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Review on Solar Collector for Agricultural Produce

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ABSTRACT

Among the most important components of solar energy systems, solar collectors are devices that receive solar energy and convert it into thermal energy, as most essential components of solar dryer. This review presents description and previous work performed on performances of solar air collector for agricultural produce. In addition, various solar collectors are classified and described. Solar air collectors for drying application of agricultural produce are presented and summarize. The energy and exergy efficiency of the solar air collector ranges from 28% to 62% and from 30% to 57%, respectively.

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1. INTRODUCTION

Today the world is mainly facing two problems. One is the power crisis that is fast depleting of fossil fuels and other one is pollution problem like global warming and carbon emission. The best solution for this problem is utilization of renewable energy resources [1]-[3]. Solar energy is a renewable source of energy that is available as a practically endless source, with no emissions, and with no risks for the environment [4]-[6]. Due to the current trends towards scare and expensive of fossil fuel, and uncertainty regarding future cost and availability, use solar energy in drying of agricultural products will probably increase and become more economically feasible in the near future. Open sun drying is traditional method to preserve agricultural products in tropical and subtropical countries. Considerable saving can be made with this type of drying since the source of energy is free and sustainable. However, open sun drying have many disadvantages such as degradation by dust, rain, wind-blown debris, storm, insect infestation, rodents and animal interference which will result in contamination of the product. Additionally, the drying time required for a given commodity can be quite long and result in post-harvest losses. The quality of the dried products may also be lowered significantly. An alternative to the traditional method and a contribution towards the solution of these problems could be use of a solar drying [7]-[14].

Numerous studies have been conducted on the use of solar air heaters in thermal industrial processes, space heaters and solar dryers. The solar drying of agricultural and marine products is among the most significant potential applications of solar air heaters. Given that solar air heater is an essential component of the indirect-type solar dryer, improving the solar air heater would lead to the quality performance of the drying system. Heat transfers in varied absorber plate configurations can be extremely difficult to model accurately. Therefore, experimental work is required to verify the results obtained by the theoretical models. Diverse theoretical and experimental studies have been performed to increase the thermal performance of solar air heaters through different techniques [15]-[21]. In this review, we focused on the flat-plate solar air collectors for crop drying aplications.

2. TYPES OF SOLAR COLLECTORS

Solar collector is one of the most significant parts of a solar energy system. It is a device designed to receive solar energy, convert it into thermal energy, and transfer the thermal energy to the fluid that flows into the collector. A well-known type of solar collector is the flat-plate collector. The simplest solar collector, which has no glazing and comprises an absorber plate without insulated sides. This collector is the most suitable for swimming pool heating, where water temperature needs to be increased by only a few degrees above the ambient air temperature (0 °C–10 °C increase). Therefore, heat losses are relatively unimportant. A glass or plastic cover can be used to reduce heat loss. A solar collector with glazing consists of a cover, an absorber plate, and an insulation at the bottom and on the sides. The cover can reduce heat loss at the top of the collector, while the absorber plate can be insulated to reduce heat loss at the surroundings. A flat plate collector with a glass cover and an air passage (single pass) is commonly called a conventional solar collector. It often uses an absorber plate painted in black. Higher-temperature collectors usually incorporate one or more glazing layers.

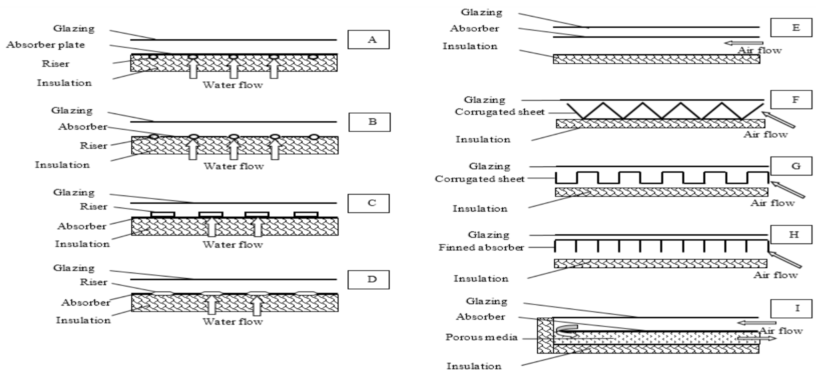

Figure 1. Various Types of Flat-Plate Solar Collectors: A-D: Water-Based Solar Collectors, E-I: Air-Based Solar Collectors

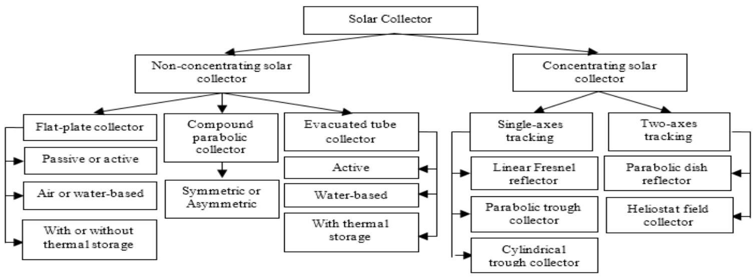

Figure 2. Classification and Indicative Temperature Range of Solar Collectors

Figure. 1E presents a conventional flat-plate collector consisting of a transparent cover, absorber, insulation, and frame. Accordingly, flat-plate collector consists of one or more glass sheets or a transparent material placed above an absorbing plate with air flowing around it. Conventional flat-plate collectors have low thermal efficiency. Thus, the use of extended heat transfer areas, such as corrugated surfaces (Figure. 1F and 1G), finned absorbers (Figure 1H), and porous media (Figure. 1I), is required to attain substantial collector
efficiency improvement.

Motion-based solar collectors have two types: non-concentrating solar collector and concentrating solar collector [22]. Figure 2 displays a systematic classification of the basic solar collector types. Non-concentrating solar collector may be classified as a flat-pate collector, evacuated tube collector, or compound parabolic collector. It may be further categorized into passive or active non-concentrating solar collector. A passive non-concentrating solar collector does not require any electrical/ mechanical power to run a pump or fan, whereas an active non-concentrating solar collector requires a blower/fan to pump the air into the thermal storage. In addition, non-concentrating solar collector may also be classified as air- or water-based non-concentrating solar collector.

3. SOLAR AIR COLLECTOR FOR AGRICULTURAL PRODUCE: AN OVERVIEW

Several types of solar air collectors for drying applications have been designed, evaluated, and developed in various countries, yielding varying degrees of technical performances based on energy and exergy analyses. Table 1 shows summarizes the studies conducted on solar air collectors for agricultural produce as reported by different researchers. A number of solar collectors for agricultural produce were developed in Indonesia, including solar air collectors integrated or combinations with (a) heat pumps, (b) biomass furnaces, (c) fluidized beds, and (d) heat pumps and biomass furnaces.

Table 1. The studies conducted on solar air collector for agricultural produce

Ref.	Type of solar collector	Agriculturalproduce; load, kg	Moisture content, %wb; final (M_t), initial (M_i)		Drying time (h)	Specific moisture extraction rate (kg/kWh)	Efficiencies, %; drying (η_d), pick-up (η_p), collector (η_c), exergy (η_{Ex})			
			M_t	M_i			η_d	η_p	η_c	η_{Ex}
		Bamboo								
[23]	Double-pass solar collector	40	17	96	33	-	23	61	56	-
		Banana								
[24]	Conventional solar collector	300	30	69	36	-	-	-	-	-
		Cassava								
[25]	Solar collector with double duct	49	17	66	-	-	34	-	-	-
[25]	Solar collector with double duct	66	17	67	-	-	34	-	-	-
[25]	Solar collector with double duct	162	17	66	-	-	36	-	-	-
		Chili								
[26]	Double-pass solar collector	22	-	-	11	0.14	9	-	-	-
[27, 28]	Double-pass solar collector with fins	40	10	80	33	0.19	13	45	28	57
[29]	Back pass V-groove collector	24	10	80	31	-	6	30	38	-
[30]	Solar collector integrated with gravel as heat storage material	40	9	73	24	0.84	21	-	-	-
[31]	Double-pass solar collector	38	10	90	32	-	24	22	62	-
		Cocoa								
[32]	Solar collector with fins	50	7.5	67	21	-	38	-	-	-
[33]	Solar collector with fins	48	8.6	67	20	-	20	-	-	-
		Copra								
[34]	Solar collector integrated with gravel as heat storage material	60	9	52	66	0.84	-	29	-	-
		Curcuma								
[35]	Solar collector with fins	30.7	7.5	80	8.5	0.55	36	-	-	-
[36]	Solar collector with fins	30.7	7.5	80	9.5	0.40	26	-	54	-
		Fish sardines								
[37]	Conventional solar collector	52	16	67	30	-	30	-	-	-
		Green peas								
[38]	Solar collector integrated with desiccant	20	5	80	14	0.82	-	42	-	-
[38]	Solar collector integrated with desiccant	20	5	80	18	0.65	-	35	-	-
[38]	Solar collector integrated with desiccant	20	5	80	21	0.55	-	25	-	-
		Jackfruit leather								
[39]	Conventional solar collector	50	12	76	14	-	48	-	33	41
		Mackerel								
[40]	Conventional solar collector	25	16	72	27	-	20	-	-	-
		Mushroom								
[41]	Conventional solar collector	160	6	89	8	-	52	-	34	-
		Paddy								
[42]	Solar collector with fins	12	14	20	0.36		-	-	16	50
[43]	Solar collector with fins	12	14	20	0.66	0.19	-	-	56	-
		Seaweed								
[44]	Double-pass solar collector	40	10	90	15	0.38	27	95	35	30
		Silver jewfish								
[45]	Back pass V-groove collector	51	10	64	8	0.34	23	-	40	-

4. CONCLUSIONS, RECOMMENDATION AND FUTURE SCOPE

Based on the present review, the following conclusions can be drawn:

- Solar collectors are used for drying applications, the collector and drying efficiency rates were 44% and 27%, respectively. The minimum and maximum collector efficiencies were 28% and 62%, respectively.
- The exergy efficiency ranges from 30% to 57% with an average of 43%.
- The Specific moisture extraction rate ranges from 0.14 kg/kWh to 0.84 kg/kWh with an average of 0.49 kg/kWh.

The present review mainly focuses on the development and analysis of solar air collectors. Various analysis methods have been utilized to evaluate solar collector performances, which are generally based on energy and exergy analyses. As suggestion, researchers can be conducted environmental aspect to analyze the performances of energy systems. The economic analyses of solar collectors used for drying applications are very limited in the literature. In addition, few studies are available on the economic analysis of solar dryers, but no details are available on the economic or cost analysis of solar collectors. Furthermore, technoeconomic and thermoeconomic analyses are limited in the literature. Hence, further research on this topic can be conducted, and the results of these analyses can be applied for the improvement of solar collectors or the energy system performance. Additional performance analysis is required for computational software simulations and numerical methods to investigate the process characteristics of any system before its construction. Moreover, the costs and benefits associated with solar dryers with V-groove collectors, finned absorbers, storage materials, and reflectors as the sun tracking system should also be studied. The development of a hybrid photovoltaic solar collector, also known as photovoltaic thermal collector, is a very promising area of research. Today, hybrid solar collectors are utilized in various applications, such as solar drying, solar cooling, water heating, desalination, and pool heating. The future research trends about solar collector for drying application is greenhouse dryer with hybrid solar collector for industry scale. Further research is required to find new thermal storage materials and desiccant materials for this hybrid solar drying systems.

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