable and appropriate for the use in the remote rural areas where no power supply from the grid is available.

3. CONCLUSIONS

Four types of solar drying systems have been developed for agricultural produce. This high performance of force convection solar assisted drying systems consists of the solar collector, blower, auxiliary heater, and drying chamber. The first drying system used the V-groove type solar collector, the second drying system used the double-pass solar collector with porous media in the second channel, the third system used evacuated tube solar collector to improve the absorbing efficiency and silica gel as moisture absorbing material, and the forth system utilized both electricity and thermal energy converted from solar radiation simultaneously. The drying chamber for the first, third and fourth dryers are the cabinet type with perforated tray, and the drying chamber for the second dryer is a flat bed type. The first dryer is suitable for agricultural produce such as chilies, green tea, and dried fruits. The second dryer produces a much higher outlet temperatures compared to the first drying system. The third dryer is also suitable for the drying of herbs and high quality products, and the forth system is more suitable for applications at remote location.

4. ACKNOWLEDGEMENT

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