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CONSTRUCTION AND EVALUATION OF REFRIGERATOR FOR GREEN BEAN USING PELTIER EFFECT

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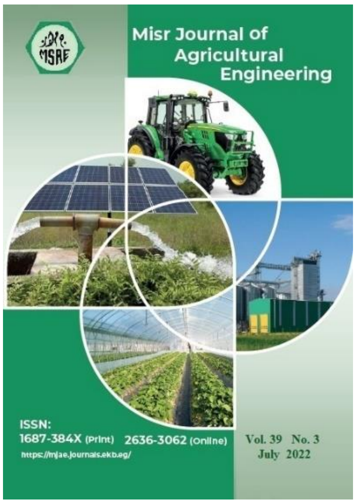


Keywords:
Green bean; Thermoelectric; Cooling crops; Peltier; Refrigerator; Post-harvest.

ABSTRACT

The creation of air conditioning and refrigeration was one of the biggest achievements. This study aimed to see how well the Peltier cooler system, to store vegetables and fruit, performed. To test performance, a thermoelectric module with (1, 2, 3, and 4) with and without fans, as well as two methods of attaching Peltiers, was employed (serial and parallel). The performance of the cooling system is determined by collected and analyzed data from the measuring system. The temperature distribution on each component of the cooling system is recorded using thermocouples connected to the data acquisition. Temperature for green bean cooling was 5 ˚C, which provides perfect cooling for 14 days by 4 Peltiers, serial connection electric at average cooling load of 525.51 W in just 5 min without freezing, with the use of a fan. The parallel connecting increases the consumed power from 2.1 W to 16.8 W therefore the serial connection is reduced the power consumption to 0.26 W. The coefficient of performance (COP) values were reduced with the operating time to be 0.08 and 0.07 in parallel and serial connection respectively and one Peltier, but with the 4 Peltiers the COP values were 0.17 and 0.08 in parallel and serial connection.

1. INTRODUCTION

Global expansion of agricultural production and the preservation of agricultural products in their best quality, because they are perishable and must be kept as fresh as possible, the temperature should be lowered immediately after harvest, and thus for export and distribution over long distances for marketing and consumers. Temperature and relative humidity should be maintained throughout storage, these requirements differ depending on the product. As the cooling process is one of the types of energy is now a critical component of rising people's living standards, as well as economic and social growth. As a result, the goal of this research is to employ the Peltier unit to lower the amount of energy needed in the cooling process. In recent years, interest in new renewable technologies has been spurred by social expectations in the field of lowering air pollution caused by fossil fuels, as well as long-term programs to reduce carbon emissions **(Asdrubali** et al., **2015 and Zelazna** et al., **2016)**. In air conditioners and freezers, there are three primary types of cooling systems, each with its own set of advantages and disadvantages. Vapor compression coolers, absorption coolers, and thermoelectric coolers are examples of these systems **(Bansal and Martin, 2000).** The rising global demand for refrigeration in fields such as refrigeration, air conditioning, food security, vaccine storage, medical services, and electronic device cooling has resulted in more energy being generated and, as a result, more CO_2 being released globally, contributing to global warming and climate change.

Since the turn of the century, conventional refrigeration systems have been extensively used. This has led to significant issues with the use and storage of chlorofluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs), with ozone layer degradation as the worst-case scenario.

However, attempts have been made to develop non-conventional refrigeration technologies such as thermoelectric refrigeration, magnetic refrigeration, and thermo acoustic refrigeration, which have proven to be environmentally benign, cost effective, and efficient in operation. Traditional cooling systems, such as found in refrigerators, rely on a compressor and a working fluid to transfer heat. Thermal energy is received and released as the working fluid expands and contracts and transitions from liquid to vapor and back. As a result, thermoelectric refrigeration is in high demand, notably in underdeveloped countries, where long-term durability and low-cost maintenance are critical. Semi-conductor thermoelectric coolers (Peltier coolers) are solid-state devices with no moving parts, making them durable, efficient, and quiet. They do not need any form of refrigerant **(Chaudhary** et al., **2018)**. They are environmentally friendly refrigerators since no CFC or other refrigerant gas is used **(Patil** et al., **2017)**. They don't require ozone-depleting chlorofluorocarbons, making them a potentially cleaner option than standard refrigeration. They can be significantly more compact than compressor-based systems. Peltier modules are used in thermoelectric cooling to induce heat flow between both sides of the module. There are no moving parts and no CFCs in the Peltier. The design specifications are to cool their volume to selected temperature in less than 6 hours and provide retention for at least the next half hour, according to the study of **(Awasthi and Mali, 2012)**. Demonstrated thermoelectric cooler output using two paralleled modules and a Peltier module TECI-12715 with 231 W, 15.4 V, and 15 A **(Vadi and Kulkorni, 2015)**. Inside a cooler box with a volume of 66500 cm3 and a power input of 195.6 W, a temperature differential of 10° C was obtained for 25 minutes. Studied the thermal efficiency of a thermoelectric cooler while the input cooling load and electricity consumption were changed. The study used three different input power variations (50.5, 72.72 and 113.64 Watt) as well as two different cooling load variations utilising mineral water (1440 and 2880 milliliter) with input power 113.64 Watt. At input power of 50.5, 72.72 and 113.64 Watt, the box temperature is 19.98, 19.77 and 18.52 C°, respectively **(Mainil *et al.*, 2018)**.

Food legumes are significant in impoverished people's agricultural systems and diets around the world, making them ideal crops for attaining three developmental goals at once: poverty reduction, improved human health and nutrition, and higher environmental resilience **(Akibode and Maredia, 2011)**. Dry beans are a good source of nutrients in the diet and serve as a protein and mineral supplement to cereal crops **(Hangen and Bennink, 2002 and Baudoin and Maquet, 1999)**. In terms of agronomy, they function as a cereal rotation crop, minimizing soil pathogens and supplying the cereal crop with needed nitrogen They also serve as an important source of animal feed in small-scale livestock operations, serving as both human and animal sustenance **(Gepts, 2004)**. Beans should have a moisture content of

13 to 15%. However, this varies based on the variety. In tropical countries, ambient storage temperatures range from 20 to 30 degrees Celsius, with relative humidity ranging from 65 to 75 percent **(Hayma, 2003)**. Higher temperatures require lower moisture content **(Kilmer *et al.*, 1994)**.

For example, the HTC disorder is caused by keeping cowpeas at high temperatures (30-40 C°) and high relative humidity (60-80 %) **(Ndungu *et al.*, 2012)**. The storage time ranges from a few months to a year or more, which has an impact on the cooking time **(Kaur and Singh, 2007)**. Warm, humid weather accelerates the development of the HTC fault in stored beans in many parts of the world with subtropical and tropical climates **(Berrios *et al.*, 1998)**. In Egypt, smallholders and commercial producers depend upon vapor compression refrigeration systems to store vegetables and fruits. Vapor compression systems caused many problems from point of view climate change and pollution of weather. These issues include negative effects on the environment and dangers from global warming, natural resource depletion, and, to some extent, the need for energy independence.

Many of researchers studied using Peltier effect from the side of engineering construction and electrical energy consumption. In addition, others concerned on cooling of electronic parts. But they do not apply it's on the agricultural crops although this method may be effective to cool some vegetables without any pollution and reducing energy consumption when used. Therefore, the hypothesis of this present study depends upon test the availability of Peltier effect method to refrigerate the green bean which represents a vegetable.

Thermoelectric coolers can be employed in Egypt to reduce the negative impacts that produced from refrigerants associated with vapor compression systems and decrease electrical power consumption in storage processes. Therefore, the aim of this study possibility using thermoelectric coolers by Peltier effect for cooling green beans in Egypt. In addition, the specific objectives are improving intrinsic efficiencies the thermoelectric coolers using 1,2,3 and 4 Pelteiers, improving the thermal design efficiency through parallel and serial connection plates of Peltier and between Peltiers and measuring cooling effect on crop.

2. MATERIALS AND METHODS

The steps in the project methodology are as follows:

- Module selection (Peltier) thermoelectric.
- Design and building of experimental setup and experimentation.

Selection of thermoelectric (Peltier) module:

Used a mid-range Peltier module with minimal cooling power. As a result, choose Chinese thermoelectric and model (TEC 12706) which has a cooling capacity of 50- 60 Watts.

The thermoelectric module operates with the Peltier effect. When current flows through two different materials, it will produce a hot side at one junction and a cold side at the other junction.

Experimental setup design and construction:

Different numbers of Peltiers (1, 2, 3, and 4) were used in the experiment, with and without fan, and at various voltages (10, 11, 12, 13, 14 and 15 Volt), Performance was assessed using two different methods of connecting Peltiers (serial and parallel).

Experimentation:

The values for cooling rate or temperature differential for a specific time frame are measured and recorded in the refrigerator's initial condition. Using a thermoelectric module, some readings had been taken for the same refrigeration system under various conditions.

2.1. Crop

As illustrated in Fig. (1), Fresh green bean of the (Giza-3) variety is a food material that is refrigerated by the Peltier effect. Giza 3 variety is characterized as a dual-purpose local variety, with an average snap bean thickness of 7 mm, round, and an average horn length of 12 cm. A fixed amount of 3.5 kg was taken for preservation. Moisture content 91% on wet basis.

Fig. (1): Fresh green bean (Giza-3)

2.2 Cooling system

The main component of the cooling system is the Peltier thermoelectric cooler. The specifications of thermoelectric Peltier cooler are shown in Table 1.

Table 1 Specification of thermoelectric Peltier cooler.

Type Number	TEC1-12706
Number of thermo Couples	127
U max (v)	15.2
ΔT max (C˚)	67
Dimensions (mm)	40×40×4
Ohm	1.3-1.5
Current (A)	6
Max power consumption (W)	70

The cooling system consists of 4 units, each unit consists of a thermoelectric cooling (TEC1-12706), a pair of radiators installed on both sides of the (TEC1-12706) and two fans to distribute air, as shown in Figs. (2) and (3).

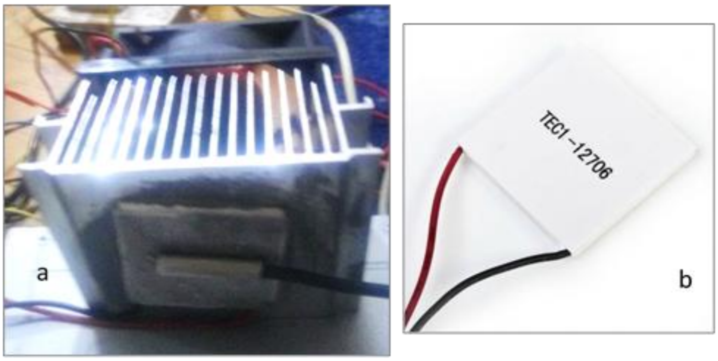
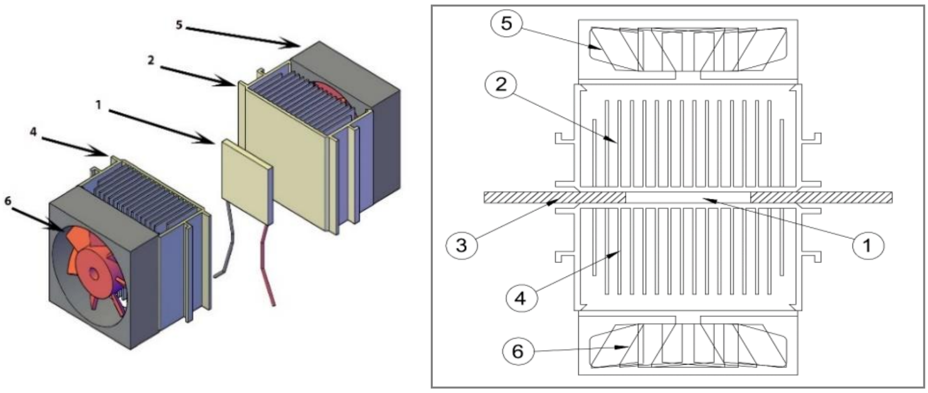


Fig. (2): (a) cooling unit (b) thermoelectric cooling



1 Thermoelectric (TEC1-12706) 3 Thermal insulation surface 5 Hot sink fan
2 Hot surface heat sink 4 Cold surface heat sink 6 Cold sink fan

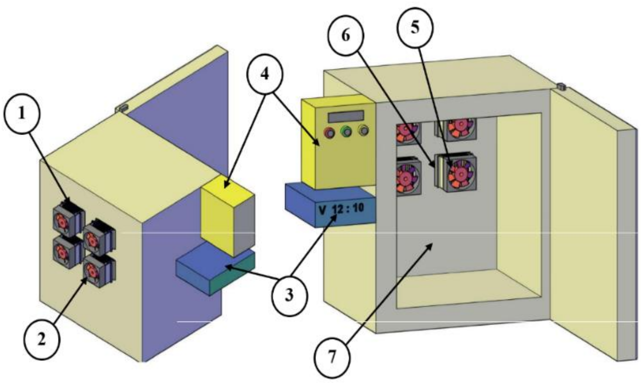
Fig.(3): Schematic of cooling unit

2.3 Mini-Bar Refrigerator

The main body of the refrigerator mini bar is 500 mm high, 450 mm wide, and 350 mm deep, with a capacity of 50 liters and is well insulated to prevent heat loss to the surrounding air. Two walls, the outer sheet metal, and the inner plastic, are separated by an insulating material with a thickness of 50 mm in the cross section of this tiny bar, as shown in Figs. (4) and (5).

(a) (b)

Fig. (4): The main body of mini bar (a) before using (b)after using



1 Hot surface heat sink 3 Power supply 12 V 5 Cold sink fan 7 Inside mini bar
2 Hot sink fan 4 Control unit 6 Cold surface heat sink

Fig. (5): Schematic of cooling system

2.4 Power supply

The SMPS-type power supply converts 220 V to 12 V and features a variable resistance that allows for voltage control up to 15 V and a maximum current of 30 A.

Methods

Construction and evaluate a refrigerator to preserve fresh, perishable vegetables during storage, transportation, handling, and marketing until reaching the consumer and preserving them for the longest period of storage according to the following criteria:

1. Selection of a vegetable crop (fresh green beans) for storage in the refrigerator and without using the refrigerator and was evaluated by the appearance, vitality of the green beans and consumer acceptance of them.
2. Using a variable number of thermoelectric (peltier) (1, 2, 3, and 4).
3. The use of two methods for distributing heat inside the refrigerator by installing a fan and without a fan on the heat sink.
4. Use various voltages (10,11,12,13,14 and 15 Volt).
5. Two methods are used to connect the thermoelectric (peltiers) in serial and in parallel.

Instruments

A balance scale (OHAUS U.S.A) was used to find the mass of fresh green beans samples. The maximum mass of the balance was 50000 g. Its accuracy was 0.1 g. Fresh green beans moisture contents were determined by the standard oven method. Moisture content percentage was calculated in relation to the dry sample according to the following equation:

$$\mathbf{MC = ((Mw - Md) / (Md)) \times 100} \quad \textbf{(1)}$$

Where: MC was fresh green beans moisture content, %; Mw was the sample's mass before drying, g; and Md was the mass of the dried sample, g.

Consumed time for each treatment was measured by using a digital stopwatch (Casio JHS) with 1/100 second accuracy was used to record the time.

A digital Vernier calliper with an accuracy of 0.01 mm was used to measure the diameter of horn thickness and horn diameters.

Measuring the current intensity and voltage. The specification of the used clamp meter and voltmeter are as following: Made in: Japan; Category: Super 600 V~AC 50 Hz; Measurement: AC amperage, AC voltage, and resistance

Measurements

The refrigerator was evaluated by measuring the amount of heat required for cooling and maintaining the ideal temperature for storage for the longest period and the heat absorbed from green beans from the cooler with and without crop load in order to calculate the refrigerator performance factor. The absorbed heat in the cold side (Qc), the wasted heat in the hot side (Qh), and the refrigerator's performance (COP) are calculated by **(Jugsujinda *et al.,* 2011)**:

$$Q_c = \alpha I T_c - 0.5 I^2 R - k_t (T_h - T_c) \quad (2)$$

$$Q_h = \alpha I T_h + 0.5 I^2 R - k_t (T_h - T_c) \quad (3)$$

$$P_{in} = Q_h - Q_c \quad (4)$$

$$COP = Q_c / P_{in} = Q_c / (Q_h - Q_c) = T_c / (T_h - T_c) \quad (5)$$

Where: P_{in} is the power input (Watt); I is electric current (Ampere); R is the electrical resistance of TEC (Ω), α is seebeck coefficient volt K^{-1}; COP is coefficient of performance of the cooler system and k_t is the thermal conductivity W mK^{-1}.

There are two forms of heat load:
Active, passive, or a combined of the two are all options. An active load is the amount of energy wasted by the equipment being cooled. It's usually the same as the device's input power. Radiation, convection, and conduction via **(Holman, 1992)** are examples of parasitic heat loads.

a) Active heat load:

$$Q_{active} = V^2 R^{-1} = V I = I^2 R \qquad (6)$$

Where: Q_{active} is active heat load (Watt); R is device resistance (Ohms); V is voltage applied to the device being cooled (volts) and I is current through the device (amps).

b) Radiation:

$$Q_{rad} = F\, e\, s\, A\, (T_{amb}^4 – T_c^4) \qquad (7)$$

Where: Q_{rad} is radiation heat load (Watt); F is shape factor (worst case value =1); e is emissivity (worst case value = 1); T_c is TEC cold ceramic temperature (Kelvin); s is Stefan – Bolzman constant ($5.67X10^{-8}$ W/m^2K^4); T_{amb} is ambient temperature (Kelvin) and A is area of cooled surface (m^2).

c) Convection

$$Q_{conv} = h\, A\, (T_{air} – T_c) \qquad (8)$$

Where: Q_{conv} is convective heat load (Watt); T_{air} is temperature of surrounding air (C°); h is convective heat transfer coefficient (W/m^2 C°); T_c is temperature of cold surface (C°) and A is exposed surface area (m^2)

d) Conduction:

$$Q_{cond} = (KA)\, (\Delta T) / L \qquad (9)$$

Where: Q_{cond} is conductive heat load (Watt); K is thermal of the material (W/m^2 C°); A is cross–sectional area of the material (m^2); L is length of the heat path (m) and ΔT is temperature difference across the heat path C°.

e) Transient
Some designs require a set amount of time to reach the desired temperature. The following equation may be used to estimate the time required:

$$t= [(Rh_o) (V) (C_p) (T_1 – T_2)]/Q \qquad (10)$$

where: Rho is density, g/cm^3; V is voltage applied to the device being cooled (volts) ; CP is specific heat (J/g.°C); (T_1-T_2) is temperature change and Q is [Q_{to} + Q_{t1}]/2, Q_{to} is the initial heat pumping capacity when the temperature difference across the cooler is zero. Q_{t1} is the heat pumping capacity when the desired temperature difference is reached, and heat pumping capacity is decreased.

f) Product load

The product load is the amount of heat that must be removed from the products inside the refrigerated space. Because the refrigerated space has a larger specific heat capacity, the product load is determined from the equivalent water contents of the products in the refrigerated space by **(Desai, 2004)**. Therefore, product load is defined as

$$Q_p = M_w \, CP_w \, (T_{w2} - T_{w1}) \qquad (11)$$

where: Q_p : Product load, kJ ; M_w : Mass of green bean, kg ; CP_w : Specific heat capacity of green bean, J/kg.K and T_{w2} , T_{w1} : initial and final temperature of green bean, °C .

Fig. (6) shows the green bean during cooling in refrigerator and Fig. (7) shows the Product after 14 days of cooling inside the unit and then it had been left at the surrounding atmosphere for the same period.

Fig. (6): Green bean during cooling in refrigerator

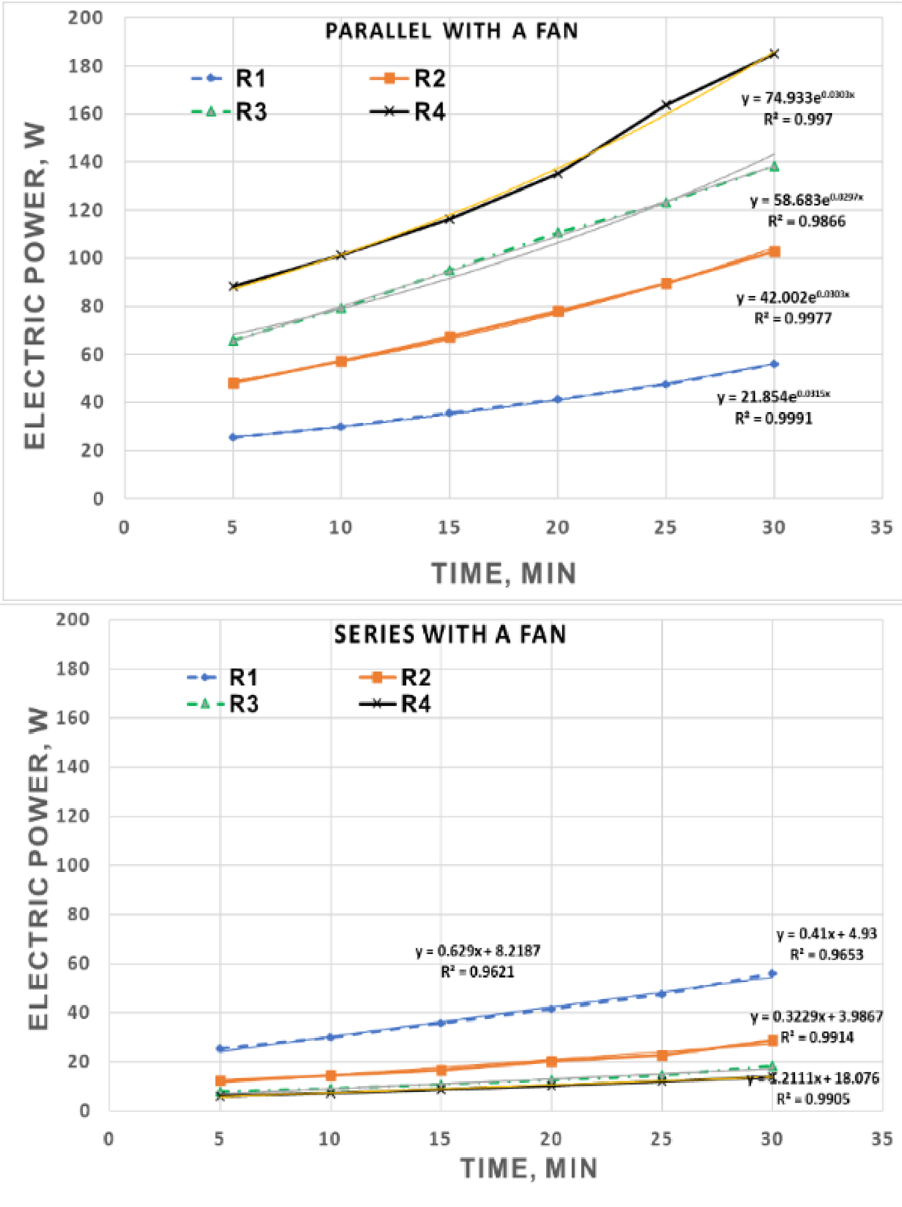
(a) (b)

Fig. (7): (a) Product after 14 days of cooling inside the unit, and (b) The beans after 14 days at the surrounding atmos-phere.

3. RESULTS AND DISCUSSION

3.1.The consumption of electrical power

Various generator modules are frequently used in a system in functional works. During operation, the modules are frequently exposed to a wide variety of temperatures. As a result, each module's electromotive force will be distinct. Two systems are established to compare the performance of the systems in various connections of modules in such a circumstance. The refrigeration cabinet was operated for many different values of input current. The temperature, time and power input were considered in this present study. The intensity of the module's supply current has been represented on the graphs in this working investigation. Because the electromotive force created by each module is different, the electric power values in the modules in the parallel-connected system are distinct, as shown in Fig. (8).



* R1: one thermoelectric cooler, R2: two thermoelectric cooler, R3: three thermoelectric cooler, R4: four thermoelectric cooler.

Fig. (8): Influence number of Peltier units on the electrical power consumption in time with fan.

These results achieved when the currents decreased in the module with the increasing load resistance. Mathematically, electric power is a function in both current and voltage. As a result, a linear relationship between the output voltages and output currents in the two systems is possible. The serial-connected system can also increase the ultimate output voltage.

The parallel connected system, on the other hand, can increase output currents. The higher the value of electric power, the closer the steady state is to the intersection of Peltier's cooling and Joule's heating effects. On the cold side, the maximum cooling capacity is given, and the Joule impact is often obscured by the Peltier cooling effect. As a result, the Joule effect governs heat transfer on the cool side. The supply current gradually exceeds the optimal current, the power released by the Joule effect gradually increases, and a considerable amount of heat is gradually conveyed to the cold side by conduction, reflecting the fact that the cold side temperature rises to tend towards the hot side temperature.

Furthermore, in the current practical investigation, numerous peltier plates are frequently used in a device. When the modules are in operation, they are frequently working at various temperatures at the same time. As a result, each module's electromotive force will be distinct. Four systems are set up to compare the performance of the systems in different TEG module connections under such conditions, employing 1, 2, 3, and 4 peltier systems coupled in serial and parallel. Without a fan, hot surface temperatures ranged from 64.5 to 87.8 °C, with a 23.3 °C increase, and hot surface temperatures ranged from 29.4 to 38.5 °C, with a 9.1 °C increase. All of the cold surface temperatures are regulated at 5 degrees Celsius. Both systems have a load resistance that varies from 1.9 to 8.4 Ω with a 6.5 Ω increase.

The relation between electric power and time had the same trend in both cases, parallel and serial with fan, but the regression analysis gave the variation between of them from linear or exponential function as shown in Fig. (8). In addition, the values of R2 differed within the same treatment and between treatments. The maximum value of the electrical power indicated with connecting four Peltier (R1 paltrier number 1, R2 paltrier number 2, R3 paltrier number 3 and R4 paltrier number 4) in parallel, the value of R2 was 0.997, while the value of R2 in the serial case was 0.991 and gives the lowest consumption of electrical power. Also, Fig. (8) indicated that the consumed electrical power in parallel with fan more than serial in the same conditions. This means that the relation between electric power and time had the same trend in both cases, parallel and serial without fan, but the regression analysis gave the Variation between of them from linear or exponential function as shown in Fig. (9). In addition, the values of R2 differed within the same treatment and between treatments. The maximum value of the electrical power indicated with connecting four Peltier in parallel, the value of R2 was 0.9887, While the value of R2 in the serial case was 0.988 and gives the lowest consumption of electrical power. The output voltages vs output currents in the two systems are the outcome of the preceding results. In both systems, the relationship between output voltages and output currents can be seen to be linear. The maximum output voltage of a serial-connected system can be increased, while the maximum output current of a parallel-connected system can be increased.

3.2. Performance coefficient of the cooler system

The obtained COP for the different treatments is shown in Fig. (10) and Table (2). The equations 1,2,3, and 4 were used to determine the COP value for each input power, and the results revealed that when one Peltier with fan was employed, the COP value was higher. Meanwhile, when used four Peltier in serial with fan the COP achieved the best values and the best fit. In addition, the values of R^2 differed within the same treatment and between treatments. The maximum value of COP indicated with connecting four Peltier in serial, the value of R2 was 0.982, while the value of R2 in the parallel case was 0.933.

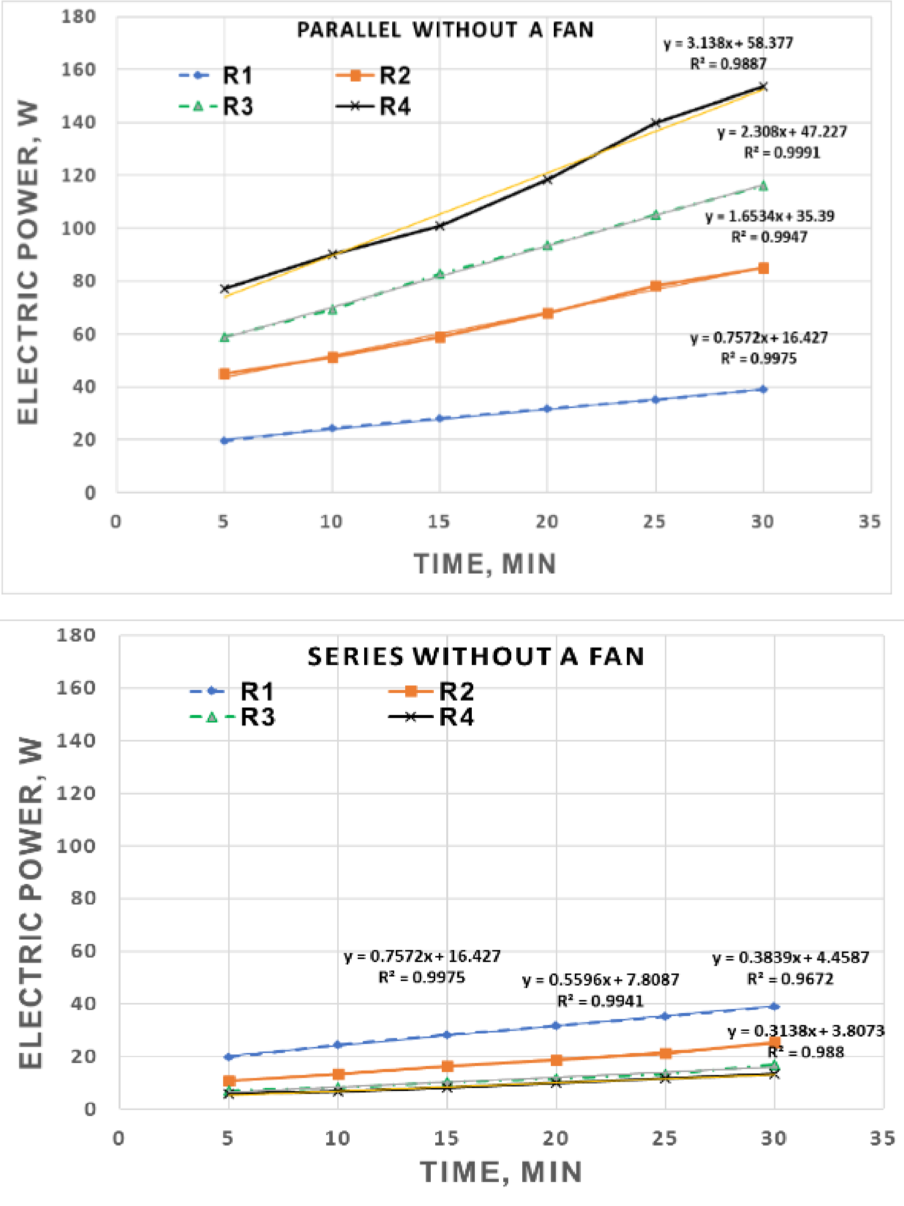
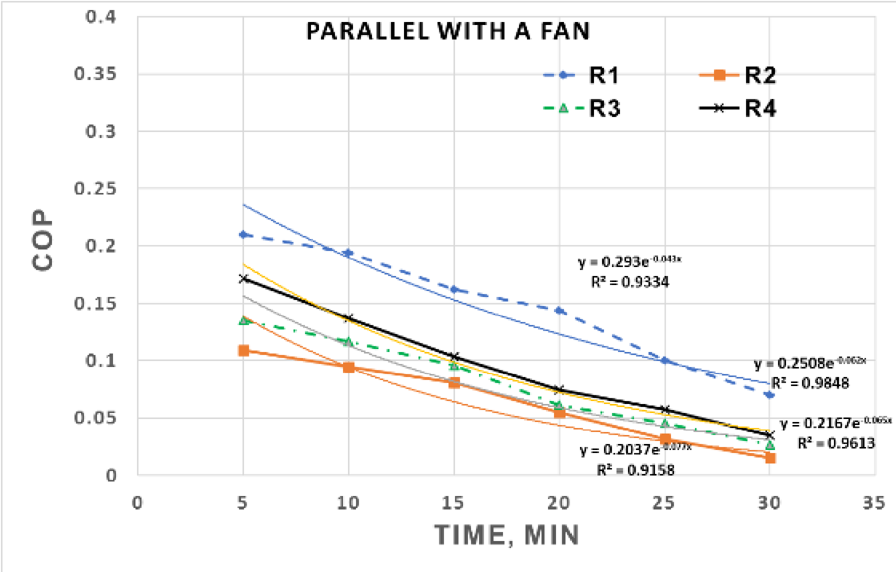


Fig. (9): Influence number of Peltier units on the electrical power consumption in time without fan.

Also, in two cases the COP decreased when the time is increased. In addition, the true coefficient of performance of the least electrical power required by the module will be determined with respect to this initial optimal current for each modification of the module's supply current. Because it varies over time depending on the supply current. The cooling power has a share, indicating the presence of a maximum corresponding to the module supply current's second optimum value and other values.

Table (2) shows that there was no significant difference in temperature when the circuits were linked in serial and parallel, but the effect is with a fan or without a fan, the regression analysis gave the variation of exponential function. As the value of R2 with a fan was 0.999, while the value of R2 without a fan was 0.978, which confirms the results that there must be a fan inside the refrigeration cabinet to help balance the temperature inside the refrigeration cabinet.



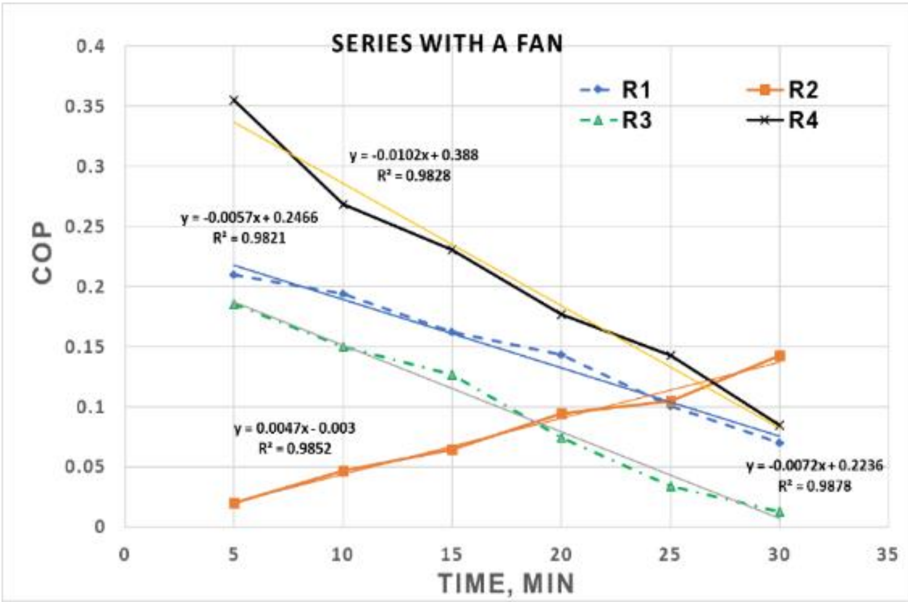


Fig. (10): Relationship between number of Peltier units on COP in time.

Table (2): Effect of serial and parallel connection on COP in time with fan (B) and without fan (A).

Time (min)	**5**				**10**				**15**				**20**				**25**				**30**			
Num. of Peltier	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Parallel- Cop A	0.66	0.32	0.38	0.39	0.90	0.28	0.33	0.32	0.88	0.22	0.26	0.28	1.09	0.20	0.23	0.23	1.44	0.18	0.21	0.22	1.54	0.15	0.18	0.17
Parallel- Cop B	0.21	0.11	0.14	0.17	0.19	0.09	0.12	0.14	0.16	0.08	0.10	0.10	0.14	0.05	0.06	0.07	0.10	0.03	0.05	0.06	0.07	0.02	0.03	0.03
Serial-Cop A	0.66	0.66	0.66	0.66	0.90	0.90	0.90	0.90	0.88	0.88	0.88	0.88	1.09	1.09	1.09	1.09	1.44	1.44	1.44	1.44	1.54	1.54	1.54	1.54
Serial-Cop B	0.21	0.02	0.19	0.35	0.19	0.05	0.15	0.27	0.16	0.06	0.13	0.23	0.14	0.09	0.07	0.18	0.10	0.10	0.03	0.14	0.07	0.14	0.01	0.08

The values of temperatures were measured at different points such as cold, hot and ambient temperature with and without fan. Table (3) shows the effect of fan operation, with the cold side temperature ranging from -10 to 0 °C. But it's ranged from 20 to 50 °C without fan because the system had not been ability to distribute the cold air during the components of Peltier. Also, the hot side temperature under using fan gave values less than without fan. Peltier's efficiency is determined by the temperature difference between the hot and cold sides. Temperature differences can occur as a result of voltage fluctuations. When the voltage is steadily increased, the temperature of the hot surface continues to rise, while the temperature of the cool surface decreases first, then rises. The temperature gradient will progressively increase until it reaches a stable value.

Table (3): Fan application on the Peltier unit surfaces temperature (B) with fan (A) without fan and ambient temperature

Time (min)	Cold side A	Cold side B	Hot side A	Hot side B	Ambient
5	25.66	-7.8	64.5	29.4	18.5
	15.8	-3.6	64.5	29.4	18.5
	17.7	3.5	64.5	29.4	18.5
	18.1	4.3	64.5	29.4	18.5
10	32.3	-7.4	68	30.7	18.5
	14.8	-3.2	68	30.7	18.5
	16.7	3.2	68	30.7	18.5
	16.5	3.7	68	30.7	18.5
15	36.4	-6.2	77.6	32	19.4
	13.9	-2.8	77.6	32	19.4
	15.8	2.8	77.6	32	19.4
	16.9	3	77.6	32	19.4
20	42.1	-5.8	80.6	34.6	20.1
	13.3	-2	80.6	34.6	20.1
	15.2	2	80.6	34.6	20.1
	15.3	2.4	80.6	34.6	20.1
25	49	-4.1	83	36.8	19.7
	12.5	-1.2	83	36.8	19.7
	14.4	1.6	83	36.8	19.7
	15.1	2	83	36.8	19.7
30	53.2	-2.9	87.8	38.5	18.2
	11.6	-0.6	87.8	38.5	18.2
	13.5	1	87.8	38.5	18.2
	12.9	1.3	87.8	38.5	18.2

These variations of temperature values around 20° C as ambient temperature is shown in Fig. (11). Also, there was no significant difference in temperature in the case of connecting Peltier in parallel or in serial According to the energy condition of the module, it has 0% cooling capability when it first starts up. As shown in Table (3), the temperature of the module's cold side decreases as it approaches the calibration value or its minimum value as a function of voltage and supply current. indicated the values of both cooling and heating sides in with and without fan. The ambient temperature around 20° C (300 K). Because it is related to both the temperature of the cold side and the supply current of the module, the cooling capacity changes at the same rate in an increasing direction. As a result, as the current varies, the cooling capacity varies as well. From the table cleared that using fan gave the best values in cold side that reflected on cooling performance. Also, energy consumed in hot side when used fan is less than the without fan. This revealed that the convection heat transfer coefficient was varied with using fan and without. Table (4) shown the average cooling in the case of serial, parallel and the case of one, two, three, four thermal resistances, respectively.

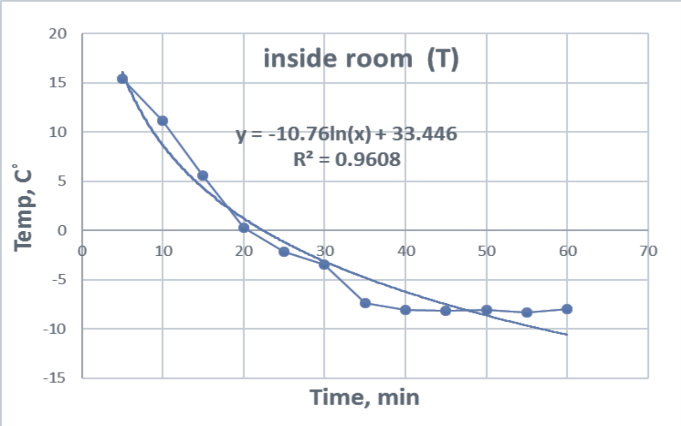


Fig. (11): The Relation between temperature and time for cooling inside cabinet

Table (4): Average values of cooling load (W) when used one to four Peltier in parallel and serial connections

Num. of Peltier	1	2	3	4
Parallel	833.64	737.89	612.90	606.96
Serial	833.64	776.62	610.22	525.51

4. CONCLUSIONS

The findings of a 14-day cooling experiment with a thermoelectric cooler (Peltier) on a green bean crop with varied input power and cooling load have been published. The temperature at the cool side of the heat sink and cooler cabinet falls as the input power supplied to the system grows, since the more heat absorption in the cool side of the TEC modules, the lower the temperature attained at the cool side of the heat sink and cooler cabinet. As the input power increases, more heat is absorbed in the cool side of the TEC (inside cooler cabinet) and more heat is rejected in the hot side of the TEC (outside cooler cabinet), causing the hot sink temperature to rise. Green bean cooling ideal temperature 5 degrees Celsius, which gives the ideal cooling for 14 days by 4 Peltier, serial connection electric at average cooling load 525.51 W, only 5 minutes to cooling not freezing, with the use of a fan, thermostat cut current to save degrees about ideal. The temperature in the cabinet drops when the input power is shifted from low to high, resulting in a drop in COP. This is because more energy may be absorbed when the input power is high. Because it takes more energy to lower the temperature of the cooling cabinet, the higher the cooling load given in the cooling cabinet, the longer the temperature stability of the cooling cabinet may be maintained.

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إنشاء وتقييم مبرد الفاصوليا الخضراء باستخدام تأثير بلتيير

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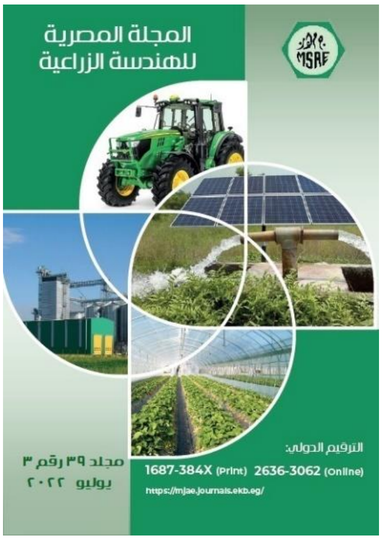

الكلمات المفتاحية:
الفاصوليا؛ كهروحراري؛ تبريد المحاصيل؛ بلتيير؛ ثلاجة.

الملخص العربي

تطوير أجهزة تكييف الهواء والتبريد من أهم الإنجازات الحديثة. هدفت هذه الدراسة إلى معرفة مدى جودة أداء نظام التبريد بلتيير لتخزين الخضار والفاكهة. لاختبار الأداء ، تم استخدام وحدة كهروحرارية مع (١ ، ٢ ، ٣ و٤) مع وجود وبدون وجود مراوح ، بالإضافة إلى طريقتين لتوصيل وحدات Peltiers (على التوالي والتوازي). يتم تحديد أداء نظام التبريد من خلال البيانات المجمعة والمحللة من نظام القياس. يتم تسجيل توزيع درجة الحرارة على كل مكون من مكونات نظام التبريد باستخدام مزدوجات حرارية متصلة بالحصول على البيانات. درجة حرارة التبريد لقرون الفاصوليا الخضراء ٥ درجات مئوية ، والتي توفر تبريدًا مثاليًا لمدة ١٤ يومًا بواسطة ٤ Peltiers ، توصيلات كهربائية على التوالي وبمتوسط حمل تبريد ٥٢٥,٥١ وات في ٥ دقائق فقط بدون تجميد ، باستخدام مروحة. يؤدي التوصيل على التوازي إلى زيادة الطاقة المستهلكة من ٢,١ وات إلى ١٦,٨ وات ، وبالتالي يتم تقليل التوصيل على التوالي من استهلاك الطاقة إلى ٠,٢٦ واط. تم تقليل قيم COP مع وقت التشغيل إلى ٠,٠٨ و٠,٠٧ في التوصيل على التوازي وعلى التوالي وواحد بلتيير ، ولكن مع ٤ peltiers كانت قيم COP 0.17 و٠,٠٨ على التوازي والتوصيل التسلسلي.