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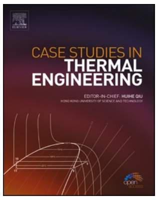

Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector

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ABSTRACT

This study investigates the use of solar energy, one of the leading renewable energy sources, to power a diffusion absorption refrigerator, thereby demonstrating the feasibility and practicality of renewable energy applications without relying on electrical energy or fossil fuels. Two mini refrigerators with identical power and features were employed in the experimental study. The aim is to evaluate the performance of two refrigerators, one powered by electricity and the other by heat from a parabolic solar collector. The heat transfer oil circulating in the parabolic solar collector was transferred to the generator of the solar refrigerator through a special apparatus. Various parameters such as mass flow rates, system pressure, solution concentrations, and thermal and COP values of diffusion refrigerators were meticulously analyzed. Experimental results obtained from both refrigerators were compared for a comprehensive evaluation. While the Coefficient of Performance (COP) of the electric refrigerator was determined as 0.398, the COP value of the solar refrigerator was determined as 0.380. These findings highlight the potential of solar energy in sustainable cooling applications and provide valuable information on comparing electric and solar cooling systems. The study contributes to the ongoing efforts to promote eco-friendly and energy-efficient technologies, emphasizing the role of solar energy in reducing dependence on traditional energy sources.

1. Introduction

The increase in energy demand due to the rise in the world population and the necessity for energy supply in these regions have brought renewable energy to the forefront as a suitable energy source [1]. Fossil resources are exhaustible and carbon emissions resulting from their consumption are increasing simultaneously. Therefore, many countries have increasingly adopted renewable energy as a sustainable alternative [2]. Renewable energy sources are diverse, but solar energy is the most used because it is easy to find and has the least impact on the environment [3]. In addition, renewable energies are a suitable choice to meet the electrical energy and cooling demands of remote regions. The importance of using off-grid renewable energy should be considered for regions that are particularly sensitive to climate change, such as Africa [4]. Renewable energy can be integrated into independent hybrid systems including heating, cooling, and electricity [5].

As a renewable energy source, solar energy has the potential to provide energy throughout its lifetime Parabolic through solar collectors, a type of solar thermal collector, can produce electricity by reaching high temperatures. The potential advantage of using parabolic trough solar collectors is that they can be used at home and in the workplace, as well as the ability to generate electricity from them on a large scale [6]. Nowadays, both concentrating and non-concentrating solar thermal collectors are used to convert incident

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solar radiation into process heat. Incoming sunlight is absorbed at the reaching receiver/absorber surface and subsequently conveys a heat transfer fluid (HTF), typically comprising water or thermal oil. Solar collectors, employed to curtail energy expenses in existing cooling, distillation, heating, and industrial processes, find extensive application in high-temperature scenarios [7,8]. Since thermal energy is used in the absorption cooling system, renewable energy sources can be used instead of fossil fuels as a thermal source. When used in solar thermal source cooling technology, it does not harm the environment like refrigerators using vapor compression cooling systems [9].

There are many cooling systems available, including vapor compression, mechanical and absorption cooling. Diffusion absorption refrigeration (DAR) system is also a type of absorption cooling and works by using thermal energy. DAR refrigerators can be powered by kerosene or liquid petroleum gas. Electrically operated units are especially suitable for places where noise is not desired, such as hotel rooms [10,11]. The DAR system includes a bubble pump used in cooling systems. This pump both circulates the working fluid and removes dissolved refrigerant from the solution, so it is the most important component of the system [12]. The evaporation of ammonia allows the system to absorb heat from the outside. Since the evaporation effect is achieved by changing the partial pressures of the liquids in the system, the total pressure in the system remains constant. The working fluid is a mixture of three components: ammonia as a coolant, water as an absorbent, and an auxiliary inert gas (usually hydrogen or helium) [13]. The unique feature of the DAR cycle compared to the traditional ammonia-water absorption cycle is that it operates at a uniform pressure. The solution, which condenses in the condenser and becomes liquid in the system, enters the evaporator. When it encounters hydrogen gas, an inert gas, in the evaporator, there is a significant decrease in the partial pressure of ammonia and the ammonia evaporates and spreads into hydrogen gas. When the mixture consisting of ammonia vapor and hydrogen gas falls into the absorber, the ammonia vapor is absorbed by the lean mixture and returns to the boiler as a rich mixture. The hydrogen gas released from the ammonia vapor in the absorber rises as its density decreases and returns to the evaporator inlet. Thus, the pressure-balancing gas cycle is completed [14–17]. The DAR system has been developed by many researchers by making changes in the mechanical system modification of component systems using different inert gas sources and fluid types [18–21]. Some experimental and theoretical studies have been conducted by researchers focusing on increasing low COP rates [22–24].

There are studies carried out by providing thermal energy to the DAR system with solar energy, which is one of the leading renewable energy sources [25–27]. Jacob et al. performed an experimental analysis to improve the performance of a DAR machine powered by ammonia water on diffusion absorption solar cooling systems. They designed a prototype refrigerator that gets its heat from a flat plate. They reported that the COP value was 0.12–0.38 at evaporator temperatures of 12/6 °C and 18/15 °C in refrigerators with a cooling capacity of 0.7 kW–3 kW [28]. Gutierrez, studied the thermal performance of a solar-powered refrigerator. In the study [29], he developed a commercial absorption-diffusion type refrigerator with a flat plate collector for the generator. Ammonia-water solution and hydrogen were used in the system. Since there was no hot thermal storage to ensure continuous operation, cooling was only done during the day. In this system, the condenser is designed to cool the air by natural convection. The effects of ambient temperature on the equipment system have been examined experimentally. In another study, Sayyadi et al. [19], investigated the performance and optimization of a small solar-powered DAR system with 1 kW cooling capacity. This study simulated different binary mixtures of light hydrocarbons as working fluids along with helium as an inert gas. They found that 6 m^2 of solar area was needed to achieve a temperature of 126 °C and 4.2 kW power required by the driven heat energy supplied to the combined bubble pump-generator compartment. Acuna et al., analyzed diffusion absorption using a composite parabolic condenser as a heat source in the cooling system. The working mixtures tested in the cooling system in their study were NH3–LiNO3 and NH3–NaSCN. The analysis was made with a simulation and was supported by experimental results obtained by a built and tested compound parabolic concentrator. The CPC constructed was 2 m long by 0.32 m wide and had a height of 0.29 m. They found a COP value between 0.34 and 0.50 under different working conditions [30]. In studies conducted by W.Handong et al., DAR focused on working with low-grade thermal energy such as solar power and waste heat sources, which can reduce the electricity consumed by refrigerators and air conditioners. They developed a new-style DAR with a solution pump to utilize solar energy, a clean energy source, to reduce electricity consumption in heating, ventilation, air conditioning and refrigeration engineering. They designed the plate-type solution-cooled adiabatic spray absorber containing $LiNO_3$–NH_3–He as the working fluid to increase the mass and heat transfer, respectively, used by the low-temperature heat source. Theoretical results showed that the COP of the new DAR ranged from 0.11 to 0.5 [31].

The solar refrigerating system is a technology that results from coupling the cooling system with a solar collector, which provides heat to activate the cooling unit. In the DAR system, the temperature available from a flat collector or an evacuated tube collector is not sufficient to separate ammonia from the water in the ammonia-water mixture pair. To obtain a higher temperature, it is necessary to work with a parabolic collector, a Fresnel collector, or a dish-type collector. Since the refrigerators used the experiment got used to the ammonia-water mixture pairs, the parabolic collector was used. This study was experimental research that aimed to compare the performance of two diffusion absorption refrigerators, the first of which was powered by electricity, and the other was heated from the hot oil of the parabolic collector. Both refrigerators work with the DAR system and both refrigerators have the same power and features. In this study, a diffusion absorption cooling (DAR) cooling system supported by phase change material and battery bank is proposed to solve the problem using a solar parabolic collector to ensure continuity in night and cloudy environments where solar energy is not available.

2. Experimental method and material

A DAR system consists of a generator, bubble pump, rectifier, condenser, gas heat exchanger, evaporator, absorber, and solution heat exchanger. The DAR system in which the experimental study was carried out is shown in Fig. 1.

Refrigerators with the same features were used in the experiments. While one refrigerator was heated with heat transfer oil obtained from solar energy, the other refrigerator was heated with an electrical resistance. As seen in Fig. 1a, the generator has been redesigned to operate with hot oil coming from the parabolic collector. For this purpose, the electric heater was removed, and a new apparatus was prepared (Fig. 2). The hot oil coming from the collector was circulated through the generator. Fig. 1b shows another electrically powered refrigerator. The generator-bubble pump is specially insulated to prevent heat loss. The power of refrigerators that use hydrogen as a pressure regulating gas is 60 W. Thermocouples were used at the generator, rectifier, condenser, evaporator, absorber and heat exchanger inlets and outlets of the system, and the measured values were recorded with a multi-measurement device. Additionally, ambient and cabin temperatures of both systems were measured. Measured data were recorded every 1 min for 3 h using a data logger. Temperature measurement was made with K-type thermocouples (error ±0.25 °C). The inlet and outlet temperatures were measured in contact with the metallic surface of the outer tube. Since the DAR system refrigerator operates in a closed cycle, temperature values were measured from the pipe surfaces. Since hydrogen circulates in the refrigerator, it is not possible to measure the inlet and outlet temperatures of the open-loop elements. The pressure value in the system was accepted as 18 bars from the ammonia-water tables, based on the temperature of 45 °C at the condenser outlet. The ammonia concentration in the ammonia-water mixture is 30 %.

The heat required for the DAR system refrigerator is obtained from solar energy. Fig. 2 is the apparatus designed to remove the electrical heater of the generator and replace it with the inlet and outlet of the heat transfer oil coming out of the parabolic collector. 3.5 kW thermal power can be obtained from the parabolic collector shown in Fig. 3. For the manufacture of this parabolic collector, the parabola height (x) and focus values (f) were calculated for the (y) value in Equation (1).

The dimensions of the parabolic adder were determined from Eq. (1). The characteristic dimensions of the parabolic collector are given in Table 1.

$$y = \sqrt{4fx} \tag{1}$$

As shown in Tables 1 and 2, the aperture of the collector is 2y = 335 cm, the depth of the collector is x = 76 cm and the focal point is f = 92 cm (Fig. 4).

For the useful energy of the parabolic collectors transferred to the absorber, the thermal energy transferred to the fluid from the Hottel-Willer-Bliss equation can be found in the equation below [39].

$$Q_u = A_a F_R \left[I_d \alpha \rho \gamma \tau - \frac{A_y}{A_a} U_T (T_{in} - T_a) \right] \tag{2}$$

In this equation, (Qu) is the useful heat energy, (Aa) is the aperture area, (Ay) is the absorber area, (F_R) is the heat gain factor, and (Id) represents the amount of direct radiation falling over the unit aperture area. α is the absorption rate of the absorber material, γ is the intercept factor, ρ is the reflectance rate of the reflective material, and τ is the transmittance coefficient of the transparent cover. (U_T) is the total heat transfer coefficient given from the absorber to the environment, (Ti_n) is indicated by the fluid inlet temperature and the ambient temperature (T_a). Qu, F_R, $U_{T,}$ and other calculations are available in the literature [40]. The theoretical thermal efficiency is as follows [41],

$$\eta_0 = \frac{Q_u}{A_a I_d} = F_R(\alpha \rho \gamma \tau) - F_R U_T \frac{A_y (T_{in} - T_a)}{A_a I_d} \tag{3}$$

In addition, when the inlet and temperatures of the fluid and the experimental values such as the flow rate are known, the experimental

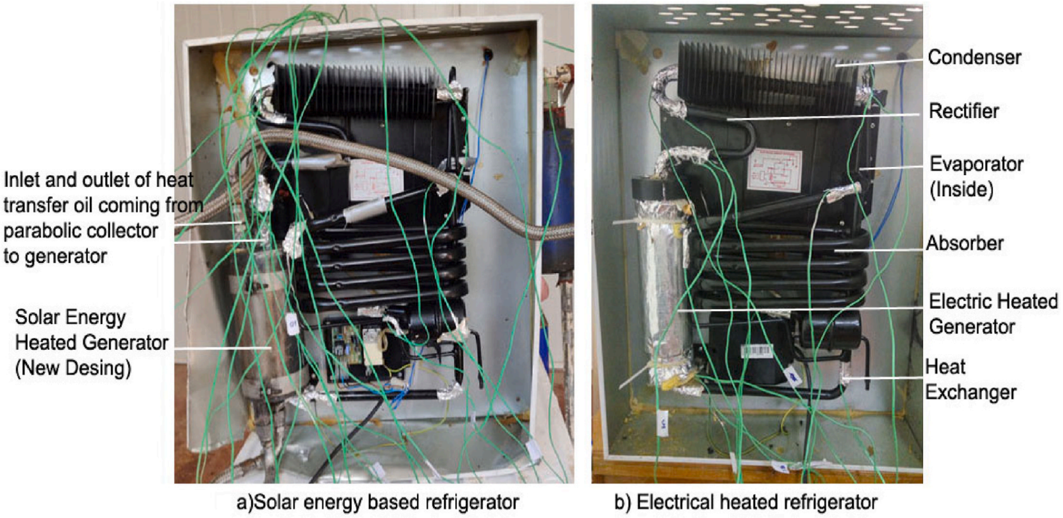

Fig. 1. DAR system, mini refrigerators based on electrical and solar energy.

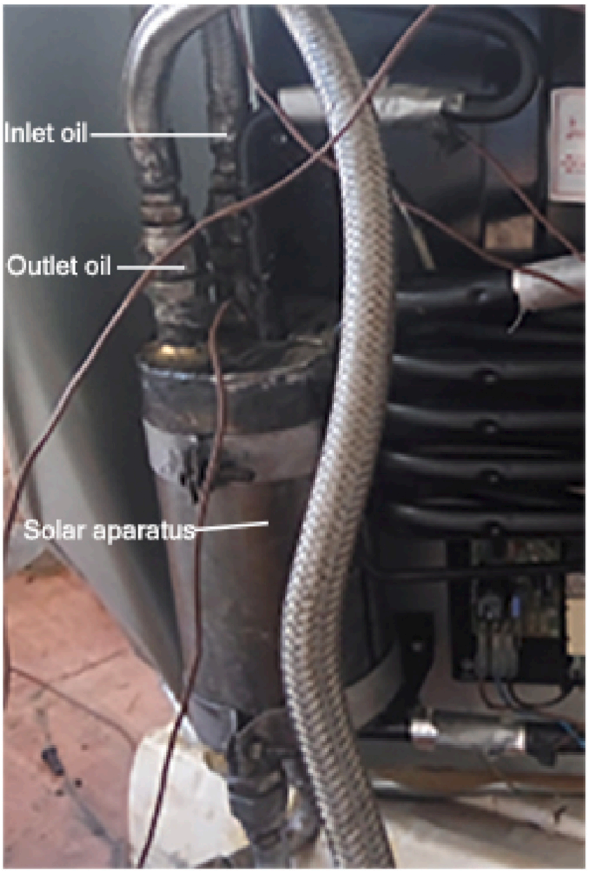

Fig. 2. Generator design for solar energy system.

Fig. 3. Parabolic collector.

Table 1
The x and y lengths of the parabolic.

Y(cm)	20.94	41.88	62.81	83.75	104.69	125.63	146.56	167.5
X(cm)	1.19	4.75	10.69	19.0	29.69	42.75	58.19	76

thermal power can be found from the equation given below

$$Q = m\, c_p (T_{out} - T_{in}) \tag{4}$$

Here, m is the mass flow rate (kg/sn) and Tout is the exit temperature of the fluid from the absorber. The experimental thermal

Table 2
Characteristics of PTC

The aperture of the collector w:	335 cm
The length of the collector **L**:	450 cm
Aperture area of the collector $\mathbf{A_a}$:	15 m^2
Depth of the collector $\mathbf{l_p}$:	76 cm
The focus of the parabolic **f**:	92 cm
Concentration ratio **c:**	14
Rim angle r_{rim}**:**	92°
The outer diameter of glass tube d_c:	10 cm
The outer diameter of copper tube d_b:	76 cm

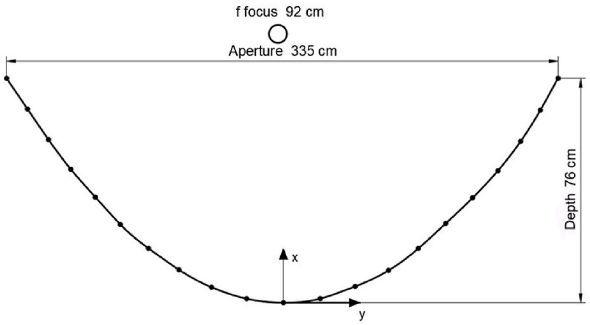

Fig. 4. The aperture, depth, and focal distance of the parabola.

efficiency is found to be equal as follows.

$$\eta = \frac{Q}{A_a I_d} \tag{5}$$

The collector has a sun sensor and follows the sun in an east-west direction. The control card moves according to the radiation received by the sun sensor [32]. Heat transfer oil was used in the system. This oil was circulated in the system with the hot oil pump. The inlet and outlet temperatures of the hot oil were measured in the parabolic collector (Fig. 2.). Oil inlet and outlet temperatures and ambient temperature measurements were recorded with a multi-channel data logger. The measured direct radiation value is around 695–738 W/m^2. Direct radiation values were taken from the radiation measurement centre at Harran University Faculty of Engineering (Şanlıurfa, Lat 37.1). The experimental set was established 20 m away from this measurement centre [33]. 2AP Tracker set of

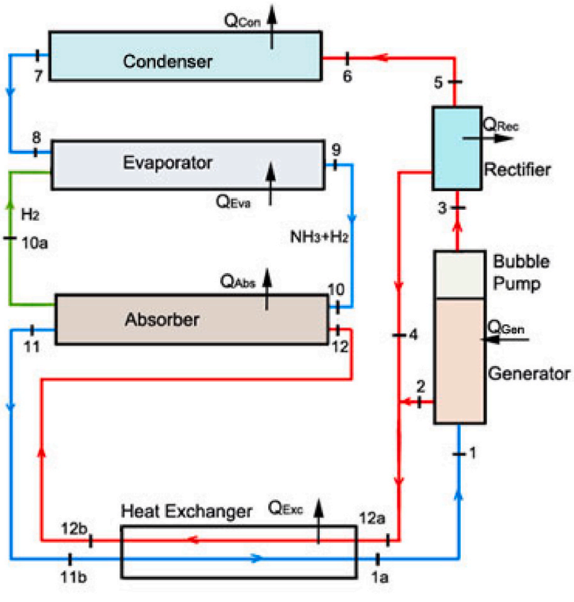

Fig. 5. Diffusion-absorption refrigerator cycle.

Kipp&Zonen company was installed in this center. These values were used in thermal calculations.

Since the sun's direct radiation is low during sunrise and sunset hours, the required temperature in the generator for the evaporation of ammonia from the ammonia-water solution in the parabolic collector could not be reached. The required temperature for the generator in the parabolic solar collector was reached only at noon. For these reasons, the experiments were carried out at noon. Heat transfer was made to the oil-heated DAR for up to 3 h, provided that the required temperature value was reached in the parabolic collector at this time of the day.

3. Energy analysis of DAR cycle

The thermodynamic analysis was performed for the absorption refrigerator. The analysis of the refrigerating system was based on the first law of thermodynamics and consisted of energy and mass conservation equations for each of the components. In the analysis, it was accepted that there was no heat transition to the environment. It was accepted that ammonia is 100 % steam in the condenser part of the system. Fig. 5 Shows the balance conditions in the numbering made for the elements in the cycle. For this system, mass and energy balance equations including heat losses-gains and heat capacities for various elements of the system are presented below [34–36].

The regenerated strong solution enters the generator from point (1) and as it starts to boil, it creates steam bubbles in the generator along with the liquid. The bubbles formed from point (3) move upward. The mass and energy balances of the generator are given by equations. General mass balance equation for Generator-bubble pump:

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3 \tag{6}$$

Ammonia mass balance equation:

$$\dot{m}_1\ x_1 = \dot{m}_2\ x_2 + \dot{m}_3\ x_3 \tag{7}$$

Energy balance equation:

$$\dot{m}_1 h_1 + Q_{Gen} = \dot{m}_2\ h_2 + \dot{m}_3\ h_3 \tag{8}$$

In the rectifier, while the wet steam coming from the generator throws the heat into the environment, the liquid melt comes back towards the heat exchanger and the steam moves towards the condenser from point 5. The mass and energy equations for the rectifier can be written as follows:

General mass balance equation for Rectifier:

$$\dot{m}_3 = \dot{m}_4 + \dot{m}5 \tag{9}$$

Ammonia mass balance equation:

$$\dot{m}_3\ x_1 = \dot{m}_4\ x_4 + \dot{m}_5\ x_5 \tag{10}$$

Energy balance equation:

$$\dot{m}_3\ h_3 = \dot{m}_4\ h_4 + \dot{m}_5\ h_5 + Q_{Rec} \tag{11}$$

The refrigerant vapor leaves the rectifier from point (5) and flows to the condenser where it condenses and exits from point (7). The mass fraction and the mass flow rate of the refrigerant at the inlet and exit of the condenser remain the same.

General mass balance equation for condenser:

$$\dot{m}_5 = \dot{m}_6 = \dot{m}_7 = \dot{m}_8$$

Energy balance equation:

$$Q_{Con} = \dot{m}_6\ (h_7 - h_6) \tag{12}$$

In the evaporator, the liquid refrigerant from the condenser enters at point (7), and the auxiliary inert gas enters at point (10a). The vapor mixture of refrigerant and auxiliary inert gas leaves the evaporator at point (9); Since the mass of the inert gas is neglected, the energy equation for the evaporator can be found from the following equation:

General energy balance equation for evaporator:

$$Q_{Eva} = \dot{m}_4\ (h_9 - h_8) \tag{13}$$

In the absorber, the gas mixture of the refrigerant and auxiliary inert gas comes to the absorber from point (10) to form a strong solution of the refrigerant. The strong solution flows towards the generator at point (11), while the auxiliary inert gas flows back to the evaporator at point (10a). Mass and energy balance equations for the absorber are given.

General mass balance equation for Absorber:

$$\dot{m}_3 = \dot{m}_4 = \dot{m}_5 = \dot{m}_{11}$$

$$\dot{m}_2 + \dot{m}_5 = \dot{m}_{12} \tag{14}$$

Energy balance equation:

$$\dot{m}_{11}\ h_{11}=\dot{m}_9\ h_9+\ \dot{m}_{12}\ h_{12}+Q_{Abs} \tag{15}$$

Solution Heat Exchanger

$$Q_{Exc} = \ \dot{m}_{12a}\ (h_{12a} - h_{11a})\text{-}\ \ \dot{m}_{11}(h_{1a} - h_{11b}) \tag{16}$$

In the equations given above, it is given as ṁ (kg/sec), Q (W), h (kJ/kgK), and x water-ammonia ratio. The coefficient of performance (COP) value of the absorption cooling system is defined as cooling per unit work and can be calculated without neglecting the work given to the pump. Since there is no pump in the DAR system, only thermal energy is supplied to the generator and is calculated from the following equation. The coefficient of performance:

$$COP = \frac{Q_{Eva}}{Q_{Gen}} \tag{17}$$

The thermodynamic analyses were conducted with the obtained temperature values, system pressure, mass flow and concentrations. The pressure of the system was determined from the ammonia table according to the condenser temperature.

4. Results and discussion

Temperature values were taken by the data logger by placing thermocouples at certain temperature points. The temperature of the electrically heated refrigerator of the absorber, condenser, generator, bubble pump, ambient temperatures as well as the inlet and outlet temperatures are given in Fig. 6. In an electrically powered refrigerator, the generator temperature is initially low, but as the melt heats up its temperature increases. It starts to stabilize after 30 min [16]. The sharp increase in the 15th and 25th min in electric refrigerators is due to the presence of a constant heat flux compared to solar refrigerators. The temperature drop in the evaporator begins after 30 min. It was observed that when the ambient temperature was 30–32 °C, the evaporator temperature dropped to −10 °C and the internal temperature of the refrigerator to 17 °C.

Fig. 7 Shows temperature values obtained from the collector during the 3 h test period. Oil temperature increased as direct radiation increased and decreased as direct radiation decreased. The lowest direct radiation value was 695 W/m^2 and the highest value was 738 W/m^2 (Fig. 8). The inlet temperature of the oil circulating in the collector varies between 99 and 102 °C and the temperature of the oil obtained varies between 144 and 162 °C. While the ambient temperature was 32–35 °C, the evaporator temperature dropped to 1 °C and the internal temperature of the refrigerator dropped to 19 °C. It was observed that the solar-powered refrigerator had less cooling than the electric refrigerator.

The temperature values taken from the electric-heated refrigerator and solar-heated one are shown in Table 3.

Condenser, evaporator, absorber inlet temperatures, absorber and condenser outlet temperatures vary slightly depending on the generator temperature, but generally remain constant. The evaporator outlet temperature depends on the generator temperature. 20 min after starting the system, the temperature drops, and cooling begins. As the generator temperature changes, the evaporator cooling temperature also changes. The mass flow rates and mass concentration values of the electrically heated and solar absorption refrigerator are given in Table 3. Xpoor and Xrich concentrations and enthalpy values were found using system pressure and temperatures [37,38]. When the water-ammonia concentration and generator temperature are known, the pressure value is read from the literature

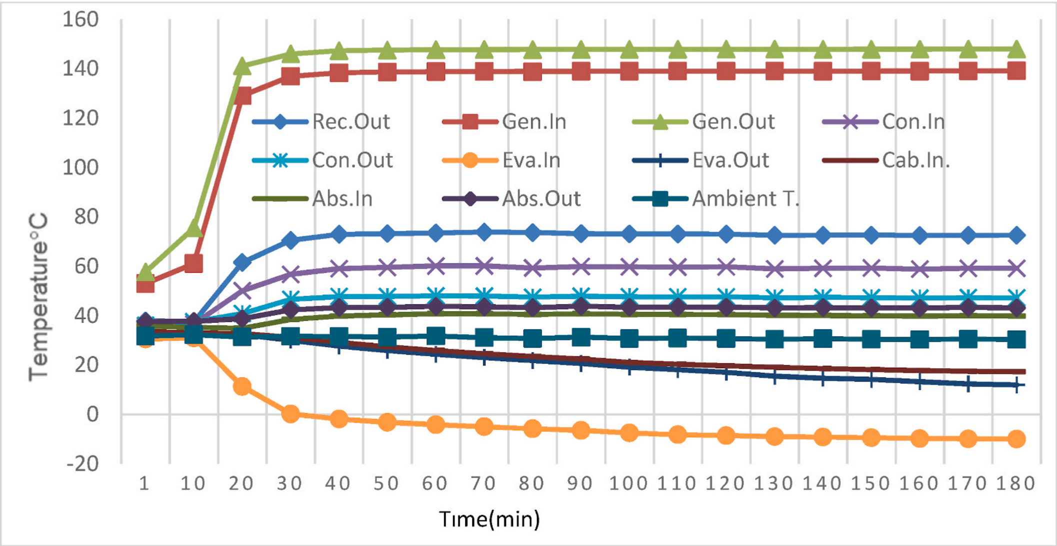

Fig. 6. Temperatures of the electrically heated refrigerator.

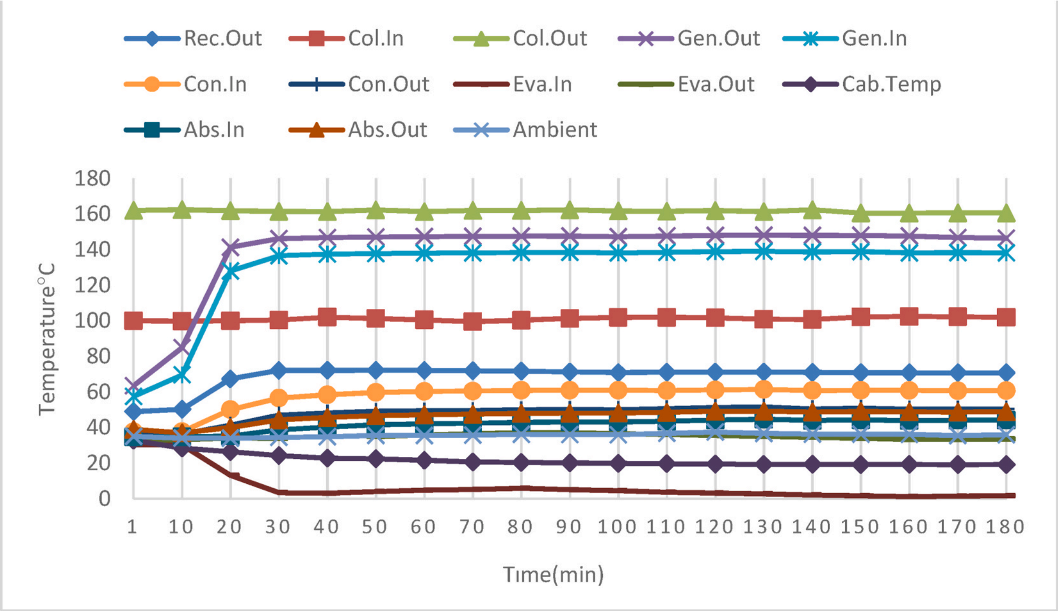

Fig. 7. Temperatures of the solar-heated refrigerator.

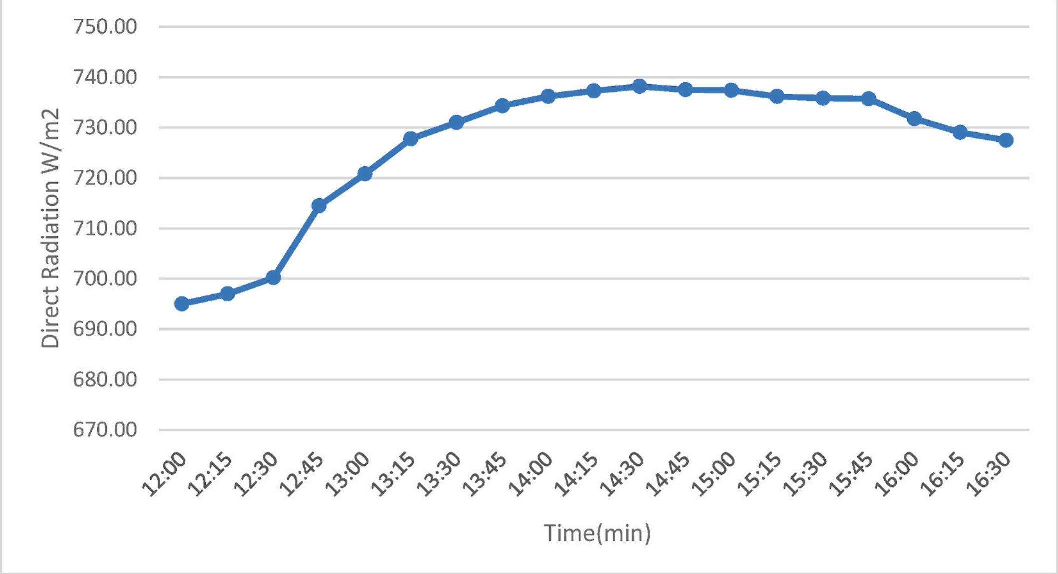

Fig. 8. Measured direct radiation values for solar-powered refrigerator.

[37]. Then, the concentration and mass ratios at the generator, condenser, evaporator and absorber inlet and outlet points are calculated with the help of the EES (Engineering Equation Solver) program. The values in Table 3 were obtained from the ammonia-water mixture x values from the EES program and the thermodynamic graphs of the ammonia-water solution [37,38]. The condenser outlet pressure of the refrigerant was considered equal to the system pressure. Temperature and performance values of solar and electric refrigerators are found in formulas (9), (10), (11), (17). It has been determined that the thermal power of the electric refrigerator, which has a constant and higher temperature, is higher than that of the refrigerator heated by solar energy (Table 4.).

In this experimental setup, enhancements in the mirrors, focusing, and tracking system have the potential to yield greater energy output, surpassing the current 3.5 kW, and achieve higher temperatures. This can be achieved with a concurrent reduction in the oil flow rate. The heat energy obtained can be given to many refrigerators. The main problem is that solar energy, like other renewable energy sources, is not continuous. Since solar radiation values are high in the region, the solar energy obtained throughout the day can be stored in batteries and phase change materials in an insulated underground heat storage tank and refrigerators can be operated

Table 3
Mass flow rates and mass concentration values of the oil-heated and electric-heated refrigerators.

Electrical DAR System			Solar DAR System	
Point	Concentration (x)	Mass Flow (m, kg/s)	Concentration (x)	Mass Flow (m, kg/s)
1	0.300	0.000566	0.300	0.000608
2	0.271	0.000538	0.271	0.000578
3	0.838	2.77E-05	0.841	3.07E-05
4	0.660	1.26E-05	0.67	1.43E-05
5	0.995	1.51E-05	0.995	1.64E-05
6	0.999	1.51E-05	0.999	1.64E-05
7	0.950	1.51E-05	0.950	1.64E-05
8	0.950	1.51E-05	0.950	1,64E-05
10	0.950	0.000551	0.950	0.000592
11	0.300	1.51E-05	0.300	1.64E-05
12	0.270	0.000566	0.270	0.000608

Table 4
Analysis results of the electric-heated and oil-heated refrigerator energy and average temperature.

Electrical DAR System			Solar DAR System	
	Energy (W)	Average Temp.In-Out °C	Energy (W)	Average Temp.In-Out °C
Generator (Q_{Gen})	61.49	131–143	62.10	130–144
Rectifier (Q_{Rec})	21,12	110–69	28.10	110–70
Condenser (Q_{Con})	24.12	57–45	17.30	58–47
Evaporator (Q_{Eva})	24.66	(−)3.41–21.1	23.85	5.3–33.6
Absorber (Q_{Abs})	25.80	39.8–42.8	22.30	42.08–46.87
Exchanger (Q_{Exc})	22.95	49–101	20.60	51–103

continuously. Continuity in cooling can be ensured by providing electrical energy support when necessary. Since there is no sunlight at night, there is no constant direct solar radiation. For this reason, solar refrigerators cannot operate continuously with the parabolic collector alone. To ensure continuous operation of solar refrigerators, when the solar energy-based temperature required for the oil in the parabolic collector cannot be reached, the oil must be heated by other methods. To mitigate the adverse environmental impacts of the system, it is imperative to enhance the operational conditions of these devices. In cases where solar energy is not available at night, sustainability can be achieved by installing a battery group and PCM-supported DAR system.

5. Conclusion

As a result of the thermodynamic analysis, the power in the electric refrigerator generator was 61.86 W, and 62.36 W in the solar refrigerator. The COP of the electric refrigerator was 0.398, while the COP of the solar refrigerator was 0.38. The electric refrigerator evaporator temperature dropped to −10 °C and the refrigerator internal temperature to 17 °C. The evaporator temperature of the solar-powered refrigerator dropped to 1 °C and the internal temperature of the refrigerator to 19 °C. As a result, it was determined that the performance of the electrically heated refrigerator is better than the solar refrigerator. The reason for this is that the temperature of the solar energy is not constant. The reasons behind the lower results of solar refrigerators than electric refrigerators are the low and continuous lack of direct sunlight, the low efficiency of the parabolic collector and the high evaporation temperature of ammonia. In this study, DAR cooling system supported by phase change material and battery bank is proposed to solve the problem using a solar parabolic collector to ensure continuity in night and cloudy environments where solar energy is not available.

CRediT authorship contribution statement

Cuma Çetiner: Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Nomenclature

COP	The coefficient of performance
h	Enthalpy [J/kg]
$\dot{m}$	Mass flow rate [kg/sn]
P	Pressure [bar]
T	Temperature [°C]
x	Ammonia mass fraction in the solution
L	Long (m)

Subscript

1.2.3	System's point designation
Abs	Absorber
Con	Condenser
Cab	Cabinet
Eva	Evaporator
Gen	Generator
Rect	Rectifier
in	Inlet
out	Outlet

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