ANALYSIS OF THE PERFORMANCE OF A COOLING SYSTEM (REFRIGERATOR) OPERATING WITH A THERMOELECTRIC COOLING SYSTEM USED TO PRESERVE CROPS AND AGRICULTURAL PRODUCTS

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ABSTRACT

This experiment was conducted to assemble and test a cooling system operating with a thermoelectric cooling system (TEC) used to preserve crops and agricultural products from April 14 to June 24, 2021 AD. The study included a test of adding Heat Sink to the cold side of the thermoelectric cooling plates (TEC) with two levels (without heat sink (A1) and with heat sink (A2)) inside the system. 6 cooling models (TEC) were used with 6 heat sinks distributed in the form of two groups, and each group includes three cooling model (TEC). The following characteristics were measured (internal temperature (Tin), temperature difference (ΔT), relative humidity (RH), time required to cool (t), cooling capacity (Qc) and Coefficient of Performance (COP). The results reveated that the presence of Heat Sink (A2) was superior than without (A1) in the following characteristics: It gave the lowest temperature inside the system 6.55C° by 35% over treatment (A1), and pointed the highest (ΔT, RH, t, Qc and COP) by (24.19 C°, 82.32% , 43.73W and 19.87%) respectively. All these obtained results give with a cooling time 4.6h which was higes about 14% than (A1). Where the electrical capacity used 220W.

Key words: heat sink, cpu cooler, temperature, relative humidity, cooling capacity, coefficient of performance

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مجلة العلوم الزراعية العراقية- 2024:55(5):1766-1773 خضير وكاظم

تحليل أداء نظام تبريد (ثلاجة) تعمل بنظام تبريد كهروحراري تستخدم لحفظ المحاصيل والمنتجات الزراعية

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المستخلص

أجريت تجربة لتجميع واختبار منظومة تبريد تعمل بنظام التبريد الكهروحراري (TEC) يستخدم لحفظ المحاصيل والمنتجات الزراعية، في الفترة من 14 أبريل إلى 24 يونيو 2021 م. تضمنت الدراسة اختبار إضافة المشتت الحراري إلى الجانب البارد من ألواح التبريد الكهروحرارية (TEC) بمستويين (بدون المشتت الحراري (A1) ومع المشتت الحراري (A2)) داخل المنظومة. تم استخدام 6 الواح تبريد (TEC) مع 6 طوارد حرارية موزعة على شكل مجموعتين ، وتضم كل مجموعة ثلاثة الواح تبريد (TEC). تم قياس الخصائص التالية (درجة الحرارة الداخلية (Tin) ، فرق درجة الحرارة (T) ، الرطوبة النسبية (RH) ، الوقت اللازم للتبريد (t) ، سعة التبريد (Qc) ومعامل الأداء (COP). تفوق وجود المشتت الحراري (A2) على عدم وجود المشتت الحراري (A1) في الخصائص التالية: أعطت أدنى درجة حرارة داخل النظام 6.55 C° تفوقت بنسبة 35٪ على المعاملة (A1) ، وأشارت النتائج (ΔT ، RH ، t ، Qc و COP) (24.19 C° ، 82.32٪ ، 43.73W و ٪ 19.87) على التوالي. تم الحصول على النتائج خلال وقت تبريد قدره 4.6 ساعة والذي كان أعلى بنسبة 14٪ من (A1). أذ كانت الطاقة الكهربائية المستهلكة 220W.

كلمات مفتاحية: المشتتات الحرارية، وحدة طرد الحرارة، درجة الحرارة، الرطوبة النسبية، قدرة التبريد، كفاءة الآداء

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INTRODUCTON

Crops and agricultural products are an essential element in human life (5,6,12,20). They as they contain vitamins and fibers that a person can benefit from, as they give him/her strength and energy in the practice of his daily life (8,9,11). As a result of the great industrial development in the field of agricultural mechanization, which was accompanied by an increase in population numbers around the world, the demand for food in general, including crops and agricultural products, has increased (5,6,13). Food must be provided for the longest possible period in which the crop is usable by providing the appropriate atmosphere for crops and agricultural products of temperature and relative humidity. (2,4,16). Compression cooling system is the most widespread in preserving and storing agricultural crops, vegetables and agricultural products, and in several other areas, due to its reliability in work and for providing the appropriate temperature for the preservation and storage process. However, what is wrong with this system is its need for maintenance from time to time, its inability to provide the ideal relative brick for storage, and its making noise during work, and it needs a cooling medium in its work, which is Freon gas (R22), which is a gas harmful to the environment due to its rapid volatilization into layers. The upper atmosphere causes the destruction of 65% of the ozone layer. Each molecule of Freon gas destroys 100,000 molecules of ozone, and also affects human health for people who work in direct contact with the gas (1,7,19,23). Work began on finding alternative systems in a year to avoid these harms and risks in 1990, so the electrothermal cooling system was discovered by the German scientist Jean Charles Peltier in 1834, by reversing the Seebeck process by passing a constant electric current (DC) between two metal connections, which produced thermal energy as well. In Figure (1) (14). This system is characterized as being environmentally friendly, as it does not need a cooling medium (gas) to operate, and does not pose any danger to human life, as it works by converting the DC current fed from the electrical source and passing between two semiconductor materials, causing a voltage difference between Between them, the material with the highest thermal conductivity is hot and the material with the lowest thermal conductivity is cold. The reason for this phenomenon is that when direct current (DC) passes between the two materials, the generated potential difference works to transfer electrons between the conductors, and this phenomenon is known as the Seebeck effect (7,22).

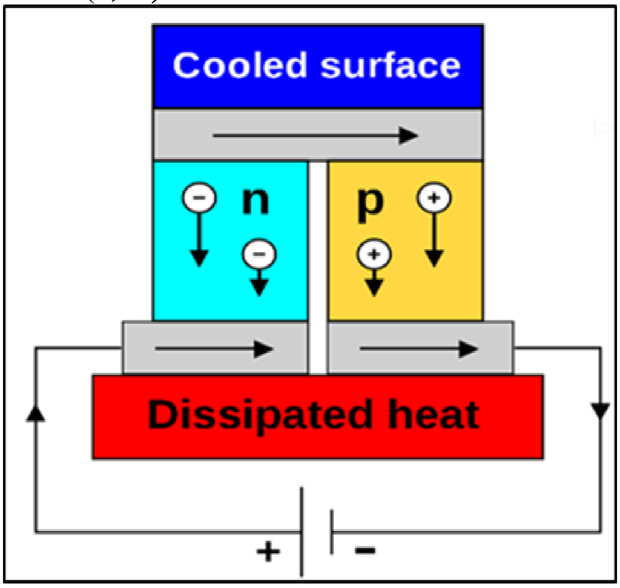

Fig 1. Effect of thermoelectric cooling

(18) made a theoretical experimental study of the method of designing a cooling device (TEC) using Heat Sink with model (TEC) and concluded that Heat Sink has the ability to reduce the temperature of the air passing through it more than not using Heat Sink (4) made a cooler box with dimensions (26.5 x 25.5 x 36.5) cm^3 and using 9 TEC models, he was able to reduce the temperature inside the box from 28C° to 19C° in a period of up to two hours 42% cooling efficiency with 113.64 W input power.(24) conducted a study to analyze the performance of an electrothermal refrigerator by creating a small model with dimensions (2.5×2.5×0.35) cm^3 using a single pellet model, which was able to reduce the temperature from 30C° to -7.4C° for 24 hour with 40.46 W input card and the cooling efficiency was 65% (26) He developed a thermoelectric refrigerator with dimensions (90×50×50) cm^3 using a single pellet piece with a Heat Sink model on the cold side with a spiral Heat Sink on the hot side through which a coolant passes through the hot side. The temperature was reduced from 20.9C° to 6C° with a 34.5W input power, and the cooling efficiency was 57.1%.(3) designed and

experimentally analyzed a small box with dimensions (18×23×32) cm^3 using 10The temperature difference between the ambient And the TEC cooling piece is about 24.5 C°, to record on the TEC unit a temperature of -4.9 C° .

MATERIALS AND METHODS

1- Thermoelectric cooling model
2- Heat Sink
3- CPU Cooler
4-Power Supply

A refrigerator structure with dimensions (90×45×45) cm^3 was used and a piece of aluminum was installed at the back of the system containing 6 thermoelectric cooling model TEC1-12706, which are shown in Figure (2) and whose specifications are shown in the table (1) As the cold side of the cooling panels was placed towards inside the system, while the hot side of the cooling model was towards the outside and equipped with heat dissipation units type (CPU Cooler) as shown in Figure (2) and whose specifications are shown in Table (2) with 6 working units On absorbing heat from the hot side of the cooling models and preserving it from damage, as shown in Figure (3). As for inside the cooling system, the fan was installed on the upper side of the system and at the bottom of it the Heat Sink was placed in direct contact with the cold side of each TEC cooling model. as shown in Figure (4). Then the 8 digital sensors were distributed within the system to measure temperature and relative humidity, display them on an LCD screen and store them in memory (RAM). After the assembly and installation of all parts of the thermoelectric cooling system (S-TEC), the temperature and relative humidity control device was supplied with electric current from the source (the house) and it controls both the Power Supply that operates the cooling panels (TEC), as well as controls the operation of Air circulation fan (Fan) inside the system as in the diagram shown in Figure (5). When the power is turned on, the TEC Cooling Units are turned on with the CPU Cooler. The cooling models cool the Heat Sink connected with it inside the system, and then the air circulation fan passes the air over the Heat Sink to be cooled.

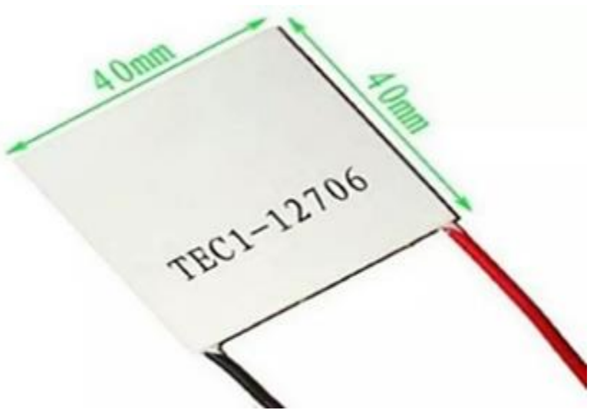

Fig 2.Thermoelectric cooling models (TEC)

Table 1. Specifications for Thermoelectric Cooling (TEC) Models

Specification	Range	
Hot Side Temperature (°C)	25	50
Q_{max}(W)	50	57
ΔT_{max}(°C)	66	75
I_{max}(A)	6.4	6.4
V_{max}(V)	14.4	16.4
Resistance (Ω)	1.98	2.30
Length (mm)	40	
Width (mm)	40	
Thickness (mm)	3.9	

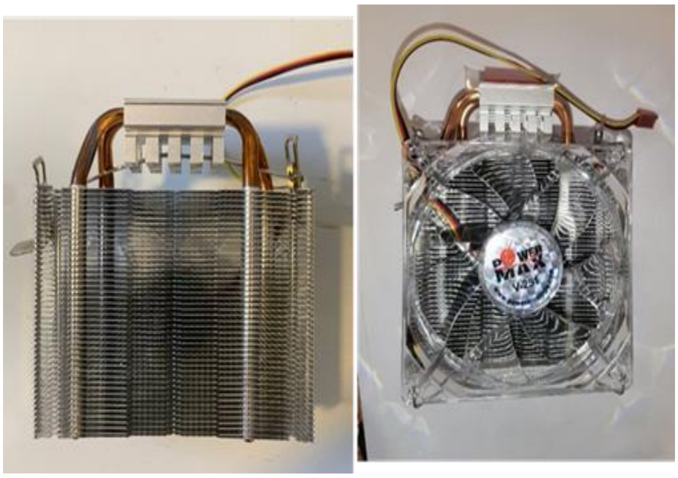

Fig 3. CPU Cooler

Table 2. CPU Cooler Specifications

Specifications	
POWER MAX V-251	Type
7	Number of fan blades
2200 RPM	Fan of speed
9.2 × 9.2 × 2.5 cm^3	Size
45	The number of aluminum plate
12.1 × 9.7× 7.5 cm^3	aluminum plate dimensions
12 V	voltage
2.5 A	consuming current

Fig 4. TEC and CPU Cooler board installation stage

Fig 5. The system with heat sink

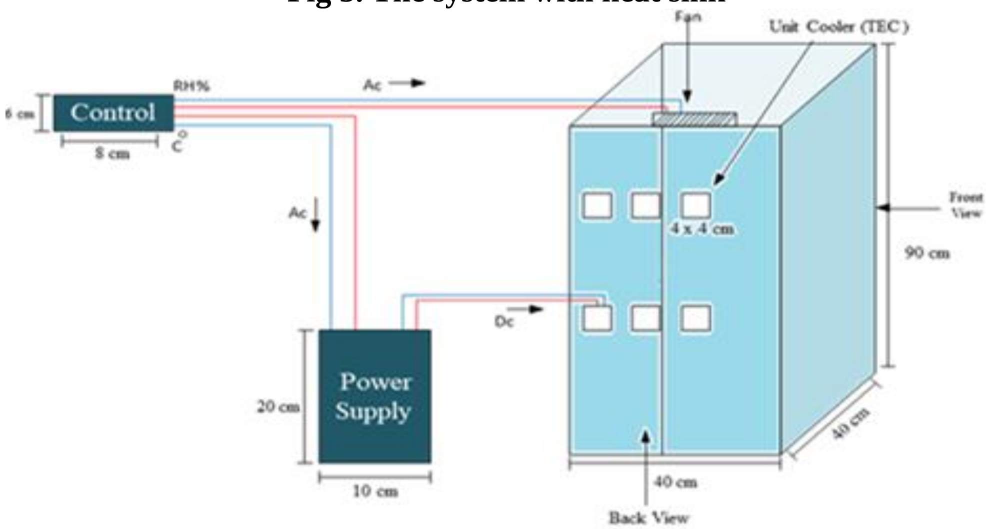

Fig 6. Scheme of the thermoelectric cooling system (S-TEC) and its connection with the control unit

Equations used

1-Measuring temperature and temperature difference (Temperature IDfference ΔT):

2-The temperature inside and outside the system (ambient) was measured using a precise sensor type (DHT22) to measure the temperature, and the following equation was used to calculate the difference. (25):- $\Delta T = T_{out} - T_{in}$ ……..(1)

2- Power depletion (P):

The depleted power from the source was measured by applying the following equation. (21):-

P = I x E ………(2)

3- Cooling Capacity (Qc):-

The cooling capacity of the thermoelectric cooler was calculated from the following equation. (17):-

Qc = ṁ Cp ΔT ……..(3)

4-Coefficient Of Performance (COP):

The ratio of the cooling capacity to the depleted capacity from the source, and the performance factor is extracted through the following equation. (15):-

COP = Qc/Pc ………(4)

RESULTS AND DISCUSSION

1-**Internal Temperature (Tin):**

Figure (7) showed the effect of adding heat sink on the value of internal temperature. It is clear from the figure that adding a heat sink in the cold side of TEC gave the lowest internal temperature which registered (6.55 Cº) which made the opportunity to dissipate the cold air that circulated inside the refrigerator ,while the highest inside temperature pointed (10.17 Cº) by A1 (without heat sink)

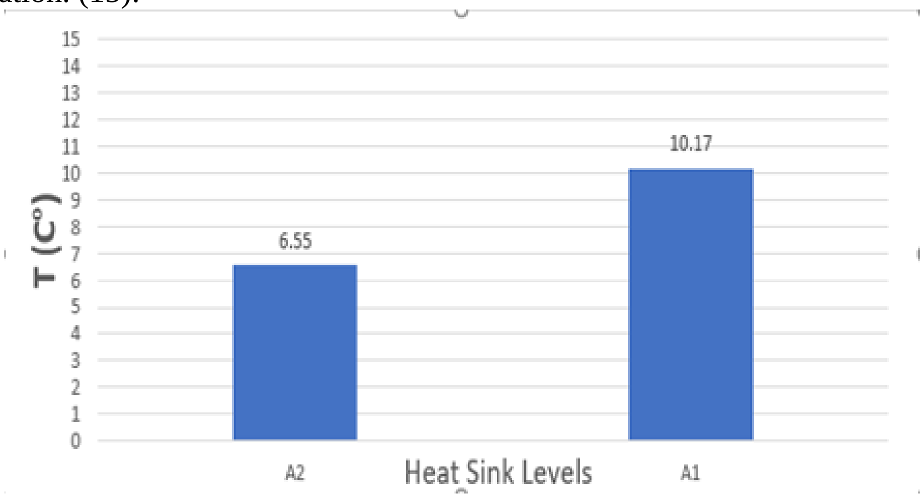

Fig 7. Effect of adding heat sink on the internal temperature (C°) of the thermoelectric cooling system (S-TEC)

2- Different Temperature (ΔT):

Figure (8) illustrated the effect of presence heat sink inside the refrigerator the values of different temperature between inside and outside the system. The figure showed that the maximum difference (Δ**T**) pointed with the utilizing A2 which registered (24.19Cº), the reason maybe that adding A2 on the cold side of TEC made an increase in the difference temperature between inside and outside the system the reason may followed to same facts above that effect on the inside temperature. The minimum (Δ**T**) remarked by A1 and was (21.073Cº).

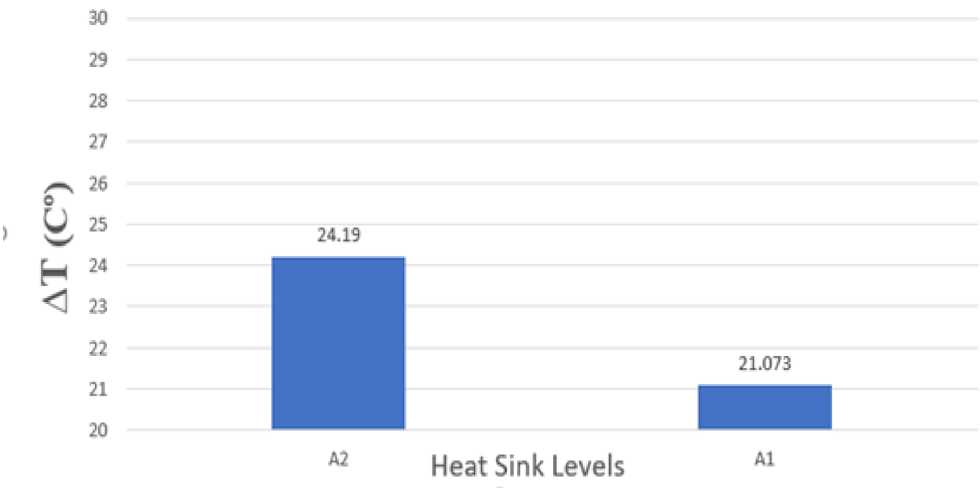

Fig 8. Effect of adding heat sink on the characteristic of the temperature difference (C°) between the thermoelectric cooling system (S-TEC) and the outside environment

3- Relative Humidity (RH %):

Figure (9) represented the effect of using heat sinks inside the refrigerator on the relative humidity. It is appear that adding heat sink (A2) made a significant effect on values of relative humidity. The maximum relative humidity registered 82% which pointed by utilizing heat sink and this value is suitable for conservator the vegetable and food products, While the minimum value of relative humidity pointed 47% by (A1) (without heat sink) . Increasing relative humidity maybe due the presence of heat sink which contribute to made drops of water (dew) inside the refrigerator and the circulating of air inside the refrigerator assit to increase the values of RH.

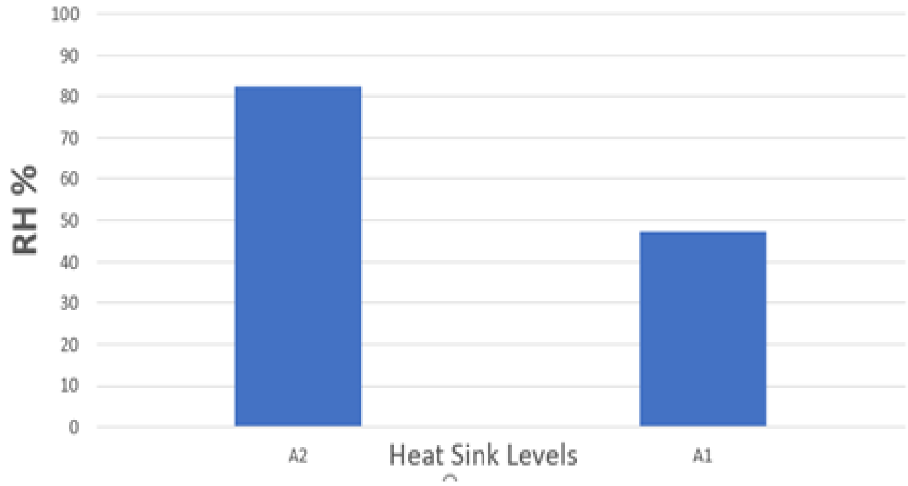

Fig 9. shows the effect of adding the heat sink on the internal relative humidity (%) of the thermoelectric cooling system (S-TEC)

4- Coefficient of Performance (COP%):

The heat dissipation affected the performance efficiency, as the second treatment (A2) gave the highest efficiency of the system, which amounted to 19.87%, higher than the first treatment (A1), which amounted to 17.98%.

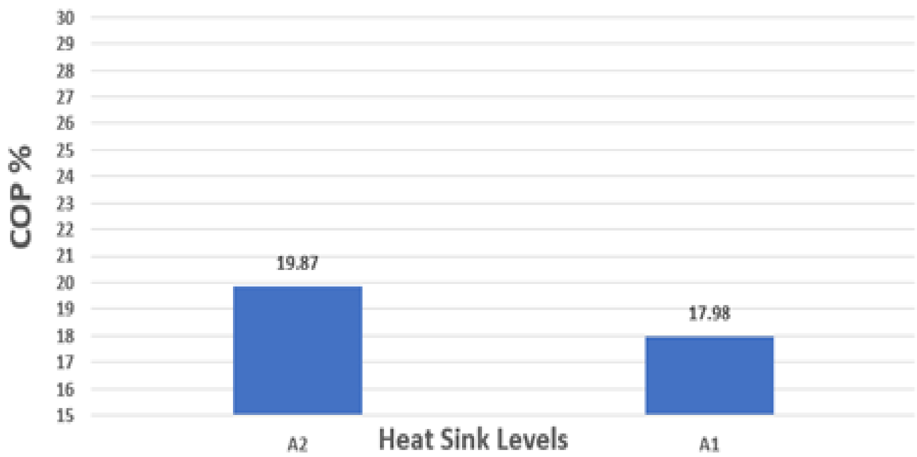

Fig 10. Effect of adding a heat sink on the characteristic of the cooling efficiency degree (%) of the thermoelectric cooling system (S-TEC)

Conclusions

1- Adding heat sinks to TEC positively affected the following, Internal temperature, different temperature, relative humidity inside the system, cooling capacity, performance efficiency and the time taken to cool the system.

2- It was found through the results that the addition of heat sinks worked to draw a greater cooling capacity from the TEC plates, which helped in obtaining lower temperatures.

3- The results showed that the addition of heat dispersions contributed to the formation of more water droplets on the dispersions, which contributed to raising the relative humidity inside the system.

4- Treatment (A2) recorded the presence of heat sinks at the lowest low temperature with the largest difference in temperature and an increase in both, relative humidity, cooling capacity and performance efficiency.

5- Treatment (A1) recorded the absence of heat sinks, an increase in temperature inside the system with the least difference in temperature and a decrease in both, relative humidity, cooling capacity and performance efficiency.

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