# Performance of a Simple Custom Air-Water Harvester Using Several Pipe Diameters as the Condensation Unit

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**Abstract.** During the dry season, several areas in Indonesia experience drought. Communities in some areas have difficulty getting clean water. One solution to overcome this problem is to use a machine that produces water from the air. This machine works by utilizing the evaporator as a component to condense water vapour from the air. Nevertheless, this machine could produce less water so far. Therefore, this machine was investigated by varying the diameter of the evaporator pipe. The purpose of this study was to determine the effect of the diameter of the evaporator pipe on the mass of water production. This research was conducted experimentally. This machine worked using refrigerant R134a with vapour compression cycle. The variation in this study was the diameter of the evaporator pipe, namely 10 mm, 8 mm and 6.35 mm. The results showed that there was no trend of the water production respecting to the pipe diameter. The machine worked well, and the highest COP of 11.82 was found in the diameter of 8 mm. The highest total heat absorbed by the evaporator from the air of 74.84 W was attained using machine having pipe diameter of 8 mm. The mass of water production obtained was 0.44 kg at the pipe diameter of 8 mm.

**Keywords:** Pipe Diameter · Water Production · Evaporator · Total Heat · COP

## 1 Introduction

As we know clean water is a basic need for humans that must be available in sufficient quantity and guaranteed quality. Although natural sources of clean water can be said to be sufficient, population growth and increased activities can change the water balance in nature. The impact is that most of the water available at that time is no longer suitable for direct consumption and requires further water treatment processes to make it fit for consumption. Basically, all water can be treated so that it can be consumed. Sources for obtaining water include rain water, river water, lake water, springs and well water. Some of these water sources certainly require prior processing so that the water obtained is

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suitable for consumption. Besides that, there are also several ways to get clean water such as a water catcher net from the fog (cloud fisher), which is a tool used to catch water from the fog using the help of a large net. The net used is made of plastic and woven so that it has a small hole. This tool imitates a spider's web to collect water droplets from the fog at night until just before sunrise. This tool can only function if there is fog in the air, Mirmanto et al. 2021 [1], Prasetyo, 2018 [2], Azari, 2021 [3].

Water is an important thing in human life that is used in everyday life. Apart from being consumed, water is also used for daily household needs. Unfortunately, many areas have difficulties to get clean water for consumption during the dry season. Therefore, to meet the need for clean water, various efforts have been made such as distillation of dirty water, distillation of sea water, as has been done by Mirmanto et al. (2019) [4], Faisal (2019) [5].

While in some major cities in Indonesia the groundwater has been polluted because on the surface a lot of household and industrial waste that cause polluted surface water to seep into the soil. In the fulfilment of clean water, various efforts are made to get it. (Atmoko, 2018).

According to Damanik (2018), the method of capturing water from the air at this time there are several types, namely:

1. Windmill catches water from the air. This windmill is used to obtain water. Having several disadvantages, namely requiring height and installation location that has a large wind speed to be able to move the ferris wheel, this method is very dependent on the weather, wind speed, altitude, and wind direction.
2. Water capture machine from the air using AC (air conditioner) components, the advantages of this method are using tools and components that are easily obtained, can be operated indoors and outdoors, and the amount of water produced is more.

Dirgantara (2020) conducted research making water-producing devices from the air using a 0.5 PK air conditioner cooling system, and R-134a refrigerant. The average amount of water obtained by water-producing machines from the air at the vertical evaporator variation was 343.2 g which was the highest amount of water in the study. The evaporator he used in the study was 60 cm long, 32 cm wide, and 6.35 mm in diameter.

Winata (2020) has conducted a study entitled 'The effect of the number of vertical evaporator pipes on water deposited from the air'. The study used an experimental method by varying the number of pipes on each evaporator he used. The length of the pipe on the evaporator used is 68 cm, with a width of 31 cm and 6.35 mm for the diameter on the pipe.

The results showed that the highest COP value occurred in a variation of 25 vertical evaporator pipes, which was 8,867. This can be influenced by the magnitude of the enthalpy value and the temperature in the engine refrigerant.

Najib (2021) has conducted research on air conditioning systems with variations in capillary pipe lengths of 40 cm, 70 cm and 100 cm with a used diameter of 0.25 in or equal to 6.35 mm with refrigerant R-134a.

The results obtained from the study are the shortest variation of capillary pipes, which is 40 cm produces a water capacity of 1,097 kg, while in the longest capillary pipe variation 100 cm of water capacity obtained is 0.823 kg.

There are several methods of obtaining clean water, such as purifying dirty water or sewage, as reported in previous studies. However, there is an alternative method that can be used in all locations and conditions, namely converting water vapor into dew by using the principle of a steam compression system cooling machine. However, this method requires electrical energy but can be minimized using alternative energy sources (Mirmanto et al., 2021).

Therefore, the author tried to utilize the system of the AC machine on the dew water producing machine to be researched. These machines are often called water harvesting machines from the air or water-water harvesters. The researchers in the paragraph above, no one has examined the effect of the diameter of the evaporator pipe on the resulting water mass.

Meanwhile, according to previous research (on heat transfer) such as Venkatesan et al. (2010), Wang and Sefiane (2012), Mirmanto et al. (2012), said that the smaller the diameter of the channel, the greater the heat transfer can be done. So hope that with the better the heat transfer, the more water mass is produced.

Based on the above paragraphs, therefore, the author conducted an experimental study to investigate the pipe diameter in relating with the mass of water production. Nevertheless, in this study, the heat transfer mechanism occurred in free convection mode to eliminate the fan power. The forced convection mode will be investigated later.

## 2 Facilities and Experimental Set Up

The way the tool works is as follows. After the engine is run, the evaporator wall cools down. The air that intersects with the evaporator wall becomes cold. This cold air has a larger density, so after intersecting with the evaporator, the air flows down. The place left by the cold air is filled by the warm air around the evaporator and so on (Figs. 1 and 2).

All temperatures were measured using K-type thermocouples calibrated in an oil bath with an uncertainty ±0.5 ºC. All pressures were measured using manifold gauges in psi units. The free variables in this study were the diameter sizes. Case A indicates the diameter size of 10 mm, Case B represents the diameter size of 8 mm and Case C stands for diameter size of 6.35 mm. The area of parallel pipes was 0.15 $m^2$. Therefore, Case A contained 16 pipes, Case B comprised 20 pipes and Case C consisted of 25 pipes. The total area of the evaporator was 0.228 $m^2$. The size of condensation room was 500 mm × 500 mm × 500 mm, it was open the top and bottom. The experiments were run at the ambient temperatures ranging from 27.6 °C to 31.5 °C and the relative humidity ranged from 79% to 85%.

The electrical power required by the compressor for the steam compression process can be calculated as follows:

$$P_c = VIF_p \tag{1}$$

$P_c$ is the power for the compressor (W), $V$ represents the voltage (V), $I$ is the current (A) and $F_p$ is the power factor.

The magnitude of the work of the refrigerant mass union compressor can be calculated by Eq. (2) taken from Cengel and Boles (1994) and expressed as follows.

$$w_i = h_2 - h_1 \tag{2}$$

$w_i$ is the compressor work, (J/kg), $h_1$ is refrigerant enthalpy at the compressor entrance, (kJ/kg), and $h_2$ represents the refrigerant enthalpy at the compressor outlet, (J/kg). The

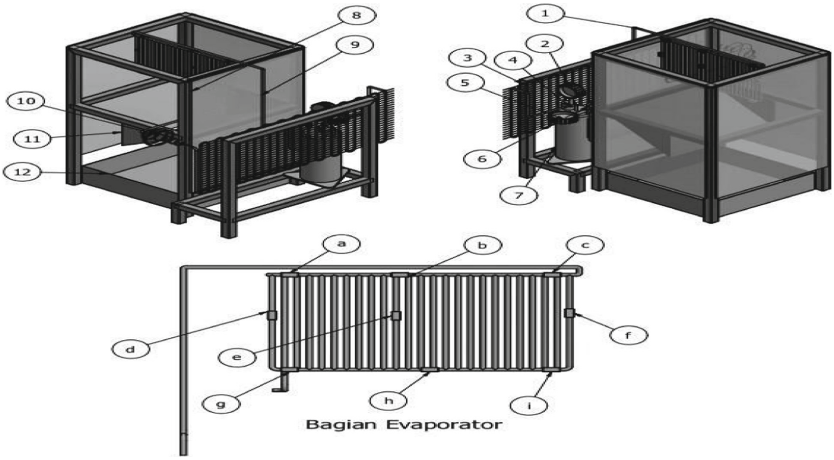

**Fig. 1.** Schematic diagram of the apparatus.

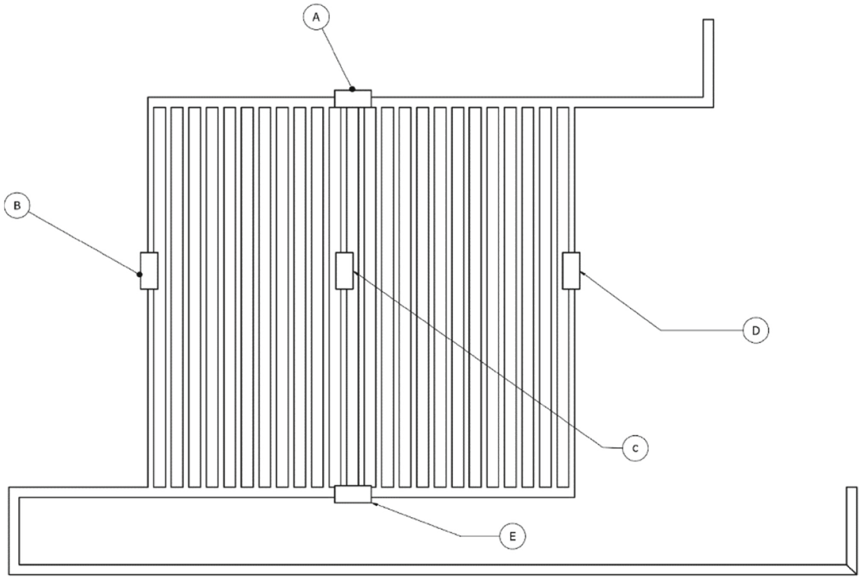

**Fig. 2.** Parallel pipe evaporator or condensing unit. A-E are the positions of thermocouples on the evaporator walls.

amount of heat energy released by the condenser can be calculated by Eq. (3):

$$q_o = h_2 - h_3 \tag{3}$$

$q_{out}$ is the heat energy released by the refrigerant at the condenser, (kJ/kg), $h_3$ indicates the refrigerant enthalpy at the condenser outlet, (J/kg). The amount of heat energy absorbed by the evaporator can be calculated by Eq. (4) taken by Cengel and Boles (1994) and expressed as follows:

$$q_i = h_1 - h_4 \tag{4}$$

$q_i$ is the energy absorbed by the refrigerant per kg, (kJ/kg), $h_1$ is the refrigerant enthalpy at state 1 (J/kg), $h_4$ is refrigerant enthalpy at state 4, (kJ/kg). *COP* (coefficient of performance) is a comparison between the energy per unit of refrigerant mass absorbed by the refrigerant in the evaporator to the compressor work per unit of refrigerant mass. Cop steam compression engine can be calculated by Eq. (5) taken by Cengel and Boles (1994) and expressed as follows:

$$\mathrm{COP} = \frac{\mathrm{q_i}}{\mathrm{w_i}} \tag{5}$$

$$\dot{m}_w = \frac{m_w}{t} \tag{6}$$

$\dot{m}_w$ is the mass flow rate of water (kg/s), $m_w$ refers to water mass (kg), t is the total time of running machine (s). The part of air moisture that is condensed $m^*$ can be estimated as

$$m^* = m_1^* - m_2^* \tag{7}$$

$$\dot{m}_{da} = \frac{\dot{m}_w}{m^*} \tag{8}$$

$$\dot{m}_{vap} = m_1^* \dot{m}_{da} \tag{9}$$

$m_1^*$ is the part of water vapor at the entrance (kg/kg$_{\text{dry air}}$), $m_2^*$ is the part of water vapor at the exit (kg/kg$_{\text{dry air}}$), $\dot{m}_{dryair}$ is the mass flow rate of dry air (kg/s), $\dot{m}_{vap}$ is the water vapor mass slow rate (kg/s). The heat transfer rate absorbed by the evaporator from the air consists of dry air heat transfer rate ($Q_{da}$), air water vapor heat transfer ($Q_{vap}$) and condensed water ($Q_w$).

$$Q_{vap} = \dot{m}_{vap} C_{pvap} (T_i - T_0) \tag{10}$$

$C_{pvap}$ indicates the specific heat of the vapor (J/kgK), $T_i$ and $T_o$ represent the inlet and outlet air temperatures (°C). $Q_{dryair}$ can be calculated using Eq. (11). Equation (11) was also used by other researchers, e.g. Winata (2020), Najib (2021) and Mirmanto et al. (2021, 2022).

$$Q_{da} = \dot{m}_{da} (h_{dai} - h_{da0}) \tag{11}$$

$h_{dai}$ and $h_{da0}$ are the enthalpy of dry air at the entrance and exit (J/$\mathrm{kg}_{\mathrm{dryair}}$).

$$Q_w = \dot{m}_w h_{fg} \tag{12}$$

$h_{fg}$ is the evaporation enthalpy of water (J/kg). Then the total heat transfer rate absorbed by the evaporator from the air can be predicted as

$$Q_t = Q_{vap} + Q_{da} + Q_w \tag{13}$$

The heat transfer rate (Qi) absorbed by the refrigerant in the evaporator can be obtained by multiplying the heat energy of refrigerant by the mass flow rate of refrigerant. This can be formulated as

$$Q_{wi} = \dot{m}_i q_i \tag{14}$$

$\dot{m}_r$ is the mass flow rate of refrigerant (kg/s) and $Q_i$ is in watt. Comparison of $\mathrm{Q_t}$ to $\mathrm{Q_i}$ is called the evaporator efficiency and written by

$$\eta_{ev} = \frac{Q_l}{Q_i} \tag{15}$$

$\eta_{ev}$ is the efficiency of evaporator (Fig. 3).

## 3 Results and Discussion

Experimental results are presented in the form of graphs. The parameters examined in this study are refrigerant temperatures, refrigerant pressures, air temperatures, heat transfer rate on the condensing unit, COP and fresh water. Figure 4 indicates the refrigerant temperature trends at States 1 to 4 for all cases. $T_2$ is the refrigerant temperature at the state 2 increases drastically and the constant. This occurs in all cases and it agrees with the results of [1, 15]. $T_3$ is the temperature of the refrigerant at State 3 or the exit of a condenser. $T_1$ and $T_4$ are the temperatures of the refrigerant at the States 1 and 4. They decrease drastically and then remain constant. These were also found by [1, 15]. $T_4$ is the lowest one because it locates at the end of the capillary pipe, in situ the lowest pressure occurs. In theory, $T_1$ and $T_4$ are the same, but in the practice, $T_1$ is higher, this is due to the evaporator heat transfer area. $T_2$ and $T_3$ are also the same in theory, but in the reality, $T_2$ is higher this is also due to the heat transfer area of the condenser. $T_1$ for Case C is higher than others, this is due to the liquid refrigerant inside the evaporator tube. The cross-sectional area of the pipe is higher than for other cases, hence, the velocity of the refrigerant flowing inside the evaporator tube is lower, consequently, the refrigerant gets higher temperatures. T2, T3 and T4 receive a consequence of T1, when T1 is higher, then others are higher.

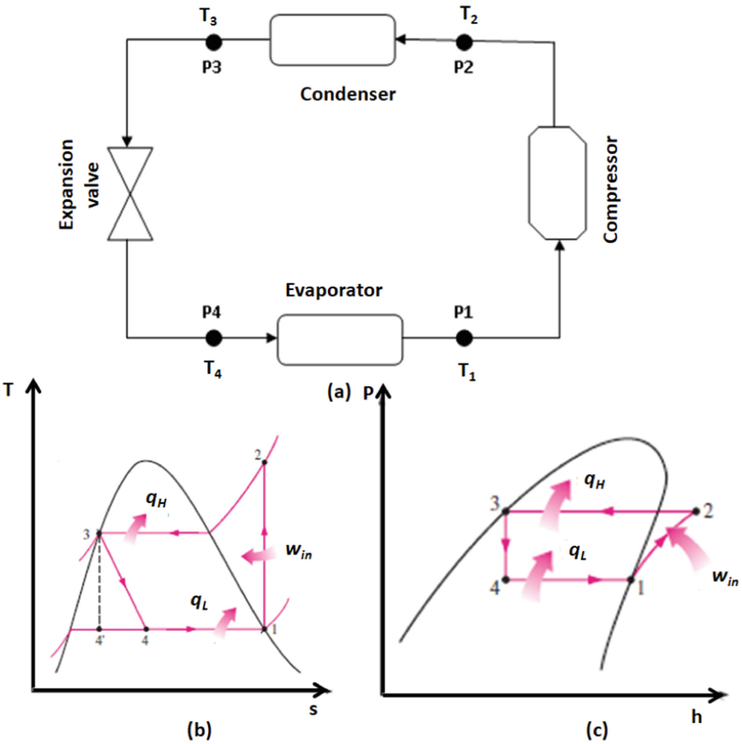

**Fig. 3.** Schematic diagram and cycles; (a) schematic diagram, (b) T-s cycle, (c) P-h cycle, [14]

Figure 5 shows pressure trends for all cases. High pressures, $P_2$ and $P_3$ increase drastically and then remain constant. The trends are the same for all cases. Meanwhile, the low pressures, $P_1$ and $P_4$ decrease sharply and then constant. P2 and P3 should be the same however due to the pressure drop along the condenser, T2 is higher than T3. Similarly, P4 and P1 should be the same but because of the pressure drop in the evaporator, P4 is higher than P1. However, for the three cases, the values of the pressures are almost the same. This was due to the pressure setting at the evaporator. The outlet pressure of the evaporator for all Cases was set at 40 psi.

The low pressures decrease sharply and then they are constant, while the high pressures increase sharply and then they get constant values. The average difference value of the low and high pressures is 170 psi. These phenomena were also found by [1, 15]. From the two variables, the effect of pipe diameter cannot be seen; hence, other parameters should be presented.

The performance of the machine can be measured using the COP parameter. The experimental COP is presented in Fig. 6. COP for all cases is not stable. COP is up and down, however, for Case C, COP is lower than for others.

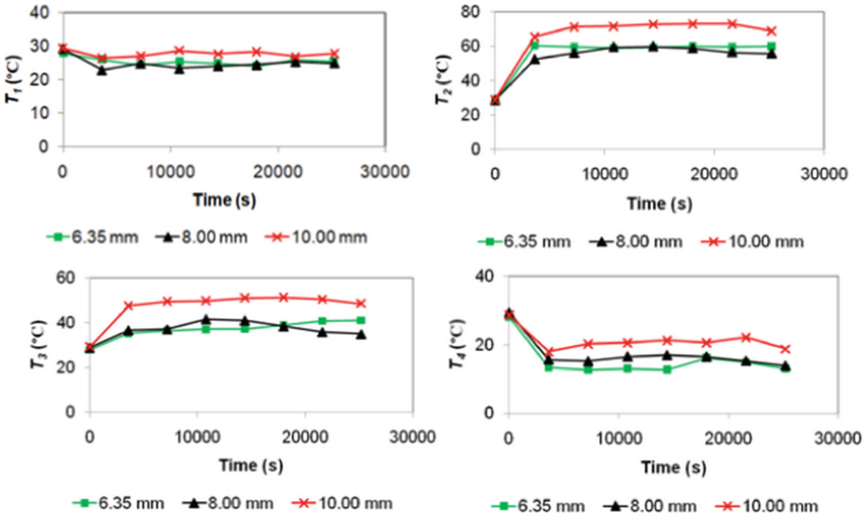

**Fig. 4.** Refrigerant temperature trends for all cases

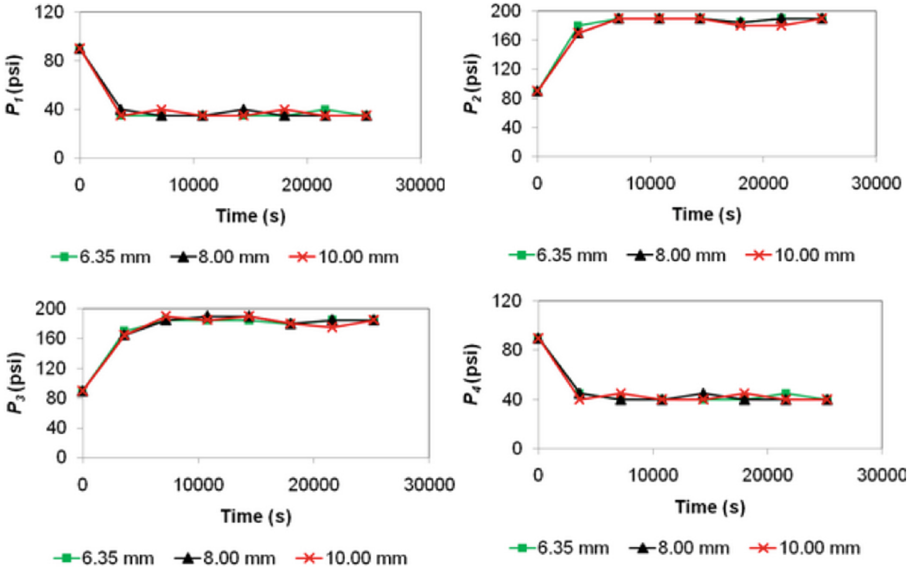

**Fig. 5.** Refrigerant pressure trends for all cases

The effect of pipe diameters on the COP is not clear. Increasing the diameter is not followed by a decrease or increase in COP. However, the lowest COP is found at the pipe diameter of 10.00 mm, while the highest COP is gained at the pipe diameter of 8.00 mm. This is because of the $Q_{total}$ and the electrical power. $Q_{total}$ for the 10.00 mm pipe diameter is the lowest one, while the electrical power used is the highest one. Hence, the effect of pipe diameter for cases A and B is not clear yet. The last parameter that

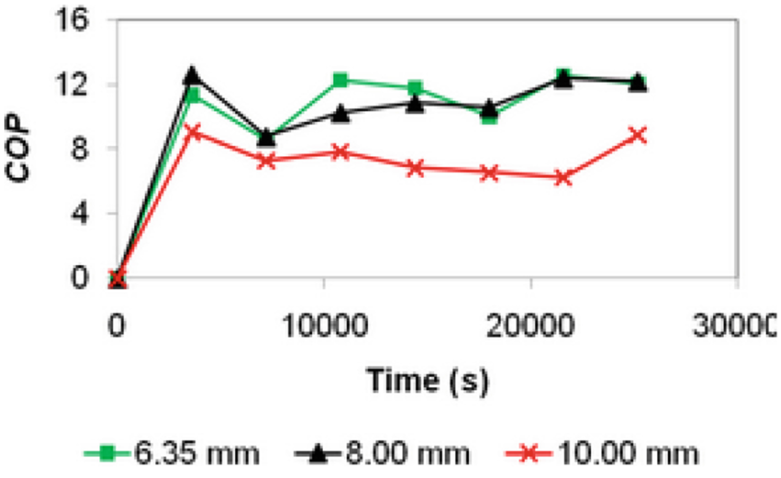

**Fig. 6.** COP

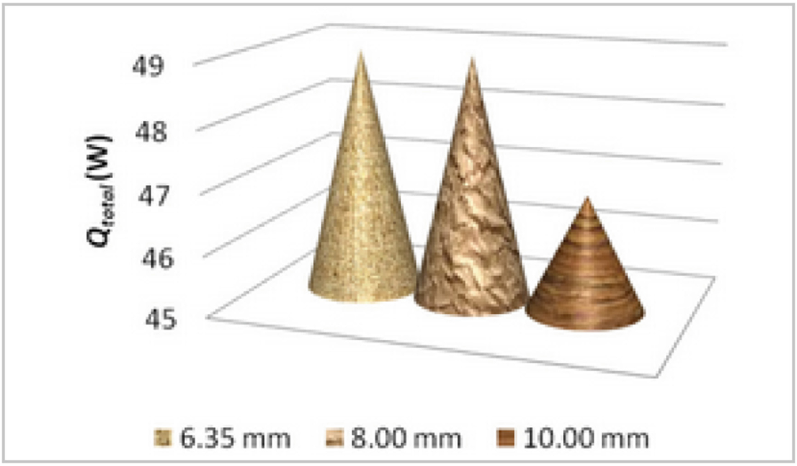

**Fig. 7.** Heat transfer rate from the air

should be examined is freshwater production. Figure 8 shows that the highest freshwater production is obtained using the 8.00 mm diameter. It means that the trend of water production concerning the pipe diameter is indistinguishable. Therefore, this study needs to be extended through several small diameters (Fig. 7).

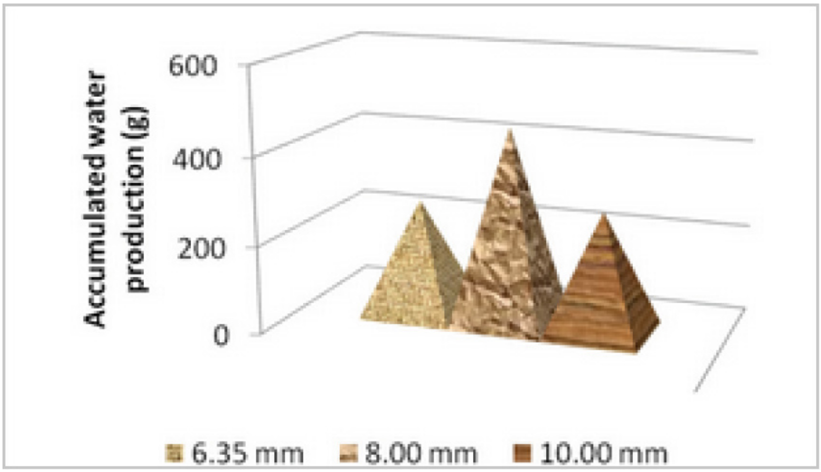

**Fig. 8.** Accumulated water production

# 4 Conclusions

Experiments to clarify the effect of pipe diameters on water production have been conducted under untreated room air conditions. The effect of pipe diameter on the temperatures, pressures, heat transfer, COP and water production has no trend, and it needs more qualified and deep investigation. The highest water production in this study is 400 g/7 h obtained using a pipe diameter of 8.00 mm.

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