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Research Article

Research and Development Work on Solar Assisted Drying Systems

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Abstract: The solar energy research group from Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia (UKM) has designed and constructed solar assisted drying systems for drying agricultural and marine products. This study is a review of numerous types of solar dryer systems developed by SERI, UKM. The classification of solar drying systems has divided by two namely air based solar collector systems and water based solar collector systems. Drying with solar assisted drying systems was found to be a viable option with many benefits such as protected drying environment, improved dried quality of products and reduces drying time compared with the traditional sun drying method. Therefore, SERI's solar assisted drying system shows a great potential for application in drying process of agricultural and marine products.

Keywords: Solar assisted drying, solar collector, solar energy, solar thermal

INTRODUCTION

Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia (UKM) was established on 1st July 2005. It was formed out of the desire to substitute the use of fossil fuel, which is known to produce environmental pollution and global warming. Limited supply, rapid depletion of resources due to increase demand and political instability are causes of fluctuation in the price of fuel.

Therefore, there is need for a source of energy which is long lasting, sustainable and environmental friendly to satisfy the requirement of mankind. Renewable energy such as solar has the potential to replace fossil fuel. To support this effort, SERI undertakes research and development to develop renewable energy technology in this challenging and exciting field. Figure 1 shows the research areas of SERI.

In this study, we focus on solar drying systems that a part of solar thermal. Researchers from SERI have conducted research with different designs for drying application. SERI has developed various innovative designs that enable major improvement in system efficiencies.

The design and performance of different types of solar dryers with air based solar collectors, which R and D in SERI, UKM were reported by Fudholi *et al*. (2013a), Sopian *et al*. (2013a, 2012) and Othman *et al*. (2006). It has developed four advanced solar dryers with air based solar collectors suitable for drying of various agricultural and marine products namely:

- The solar dryers with V-groove solar collectors
- The solar dryers with the double-pass solar collectors with fins
- Solar dryer with the double-pass collector with integrated storage system
- Solar dryer with photovoltaic thermal collector

The design and performance of different types of solar dryers water based solar collectors, was reported by Sopian *et al*. (2013b, 2012) and Othman *et al*. (2006).

Most agricultural and marine products that are intended to be stored must be dried first in an effort to preserve the quality of the final product. Most of the dried salted fish in Malaysia are dried under the open sun. There is requires large open space area and very much dependent on the availability of sunshine, susceptible to contamination with foreign materials such as litters, dusts and are exposed to rodents, insect and birds (Basri *et al*., 2015; Fudholi *et al*., 2013b, 2013c). As an alternative to open sun drying, solar

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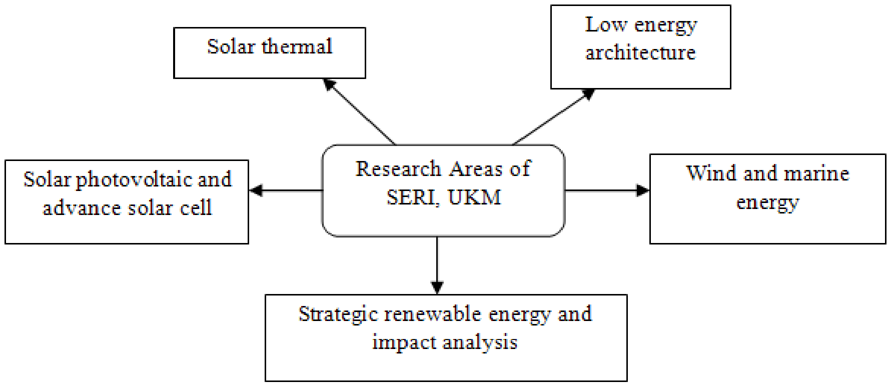

Fig. 1: Research areas of SERI, UKM

drying system is one of the most attractive and promising applications of solar energy systems. It is renewable and environmentally friendly technology, also economically viable in most developing countries.

SOLAR ASSISTED DRYING SYSTEMS

The classification of solar assisted drying systems has divided by two namely air based solar collector systems and water based solar collector systems (Fudholi *et al*., 2010a; Othman *et al*., 2006). The natural convection solar dryer, solar dryer system with photovoltaic (PV), solar dryer using porous medium, solar dryer using finned absorber, solar dryer using V-groove absorber, solar assisted heat pump dryer with multifunction solar collector and solar dryer using Photovoltaic Thermal (PV/T) -Compound Parabolic Collector (CPC) and fins are used air based solar collector systems. The design and performance on air based of different types of commercial scale solar dryers and its prospect in Malaysia has reported by Fudholi *et al*. (2013a). On the other hand, solar assisted heat pump dryer with Photovoltaic Thermal (PV/T) water based collector, solar assisted chemical heat pump dryer, solar dryer using dehumidification system and solar assisted desiccant dryer are used water based solar collector systems.

AIR BASED SOLAR COLLECTOR SYSTEMS

Natural convection solar dryer: This dryer is discontinuous type solar dryer, based on natural convection. Figure 2 shows a natural convection solar dryer. It is a simple design and can be manufactured by farmer from local materials. It has a relatively moderate cost and easy to use. The dryer system consists essentially of a solar collector integrated to the drying chamber at the base and a rotary wind ventilator at the top of the dryer chimney. The solar collector consists of V-groove absorber (painted matte black), glass cover, insulation and frame. The rotary wind ventilator was built from moving corrugated vane rotor. In order to provide air circulation in the dryer, air holes are located on the side of the drying chamber. The thermal performance and quality of products for this dryer was higher compared to open sun drying for the selected food materials. The main purpose of this dryer to provide protection from dust, dirt, rain, wind or prevent insect and animal.

(a) (b)

Fig. 2: Photograph of natural convection solar dryer; (a) view from solar collector and (b) view from drying chamber

Solar dryer system with photovoltaic (PV): Ruslan *et al*. (2003) designed, constructed and tested solar dryer system with PV. This custom designed parallel flow V-groove type collector was used in this drying system. The air was flowed through the drying system by using a fan powered by PV source. To facilitate the air flow during the absence of PV energy source, a funnel with increasing diameter towards the top with ventilator turbine is incorporated into the system. Two 12 V, 1.2 A DC fan attached to the intake of chimney were included in solar dryer. The schematic of solar dryer system with PV is shown in Fig. 3 and 4 shows the photograph of solar dryer system with PV. At plantation sites where the crops are harvested or produced, this drying system is designed with high efficiency and portability in mind so that it can readily be used.

At mean daily radiation intensity of 800 W/m^2, the efficiency was about 44% with mean air flow rate 0.16 kg/s has been achieved. Under the above condition,

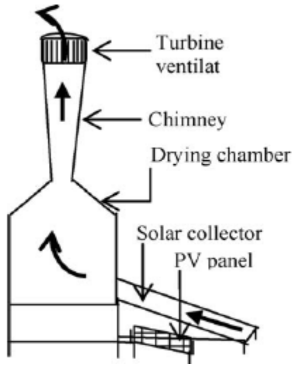

Fig. 3: Schematics of solar dryer system with photovoltaic (PV)

Fig. 4: Photograph of solar dryer system with photovoltaic (PV)

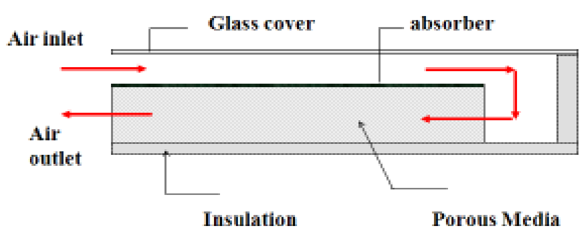

Fig. 5: The double-pass solar collector with porous medium in the second channel (Sopian *et al*., 2007)

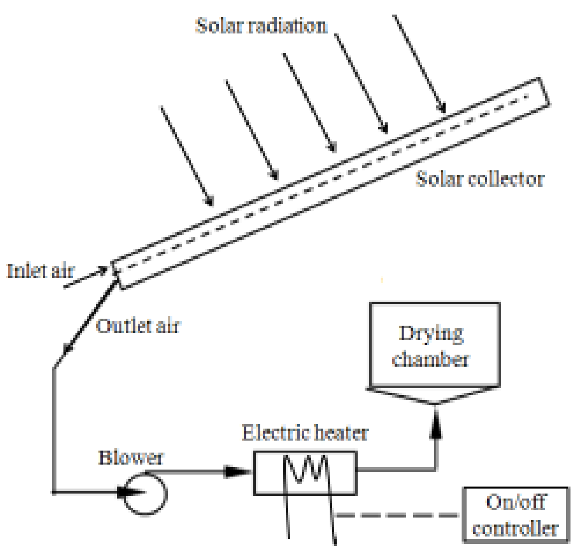

Fig. 6: Schematic of the solar assisted drying system (Sopian *et al*., 2007)

46°C was the daily mean temperature of air entering the drying chamber. The temperature of air entering the drying chamber of 45°C has been measured on a bright sunny day with instantaneous solar intensity about 600 W/m^2. As the solar radiation intensity increase, the air flow and air temperature also increase. The instantaneous efficiency decreased when solar radiation increased in the absence of PV or in natural convection flow. At 570 W/m^2 and 745 W/m^2 of solar radiation, the instantaneous efficiency recorded are 35 and 27% and the temperatures of drying chamber are 42 and 48°C respectively. Thus, this dryer is suitable for drying agriculture products.

Solar dryer using porous medium: The solar dryer using porous medium is designed for higher temperature application (Sopian *et al*., 2007; Yahya *et al*., 2008a; Sopian *et al*., 2009; Sopian *et al*., 1999). The collector used in this system is the double-pass flat plate with porous medium in the second channel. The collector width and length are 120 and 240 cm, respectively. The upper channel depth is 3.5 cm and the lower depth is 10.5 cm. 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.

The solar collector array consists of six collectors, arranged as two banks of three 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 schematic of the solar collector with porous medium and solar assisted drying system is shown in Fig. 5 and 6, respectively. The solar collector array is shown in Fig. 7 and the photograph of the system is shown in Fig. 8.

This solar assisted drying system has been evaluated for drying of oil palm fronds, which has been used as nutrition and commercially viable animal feedstock. The initial and final moisture content of the fronds are 70% (wet basis) and 10% (product basis), respectively. The drying time is about 14 h at average solar radiation of about 550 W/m^2 and air flow rate 0.14 kg/s. The average evaporated capacity of drying system is about of 3.80 kg/h. The drying system with 70% recycle may reduce drying time about 15% and increasing the drying efficiency about of 10%. Thermal efficiency and evaporative capacity depends on solar radiation, ambient temperature and air flow rate. The drying system efficiency and evaporative capacity increase with increasing of solar radiation and air flow rate.

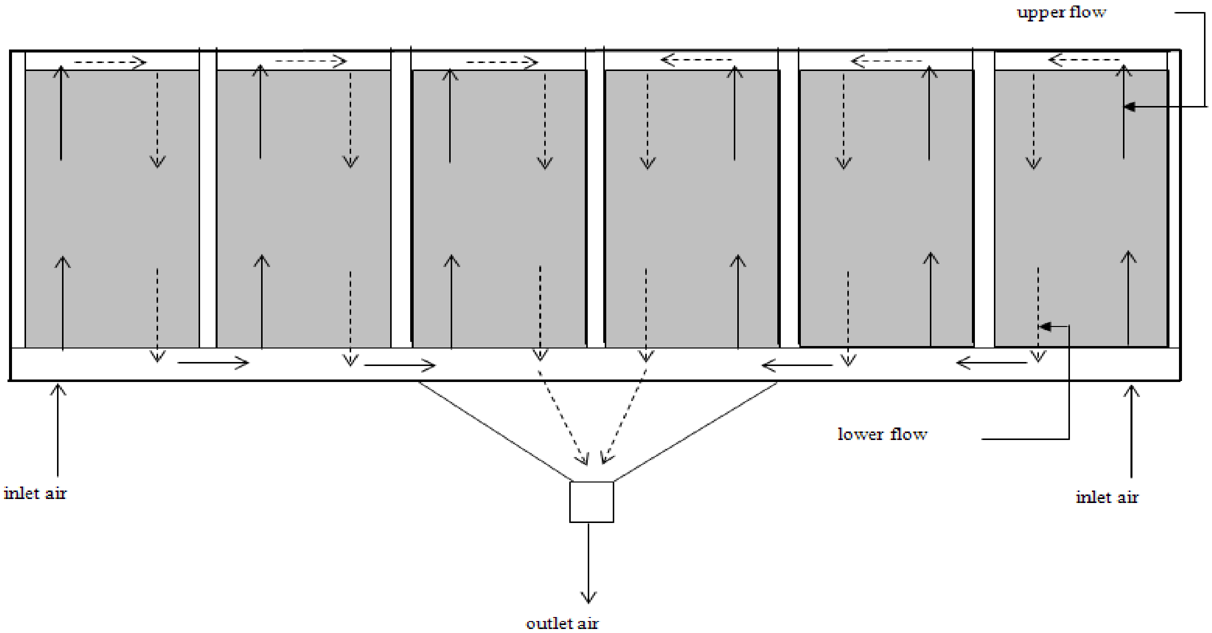

Fig. 7: The collector array for the solar dryer using porous medium (Sopian *et al*., 2007)

Fig. 8: The photograph of the system

Table 1: Specifications of the solar drying system

Descriptions	Specifications
Collector area	11.52 m^2
Drying chamber area	4.8 m^2
Capacity of dryer	150-200 kg
Mass flow rate	0.05-0.13 kg/s
Average drying air temperature	40-65°C

Solar dryer using finned absorber: Figure 9 shows the schematic diagram of the solar drying system with the double-pass solar collector with fins. The main components of the drying system consist of solar collector, auxiliary heater, blower and drying chamber. The size of the drying chamber is 4.8 m (length) ×1.0 m (width) ×0.6 m (height). Table 1 shows specifications of the solar drying system. The drying system has a total of four double-pass solar collectors

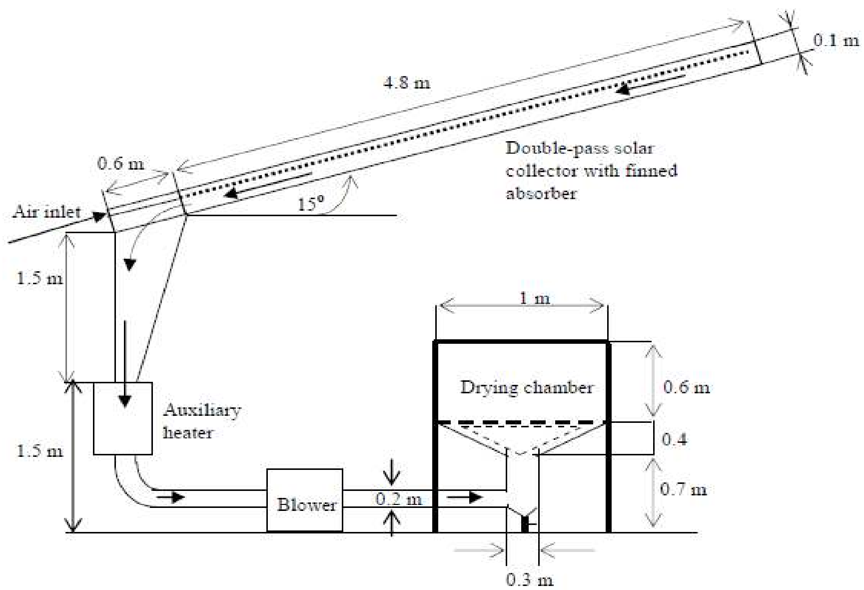

Fig. 9: Schematic diagram of solar assisted drying system

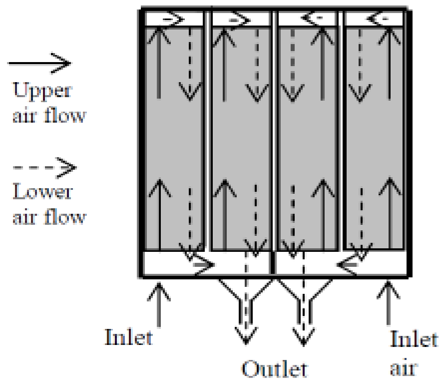

Fig. 10: The collectors arrangement for the solar drying system

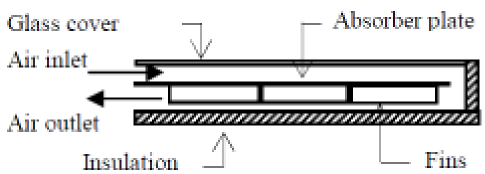

Fig. 11: The schematic double-pass solar collector with fins

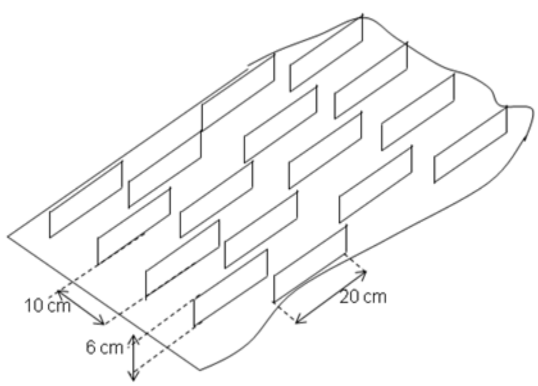

Fig. 12: Top view of the staggered fins absorber

(Fig. 10). Each collector has a length of 480 cm and a width of 120 cm. The first channel depth is 3.5 cm and the second channel depth is 7 cm. Staggered fins made of angle aluminium, 0.8 mm thickness were attached to the bottom surface of the absorber plate. The fins acts as increase heat removal from first channel to the second channel and improved the overall efficiency of collector. The bottom and sides of the collector have been insulated with 2.5 cm thick fiberglass to minimize heat losses.

Figure 11 shows the cross section of the collector with the fins and the top view of the staggered fins absorber is shown in Fig. 12. The photograph of the system is shown in Fig. 13. The performance of double-pass finned collector has reported by Fudholi *et al.* (2010b, 2011a, 2011b, 2013d, 2013e).

The solar collectors are arranged as two banks of two collectors each in series. Internal manifold are used to connect the collectors. Air enters through the first

Fig. 13: Photograph of solar dryer using finned absorber

channel and then through the second channel of the collector. The electrical auxiliary heater has been attached to the system in order to provide continuous heat as required by the drying commodity. An on/off controller is used to control the startup and shutdown of the auxiliary heater.

This solar dryer has been tested for drying of chili (Fudholi *et al.*, 2012a, 2013f, 2014a), medical herbs (Fudholi *et al.*, 2012b) and seaweed (Fudholi *et al.*, 2011c, 2011d, 2014b). This solar dryer has been evaluated for drying seaweed. The initial and final moisture content of seaweed are 90% (wet basis) and 10% (wet basis), respectively. The drying time is about of 14 h at average solar radiation of about 544 W/m^2 and air flow rate 0.06 kg/s. The collector, drying system and pick-up efficiencies were found to be 37, 27 and 92%, respectively for 40 kg seaweed.

The solar drying system using double-pass solar collector with fins has been installed at the OPF FELDA Kuantan, Malaysia. The system consisted of a drying chamber, heaters, blowers and six solar collectors of double-pass type with fin in the second pass of the collector. The length of each collector was 4.8 m and the width was 1.2 m. the collector has a glass cover and the sides are insulated and painted black on an aluminium absorber plate. The upper channel dept is 3.5 cm and the lower depth is 7 cm. the bottom and sides of the collector are installed with 2.5 cm thick fiberglass wool to minimize heat loss. The system has been evaluated for drying the oil palm fronds. For 100 kg palm oil fronds, the drying time is about of 3 drying day in sunny day (without heater) from an initial moisture content of 60% to the final moisture content of 10% (wet basis). A temperature of 55°C can be reached at a solar radiation level of 650 W/m^2 and mass flowrate of 0.13 kg/s, the overall system efficiency is about 20% (Fudholi *et al.*, 2012c, 2015).

Solar dryer using V-groove absorber: A solar dryer using V-groove absorber was designed, built and its performance studied by Ruslan *et al.* (1999a, 1999b) and Sopian *et al.* (2001). The configuration of the system is shown in Fig. 14, the configuration of V-groove collector is shown in Fig. 15 (Fudholi *et al.*, 2008) and photograph of the system is shown in Fig. 16. Table 2 shows the specifications of the solar assisted drying system.

The main components of the system were solar collectors, blower, drying chamber and auxiliary electric heater. The collector selected for this study was

Table 2: Specifications of the solar dryer using V-groove absorber

System components	Descriptions	Specifications
Collector	Type of absorber	V-groove back pass
	Absorber material	Folded aluminium sheet; SWG22: 244 cm×122 cm
	Angle of groove	49° and height 14 cm
	Collector area	100 cm×460 cm per unit collector
	Total collector area	13.8 m^2
	Top cover	Glass: thickness 2.5 mm; one side tempered
	Insulator	Fibreglass wool; 2.5 cm thickness, density 46.0 kg/m^3
Air circulation	Two unit axial fan	2700 rpm, 85 W: 230 V (AC), single phase motor
	Ducting	18 cm outlet diameter: PVC pipe
	Air flow rate	6.15-17.13 m^3/min
Drying chamber	Type	Adjustable set of shelved frame
	Size	1.0 m×2.5 m×2.9 m

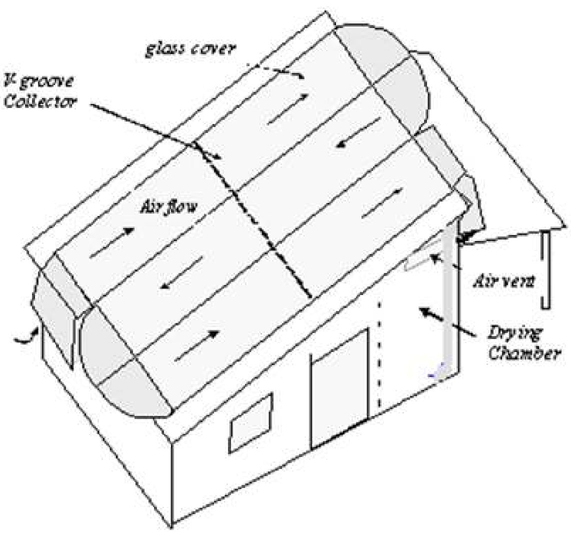

Fig. 14: Configuration of the solar dryer using V-groove absorber

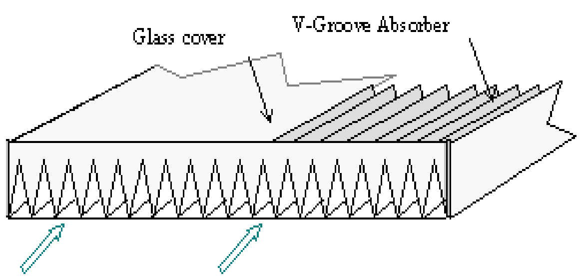

Fig. 15: Configuration of the V-groove absorber

Fig. 16: Photograph of the solar dryer with V-groove solar collector

the back pass V-groove type with dimension of 1.0 m (width) ×2.3 m (length) ×0.14 (height). The designed system consisted of six set collectors in series which gave total area is about 13.8 m^2. By using two fans with electrical power of 85 W and 2700 rpm each, the speed of air can be regulate to produce 6.15- 17.13 m^3/min of hot air to the drying chamber. The drying chamber was cabinet type with the size of 1.0 m (width) ×2.5 m (length) ×2.9 m (height). The chamber contains an adjustable rack for drying trays where the commodity to be dried were placed. The hot air from the collector entered the chamber at the bottom and exit through an air vent at the top. Two units of electric heater, 5.0 kW each, thermostat controlled were placed at the inlet of the chamber. For drying process with higher and constant temperature, auxiliary electric heaters were used.

For the continuous process, the fraction of energy used by solar is about 24% and for the daytime drying process, the fraction of energy contributed by solar is 60%. The collector efficiency is about 40-65% at solar radiation levels of 400-700 W/m^2 and ambient temperature range of 27-30°C with air flow rate ranging from 6.13-16.7 m^3/min. The drying system efficiency is about 20-30%. Herbal tea has been dried using this solar dryer. The fresh tea leaves are dried from an initial moisture content of 87% (wet basis) to 54% (wet basis) at a drying temperature of 50°C and flow rate of 15.1 m^3/min (Sopian *et al*., 2000).

Solar dryer using Photovoltaic Thermal (PV/T) - Compound Parabolic Collector (CPC) and fins: This solar dryer system was used double-pass collector with Compound Parabolic Collector (CPC) and fins as heat transfer enhancement devices. Othman *et al*. (2008a, 2002) studied an experimental validation of theoretical model of various configuration of hybrid PV/T air collector. They observed that double-pass PV/T solar collector with CPC and fins give the best performance (Alfegi *et al*., 2008, 2009). Solar cells are placed at the upper part of the absorber plate. Hence, both heating and electricity production has been produced for one single collector. The solar cells produce DC electrical power to operate a DC fan for forced mode operation. The photograph of this system is shown in Fig. 17. This system can be used for drying various agricultural products like fruits and vegetables.

Solar assisted heat pump dryer with multifunctional solar collector: The system was made by three main

Fig. 17: Solar dryer using Photovoltaic Thermal (PV/T)-Compound Parabolic Collector (CPC) and fins

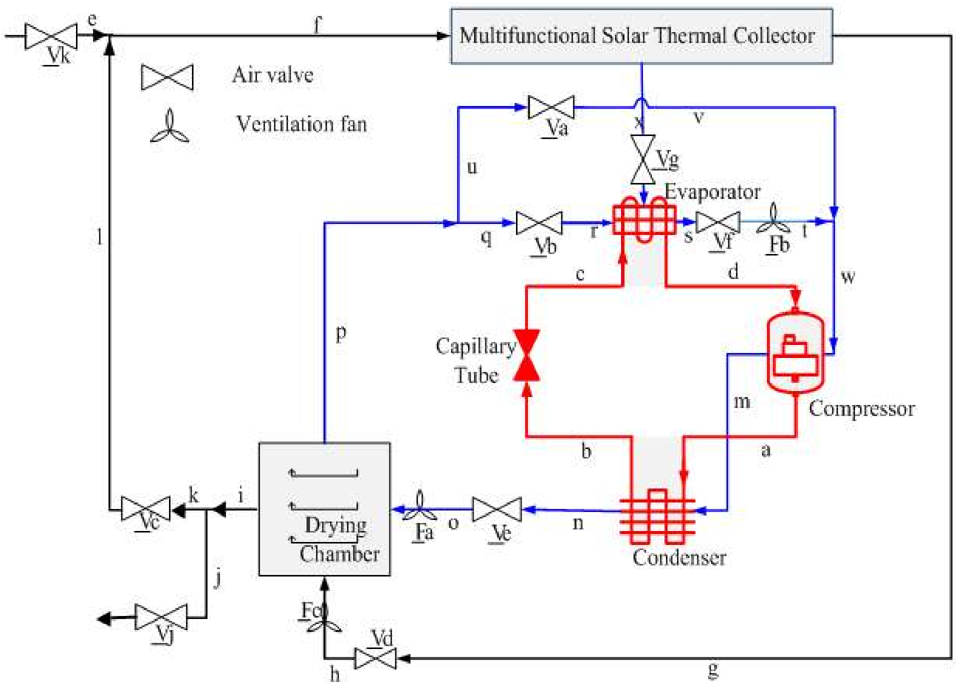

Fig. 18: Schematic diagram of solar assisted heat pump dryer with multifunctional solar collector

Fig. 19: Photograph of solar assisted heat pump dryer with multifunctional solar collector

components; heat pump system, drying chamber and multifunctional solar collector (Othman *et al*., 2008b; Majid *et al*., 2007, 2009). The heat pump system is the main component with compression power of 380 to 500 W. It will supply heat through a condenser and a compressor to the drying chamber. An evaporator is use to remove the humidity in air that was produced during drying process. Multifunctional solar collector is use to increase the heat gain from outside environment. It acts as a heater when the solar radiation is available and as a cooler during night or rainy day and also as an evaporator if the temperature is low enough. The solar collector consists of cover, cross absorber and heat absorber. Figure 18 shows schematic diagram of solar assisted heat pump dryer with multifunction solar collector and photograph of solar assisted heat pump dryer with multifunction solar collector are shown in Fig. 19.

The result indicated that the multifunctional solar collector could provide energy to the heat pump dryer during drying process with producing heat 8% when function as a cooler, 96% as a heater during open cycle and 98% as a heater during close cycle. The entire process can provide 50% of heat that required by the system in drying process. The result also shows that the multifunctional solar collector can be used to obtain heat not mainly from the solar radiation as a heater but also as a cooler or evaporator from the low ambient air temperature. The operation time can be increased, hence will increase solar collector's efficiency. This dryer is suitable for high quality of drying herbs and other agriculture products.

WATER BASED SOLAR COLLECTOR SYSTEMS

Solar assisted heat pump dryer with Photovoltaic Thermal (PV/T) water based collector: Daghigh *et al.* (2009a, 2009b) designed a solar assisted heat pump dryer with PV/T water based collector. A novel solar assisted heat pump system for space cooling, drying, water heating, dehumidification, electricity production and Building Integrated Photovoltaic Thermal (BIPVT) application using (water-working fluid) based PV/T collectors is proposed in this invention. The system comprised of PV/T, air source heat pump system (compressor, evaporator, condenser, expansion valve),

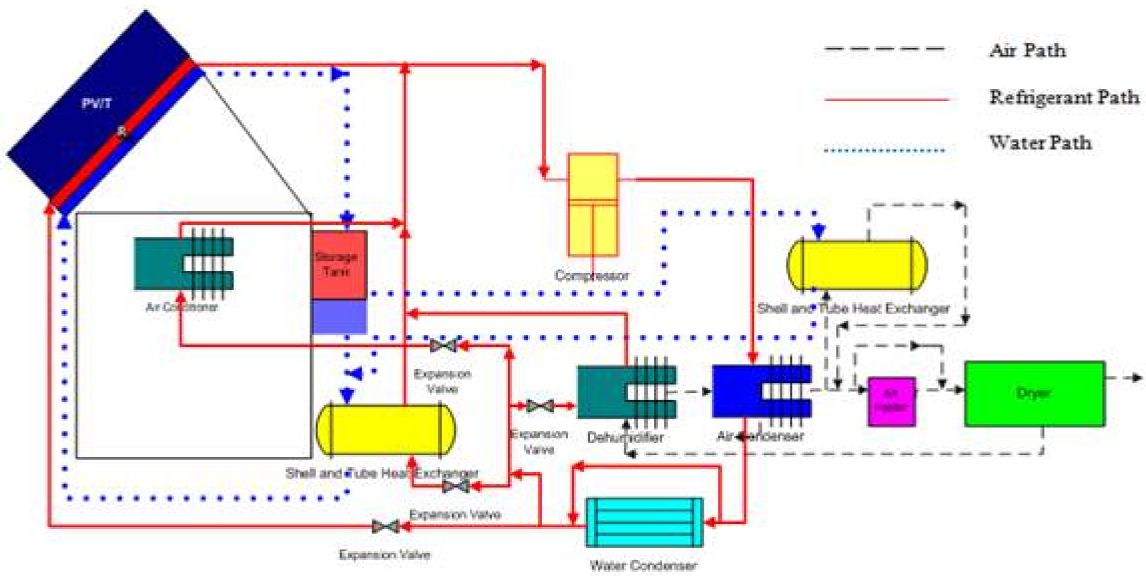

Fig. 20: Schematic diagram of solar assisted heat pump dryer with PV/T water based collector

Fig. 21: Configuration of solar assisted heat pump dryer with PV/T water based collector

Fig. 22: Photograph of solar assisted heat pump dryer with PV/T water based collector

water-cooled condenser, storage tank, heat exchangers, expansion valves, drying chamber auxiliary heater and dehumidifier. Schematic diagram of solar assisted heat pump dryer with PV/T water based collector as shown in Fig. 20. Figure 21 shows the configuration of solar assisted heat pump dryer with PV/T water based collector and photograph of solar assisted heat pump dryer with PV/T water based collector are shown in Fig. 22.

The system operation for cooling (air conditioner mode), heating (drying mode) and dehumidification air comprises of four separate modes: a cooling mode, a heating mode, a dehumidification mode and in a multipurpose mode. In the cooling mode the valve means direct refrigerant to the evaporator of heat pump a way to absorb heat by refrigerant (working fluid) from conditioning air in the evaporator, in the heating mode the valve means direct refrigerant to the air-based condenser of heat pump a way to reject heat to the air from refrigerant in the condenser. In the dehumidification mode the air at the dryer exit, direct to dehumidifier to enable the recovery of the thermal energy carried by the air, which would otherwise be wasted. In the multipurpose mode the system can serve more than one function, simultaneously.

A system for heating water and electricity production is also considered in this system. PV/T collectors collect and convert energy from the sun into electric energy and thermal energy simultaneously. The hot air for drying purpose has been forced to flow in the water to air heat exchanger. The hot water tank acts as heat storage of the solar drying system. In order to preheat the air before going into drying chamber, the hot water and air which leave air-cooled condenser will direct into one shell and tube heat exchanger and then after transferring the heat to air, water again will go inside storage tank.

Further heating of the air is occurred inside heat exchanger. The incoming air from air-cooled condenser into heat exchanger (shell and tube heat exchanger after air condenser) is more heated using hot water which is already produce in PV/T collector and have been stored in storage tank. If for a particular application more heating of air requires, the auxiliary heater will do this job. The drying chamber contains multiple trays to hold the drying material and expose it to the air flow.

The air leaving the dryer is cooled and dehumidified to get rid of the moisture absorbed in the dryer, a rejection of sensible and latent heat occurs at the dehumidifier (dehumidifier mode). Subsequently, this heat is available at the air cooled condenser for the reprocessing of the air for the next cycle. The cycle repeats until the required moisture level of the drying material is attained. When dehumidifier is not in service, the air leaving the dryer will vent to the atmosphere.

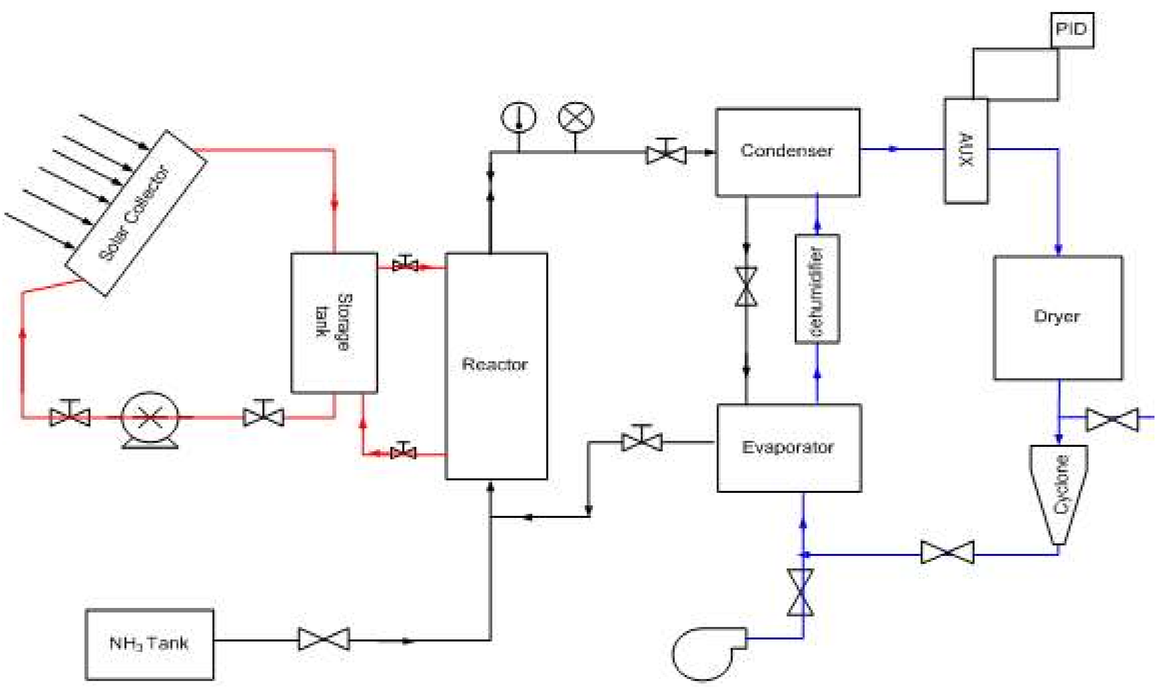

Fig. 23: Schematic diagram of solar assisted chemical heat pump dryer (Ibrahim *et al*., 2008)

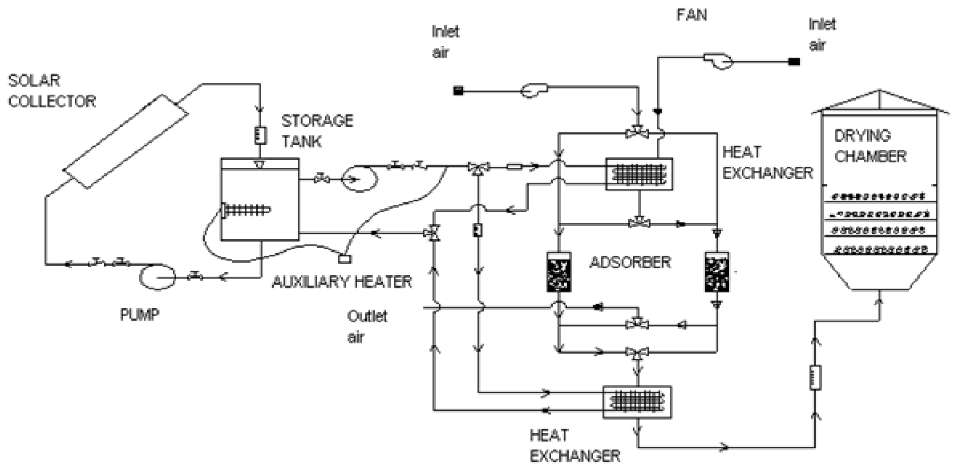

Fig. 24: Schematic diagram of solar assisted dehumidification system

The results of experimental and simulation study indicated that improved quality control, reduced energy consumption, high coefficient of performance and high thermal efficiency of the dryer can be achieved in this system. A wide range of drying conditions typically -20 to 100°C (with auxiliary heating) and relative humidity 15 to 80% (with humidification system) can be generated. Furthermore, color and aroma qualities of dried agricultural products using this heat pump dryer system are better than those products using conventional hot air dryers.

Solar assisted chemical heat pump dryer: A chemical heat pump is proposed as one of the potentially significant technologies for effective energy utilization in drying. The solar assisted chemical heat pump dryer has been constructed and tested by Ibrahim *et al*. (2008). The schematic diagram of solar assisted chemical heat pump dryer is shown in Fig. 23. The system consists of four main components; evacuated tubes solar collector, storage tank, solid-gas chemical heat pump and drying chamber. A solid-gas chemical heat pump consists of reactor, condenser and evaporator. The drying chamber contains multiple trays to hold the drying material and expose it to the air flow. The general working of chemical heat pump occurs in two stages: adsorption and desorption. An average drying chamber temperature of 55°C and air at relative humidity of 20-30% has been achieved. The total energy required to maintain a drying temperature of 55°C is 60 kWh. The system contributed 51 kWh and contributed approximately 85% of the overall energy requirement and the rest of 15% energy provided by auxiliary heater (Fadhel *et al*., 2010).

Solar dryer using dehumidification system: A solar dryer using dehumidification system has been designed, fabricated and evaluated (Yahya *et al*., 2008b, 2008c, 2001). The schematic diagram of solar assisted dehumidification system is shown in Fig. 24 and photograph of the system is shown in Fig. 25. This system was superior compared to conventional air

Fig. 25: Photograph of solar dryer using dehumidification system

based solar dryers because of low operating temperature and relative humidity. This system will be suitable for drying medical herbs or heat sensitive agricultural produce. The main components of the drying system consist of solar collectors, water tank, heat exchangers and adsorber columns, drying chamber, pump and blower. The solar collectors were used 60 evacuated heat pipes tube arranged in parallel with total area of 6 m^2. The area of absorber in tube each individual was 0.1 m^2 and distance between the tubes was 7.1 cm. The pump electrical capacity was 0.1 kW and was used to circulate water from the water tank to the solar collectors. The water was circulated to the solar collector at velocities of 0.39 and 0.6 m/s. The water tank with diameter of 45 cm and height of 85 cm was made from stainless steel and insulated using glass wool and foam rubber. Two units of cross flow type heat exchanger have been used. This system has two adsorber columns with dimension of 25 cm (width) ×25 cm (length) ×100 cm (height). The columns were filled up with silica gel to a height of 85 cm. The drying chamber was of the cabinet type with the size of 1.0 m (width) ×1.0 m (length) ×2.5 m (height). The chamber contains the drying trays with adjustable racks to place the medical herbs. The dry air from adsorber columns entered the drying chamber at the bottom and exit through an air vent at the top. The dry air was circulated by using blower with electrical capacity of 0.75 kW with air velocities of 1.75 m/s and 3.25 m/s.

Pegaga leaf which contains active medical ingredients such as *madecassoside* and *asiaticoside* was

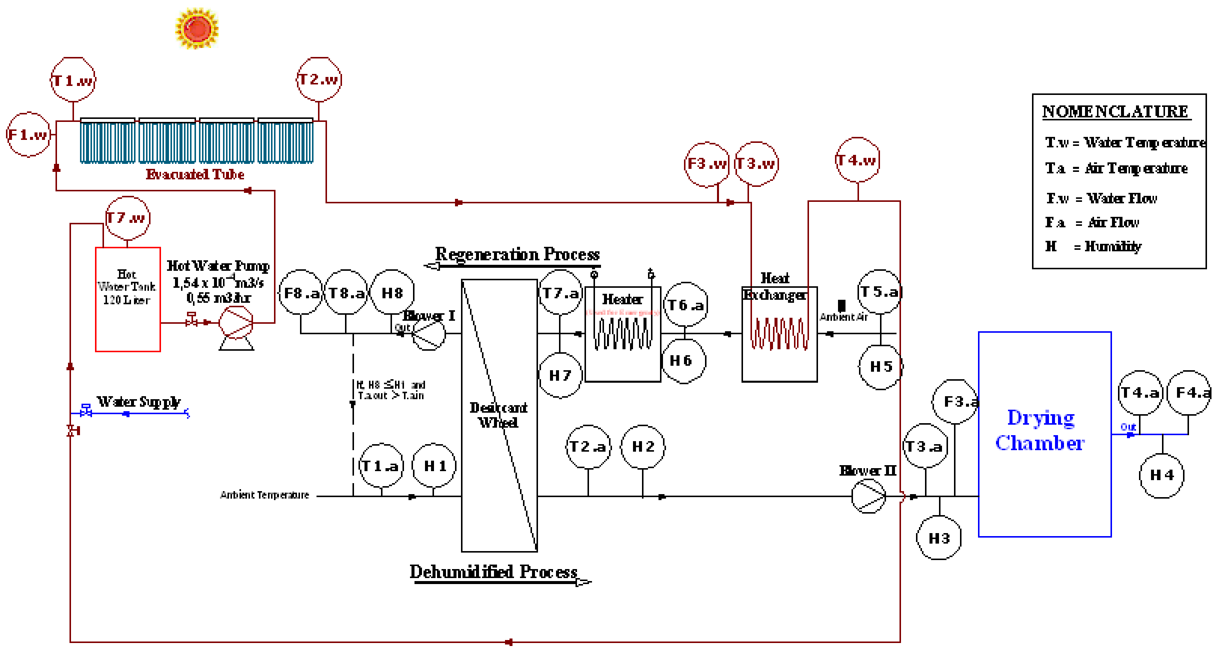

Fig. 26: Schematic diagram of solar desiccant dryer system

Fig. 27: Photograph of solar desiccant dryer system

dried in the system. The solar collector efficiency has been found to be 57% at solar irradiance intensity average of 696 W/m^2 and water velocity 0.6 m/s. The quality of the products, before and after dehumidification process has been measured using a High Performance Liquid Chromatographic (HPLC). The results indicated that there were no missing active ingredients of pegaga leaf during dehumidification process. The color of drying products was measured using a chromameter. The results indicated that the drying color was brighter than pegaga leaf dried in the conventional hot air dryer.

Solar assisted desiccant dryer: Solar assisted desiccant dryer system has been designed and fabricated for the production of dried food products (Suyono *et al*., 2011). The schematic diagram of solar desiccant dryer system is shown in Fig. 26 and photograph of the system is shown in Fig. 27. The use of desiccant wheel for absorbing the moisture in the dryer system is appropriate because not only the air becomes drier, but it also becomes hotter due to isotherms process. The system is able to provide suitable drying temperature, humidity and flow rate for home industry with capacity in accordance to the characteristics of the material. This system consists of heat pipe evacuated tube collectors with total area of 13.32 m^2, cross flow heat exchanger for regeneration and to heat the air after dehumidification, desiccant wheel with model no. 770 WSG produced by NOVELAIRE having operating system 1:1 and maximum flow rate of 1500 cfm, water pump with maximum capacity of 12 L/m, water tank with capacity of 230 liters, drying chamber and electrical heater for continuous operation and more effective temperature control.

Performance of the collectors were determined with water flow rate of 8 L/m. Experiment were conducted with two modes (1) heat exchanger to heat the air in the regeneration process and (2) heat exchanger to heat the air after the dehumidification process, while the regeneration process utilized an electrical heater. At average solar radiation of 505 W/m^2, mean water temperature and efficiency were 76.6°C and 68.3%, respectively. At average solar radiation of 624 W/m^2, mean water temperature and efficiency were 78.8°C and 69.6% respectively. Experiment on the desiccant wheel of mode (1) showed that the average effectiveness of sensible dehumidification, sensible regeneration, latent dehumidification and latent regeneration were 72.6, 82.1, 79.3 and 78.9%, respectively. In mode (2), the average effectiveness of sensible dehumidification, sensible regeneration, latent dehumidification and latent regeneration were 71.4, 72.0, 67.0 and 72.8%, respectively. Mode (1) was better than mode (2) with mean drying air temperature and absolute humidity was 58°C and 0.0167 kg$_{(H2O)}$/kg$_{(dry\ air)}$. The system was able to evaporate 10.8 kg$_{(H2O)}$/hr of water in the materials at pick up efficiency of 55%.

CONCLUSION

The Solar Energy Research Institute (SERI) has successfully establish, designed and conducted several applications of solar assisted drying systems with high performance. Hence, SERI has developed environment friendly products for a sustainable and carbon free future. These solar assisted drying systems have the advantages of heat storage, auxiliary energy source, integrated structure control system and can be use for a wide range of agricultural and marine produce. Furthermore, these innovations of green technology can improve the quality of drying agricultural and marine products.

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