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Effect of thermoelectric power and air flow on air temperature and relative humidity

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Abstract

A dehumidifier is a device for drying air by releasing moisture. A dehumidifier with a thermoelectric cooler has the advantage of being more compact and has the potential to be combined with an air heater. This study aimed to determine the effect of thermoelectric power and airflow on air temperature and relative humidity. The research method uses direct experiments with six pieces of thermoelectric as a coolant. The data taken are the cooler surface temperature, the air temperature that is dried, and the humidity of the air. The test results show that the dried air temperature can reach 25.6ºC with 78% humidity in environmental conditions with an ambient air temperature of 31ºC.

Keywords*: dehumidifier; thermoelectric cooler; air temperature; relative humidity*

1. Introduction

Drying is the process of reducing the water content in specific materials (1,2). In agricultural products, fishery products, foodstuffs, to medicines, the drying process can be a way of preservation and storage (3). Because of low humidity will reduce the ability to develop bacteria or fungi that require water. There are several drying methods, including heating, to evaporate the water content in the material. Heating is generally with solar heat because there is no need to incur additional costs, especially in tropical areas like Indonesia, which get a lot of sunlight. However, during the rainy season, sun drying cannot be done (4,5) even though the rainy season lasts quite a long time, about six months a year.

Another drying method is to circulate dry air over the material to be dried. Dry air will absorb the water content in the material due to diffusion. Several drying methods include dehumidification, which reduces air humidity by condensing water vapour (6). Water vapour will condense in cold conditions, so a cooling machine is usually used in a dehumidification device. A dehumidifier for drying has several advantages compared to drying directly under the sun. Among them: the quality of the dried product is better, the colour and aroma are also better maintained compared to high-temperature dryers, it is not dependent on weather conditions, it is not exposed to dirt from the outside air, and the drying time can be shorter (1,3).

Thermoelectric coolers work on the Peltier effect (7). Current flowing in different materials causes temperature differences so that it can convert electrical energy directly into heat or cold. Thermoelectric coolers (TEC) have many advantages over conventional refrigeration cycles that use compressors, which are smaller in size, quieter, have precise temperature control, are longer lasting, and do not require refrigerant. Due to these advantages, thermoelectric coolers have been applied to water cooler dispensers, electronic device coolers, LED lamp coolers, and medical device temperature controllers. However, TEC produces a lower Coefficient of Performance (COP) than a cooler with a compressor. And it is these obstacles that need to be continuously studied to increase efficiency (8).

Vian et al. (9) and Yudhy (10) have researched thermoelectricity as a dehumidifier coolant. Vian et al. make a two-level dehumidifier passage design, where cold air is used as a cooler on the second level while the air that passes through the hot side of the first level is used for space heating (9). Yudhy researched thermoelectric-based portable dehumidifiers by adopting the path of Vian et al. The dehumidifier mode is used to regulate the humidity of the air where the seeds are stored so the seeds can be stored longer. His research results show that four thermoelectric pieces arranged in parallel with an electric current source of 10.32 A and 28 A can reduce humidity with an average COP value of 0.65 and 0.75 and produce a storage temperature of around 40ºC (10).

In general, research on dehumidifiers with thermoelectricity has been combined with heaters so that their dehumidification ability cannot be known independently. Therefore, a dehumidifier using a thermoelectric cooler without heating needs to be investigated. Taking into account the thermoelectric power and the influence of airflow over the heatsink.

2. METHODS

The independent variables in this study are thermoelectric cooling power and air flow rate. The variation of the thermoelectric power used in this study is 6.4; 32.8; 78; and 144 Watts. The air blower varies with on and off conditions for forced convection and natural convection. The dependent variables in this study are the cooling surface temperature, air temperature, and air relative humidity. The measuring instrument used in this study is a digital thermometer to measure the surface temperature of the heatsink and an anemometer to measure the wind speed generated by the blower. Digital multimeter for measuring voltage and amperage. And humidity meters to measure the relative humidity of the air that is dried.

Data collection has been carried out by direct experimental methods on the prototype that has been made. The prototype tested is shown in Figure 1, which consists of a thermoelectric cooling device, electric current control, power supply, humidity and air temperature measuring devices, ammeters, digital thermometers, and air duct covers.

Figure 1. Prototype testing installation

3. Result and Discussion

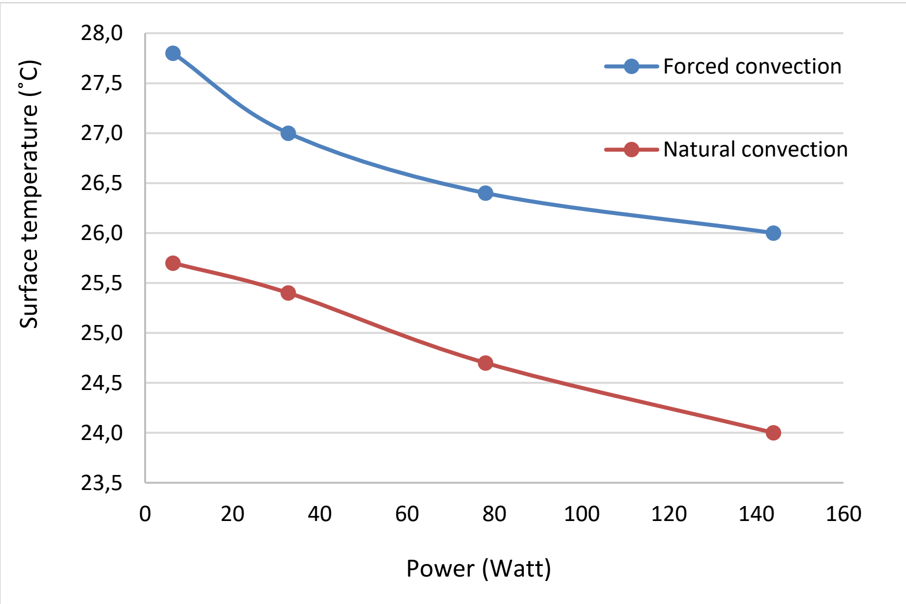
The test results with several variations of the test are then entered in Table 1. Then, three graphs are made to facilitate the analysis of the test results data from Table 1. Graph 1 shows the effect of power on the surface temperature of the cooling fins, Graph 2 shows the effect of power on cold air temperature, and Graph 3 shows the effect of power on the relative humidity of cold air. Airflow is varied with two flow types: the blower is on, which produces forced convection, and the blower is off, which produces natural convection.

Table 1. The results of the dehumidifier prototype test

Air Flow	Voltage (V)	Current (A)	Power (Watt)	Ts (˚C)	Hair (˚C)	Humidity (%)
Forced convection	4	1.6	6.4	27.8	28.5	77
	8	4.1	32.8	27	28.2	78
	12	6.5	78.0	26.4	27.7	79
	16	9.0	144.0	26	27.1	78
Natural convection	4	1.6	6.4	25.7	27.6	83
	8	4.1	32.8	25.4	26.9	81
	12	6.5	78.0	24.7	26.2	80
	16	9.0	144.0	24	25.6	79

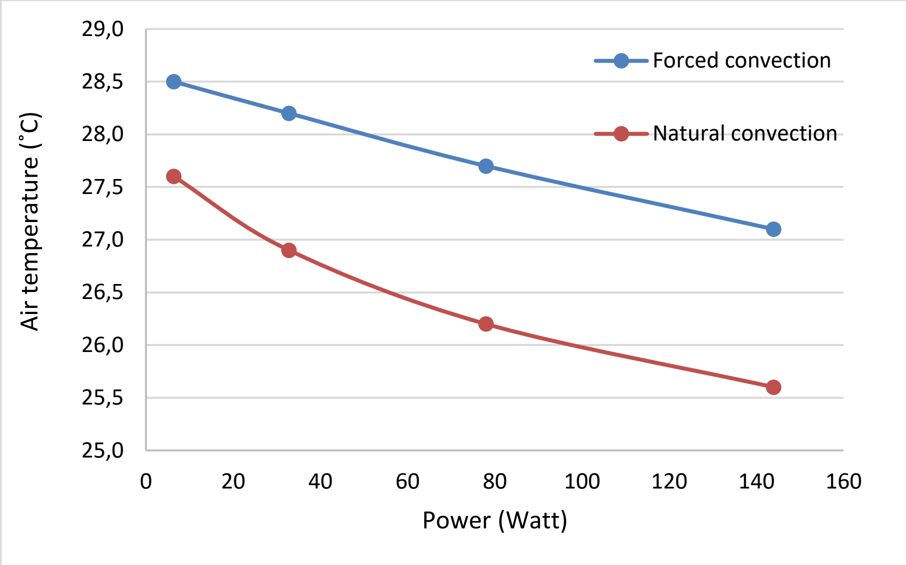
The thermoelectric, which functions like a heat pump, will transfer more and more heat from the cold side surface to the hot side fins so that the higher the electrical power supplied, the cold side fin surface temperature will decrease. The lowest temperature that can be achieved is 24ºC when the airflow blower is off, and the electric power reaches 144 Watts, as shown in Table 1.

The graph of the surface temperature of the cooling fins tends to be linear, with variations in electric power when the blower is off. It shows that the electric power is linearly proportional to the difference in temperature when the blower is off. Meanwhile, when the blower is on, the graph looks slightly curved. It shows that faster airflow will reduce the temperature difference gradient when the cooling power is increased. Because of a greater flow rate, it also requires considerable heat pump power.



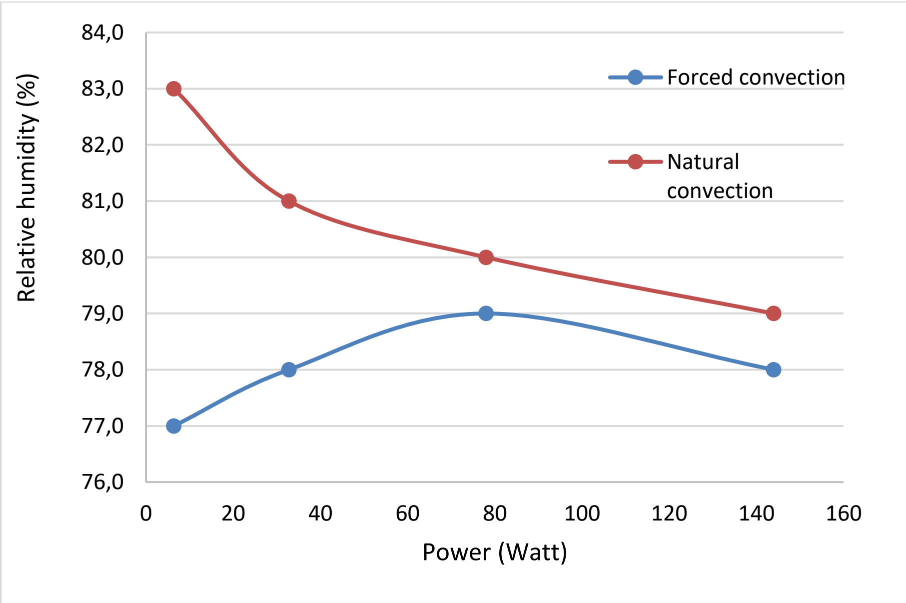
Graph 1. Effect of power on the surface temperature of the cooling fins

Graph 1 shows the effect of the cooler's electric power on the cooling fins' surface temperature when the air blower is on (forced convection) and when the air blower is off (natural convection). When the blower is on, the surface temperature of the cooling fins is higher than when the blower is off. When the blower is on, the convection heat transfer rate from the relatively hot ambient air will be greater towards the cooling fins. Meanwhile, the cooling fins will be colder when the blower is off because of the small amount of heat transfer from the ambient air.



Graph 2. Effect of power on cold air temperature

Graph 2 shows the effect of the cooling power on the temperature of the dried cooling air, as with the surface temperature of the cooling fins, the higher the cooling power, the higher the heat absorbed from the air so that the air temperature drops. When the blower is on, the air temperature resulting from cooling is higher than when the blower is off. The lowest air temperature achieved when the blower is off is 25.6 ^{o}C. Meanwhile, when the blower is on, it is 27.1^{o}C (Table 1). When the blower is on, the airflow rate is more significant, and the cooling load is greater, so the temperature difference becomes lower.



Graph 3. Effect of power on the relative humidity of cold air

Graph 3 shows the cooling power's effect on the cooled air's relative humidity. When the blower is on, the higher the electric power of the cooler, the more the air humidity rises and then drops again. It is because cooling causes the water vapour content in the air to become saturated. When the cooling power is low and the blower is on, saturated water vapour is carried up (the outlet hole), causing an increase in humidity. However, when the cooling power is increased, the surface temperature of the cooling fins decreases so that a lot of saturated water vapour increases in density so that it does not go up into the outlet hole, causing humidity to decrease.

From Graph 3, it can also be seen that the humidity reaches a lower value when the blower is turned on. Increasing the airflow rate by turning on the blower causes the air pressure to drop, the water vapour in the air becomes more saturated, and the airflow will also carry away the water vapour on the surface. The lowest humidity is achieved at 6.4 Watt cooling power, reaching a relative humidity of 77% (Table 1). When the cooling power is increased to 144 watts, the relative humidity reaches 78% and has the potential to continue to decrease if cooling is increased. With high cooling and sufficient airflow, much water vapour in the air will remain on the surface of the cooling fins.

4. Conclusion

Based on the purpose of this study, it can be interpreted that low cooling power and airflow will cause the air to tend to remain moist. When the cooling power is increased, the surface temperature of the cooling fins decreases so that the saturated water vapour increases in density and falls, causing moisture to decrease at the outlet holes. Increasing the airflow rate by turning on the blower causes the air pressure to drop, and the airflow will carry moisture to the outlet hole. With high cooling and sufficient airflow, a lot of moisture in the air remains on the surface of the cooling fins.

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