University of Thi-Qar Journal Vol.13 No.1 Mar 2018
Web Site: https://jutq.utq.edu.iq/index.php/main
Email: journal@jutq.utq.edu.iq

Double Slope Solar Still: Study, Design and Improve Productivity

https://doi.org/10.32792/utq/utj/vol13/1/11

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Abstract

Two identical of double slope solar stills with same specifications were designed to study and improve their productivity to produce fresh water (drinking water) from salty water especially in the regions where the fresh water is low or unavailable such as south of IRAQ.

One of the two solar stills was subjected to modifications in order to increase the productivity of drinking water and to compare with non-modified solar still. Covering the basin of solar still with black piece of cloth increase the productivity up to (22.35 percent). By adding charcoal powder on top of black piece of cloth the productivity was increased (34.21 percent). However, the productivity was increased to (16.69 percent) when two reflections mirror was used.

Also, thermal efficiency of solar still was calculated. The highest value of(34.13 percent) was achieved when modifications applied.

In this project, the chemical and physical properties of the water before and after distillation were analyzed. The double slope solar still produced fresh and drinkable water.

Keywords : Double slope solar still , black paint , Charcoal powder , black cloth , Design , Improve Productivity.

الملخص

في هذا البحث تم تصميم مقطرين شمسيين ذات الميل الثنائي وبنفس المواصفات والإبعاد لدراسة وتحسين إنتاجيتهما لغرض تحويل الماء المالح او قليل الملوحة الى ماء عذب وصالح للشرب وخصوصاً في المناطق الصحراوية وشبه الصحراوية , والمناطق الاخرى التي يقل فيها الماء العذب ومنها بعض المناطق في جنوب العراق (منطقة الدراسة) لقد اجريت تحسينات على احد المقطرين الشمسيين ذات الميل الثنائي لزيادة انتاجيته من الماء العذب , حيث ان اضافة قطعة قماش سوداء الى حوض المقطر الشمسي ازدادت انتاجيته بنسبة (22,35 %) كأعلى قيمة عن المقطر الاخر ذو القاعدة السوداء .

اما عند اضافة مسحوق الفحم بالإضافة الى استخدام قطعة القماش والطلاء الاسود ازدادت انتاجية هذا المقطر بنسبة (34.21 %) .

وعند استخدام مرآتين عاكستين ازدادت الانتاجية لتصل الى (16.64%) . وفي هذا الحث تم حساب الكفاءة الحرارية للمقطر الشمسي حيث كانت اعلى كفاءة حرارية وقيمتها (34.13 %) وذلك عند استخدام المرأتين العاكستين والتحسينات الاخرى .

وفي هذا البحث ايضاً تم دراسة الخواص الكيميائية والفيزيائية لعينة الماء المستخدمة وهي (قليلة الملوحة) قبل وبعد التقطير حيث تغيرت هذه الخواص كثيراً بعد التقطير وأصبح الماء عذباً وصالح للشرب .

Introduction

Since ancient, human is always seeking water. It is essential source for life, development and growth. Nowadays, the world is facing a problem of fresh water shortage due to climate change, desertification, and temperature rising. To solve the problem, technology is directed to generate fresh water from seawater for general usage (1). Many designs have been used to produce fresh water such as thermal and non-thermal. However, recently scientists focused on renewable energy to produce fresh water from seawater. Many studies around the world have been tried to improve water desalination technology using solar energy. Those studies linked between the productivity of solar still and its effective factors such as climate, design, location and others factors (2, 3).

Many of studies of improvement of water desalination system by solar energy which linked between the productivity of solar still and its effective factors such as climate, design, location and others factors have been published (2, 3, 4,5).

Many researchers have described various configuration of solar still (6-10), a hemispherical solar still (11-12), and double-basin solar still (13, 14).

Solar still could be classified to two main groups: passive and active solar still (15).

It found that the heat and mass transfer coefficients of tubular solar still linked to function of the temperature difference between saline water and the cover (16).

Recently, WHO documented urgent need for fresh water especially for third world. As more than 1.1 billion people around the world cannot access save drinking water (WHO 2000, 17).
The purpose of this study is to design and produce fresh water from salty and low salty water for dry region.

Methods

Two double slope solar still were designed from local materials. To improve properties of the design a sandwich of black paint, piece of cloth, and coal powder was used. The solar radiation was directed onto the double slop of the solar still using reflection mirrors. The evaporated water toward the double slope cover will condense into the graduated basin (plastic pipe) of solar still to measure the productivity.

Physical and chemical properties test was performed in order to evaluate the quality of produced distilled water before and after distillation. These tests were done within chemistry laboratory, college of science/ Thi Qar University. However, climate characteristics (solar radiation, temperature, and wind speed, ..etc) were obtained from Iraqi Meteorological.

Design

Specifications and dimensions of double slope solar still were aluminum base with 0.1 cm thickness, 50 cm length, 50 cm width, and 4 cm height. The aluminum base was placed within wooden box (51 cm L x 51 cm W x 8.1 cm H) Fig.(1).
The slope angle of the glass cover was 20°. This is to maximize the amount of solar radiation onto the glass cover to increase the productivity of solar still.
The specifications of top glass cover of solar still were 0.4 cm thickness, 51 cm length, and 31 cm width. This top class cover was carefully fixed with silicon adhesive to avoid any gap between inside and outside the solar still.

Experimental part

The experiments were performed during May and June of 2017 in the north of Thi Qar region, south of Iraq. This region has high level of solar radiation during this time of the year. The low salty water was put in basin of solar still for 2 cm height at early day ,and began working at 8 a.m. till 7 p. m , and record the result every day .

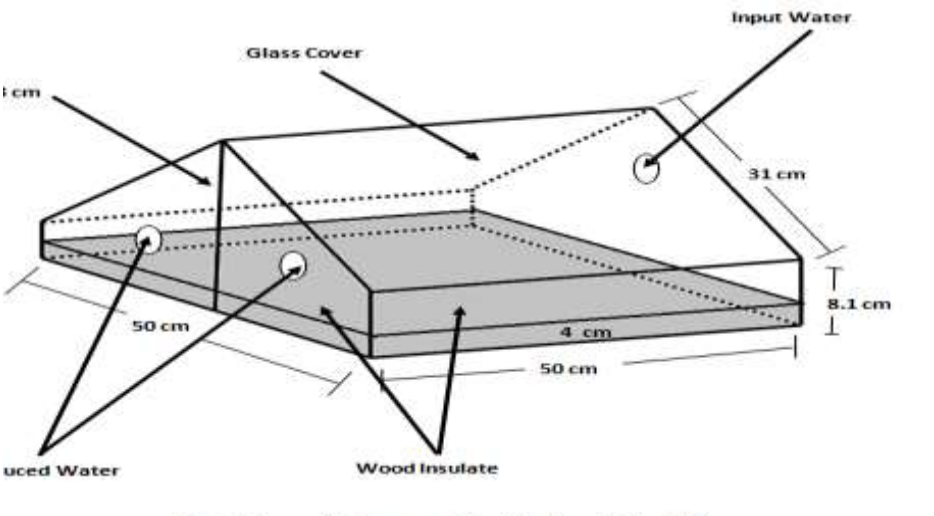


Fig 1: Schematic Diagram of Double Slope Solar Still

Results and Discussion

1. Productivity comparison between solar still with black-coated basin and solar still with black-coated basin and covered with black cloth.

The solar radiation is considered one of the most important climate factor that affect solar still productivity (Fig 2-a). For 7 days trial period from 10^{th} May to 16^{th} May 2017, the productivity of freshwater of the solar still with *black-coated basin and black cloth* increased in comparison to solar still with *black-coated basin* only. This is due to additive black cloth added on the *black-coated basin* which increased the absorption of solar radiation and raised the temperature of solar still. The consequence was the water evaporated and then condensed on the surface of the solar still before collecting into plastic pipe.

The highest productivity of fresh water was on day 12^{th} May (Fig 2-b). This is because of high temperature (43 °C) during the midday and the wind speed (5 M/s) which is reversibly proportion with the productivity

However, on day 14^{th} May and because of dusty weather, which is dispersed the solar radiation, reduction of productivity was clear.

Figure (2-c) indicates relationship between the productivity and temperature.

2. Productivity comparison between solar still with black-coated basin and solar still with black-coated basin covered with black cloth and charcoal powder.

It is clear that the productivity of modified solar still (*black-coated basin covered with black cloth and charcoal powder*) was higher than the productivity of solar still *with black-coated basin* (Fig 3-a). The modification of solar still by adding charcoal powder increased the absorption of solar radiation and the highest productivity was on day 19th May. This was in conjunction with the maximum high temperature (44 °C) and wind speed of 5M/s.

However, the lowest productivity for both solar stills was on day 21st May. This is due to cloudy and dusty weather, low maximum temperature (35.2 °C), and 10M/s wind speed.
Figure (3-b): Relationship between productivity of both solar stills and days (trial period).
Figure (3-c): relationships between the productivity and temperature.

3. *Productivity comparison between solar still with black-coated basin and solar still with black silicon-coated basin .*

Coating the basin of the solar still with 4 mm thickness of black silicon reduced the productivity compared to solar still with *black-coated basin* (Fig 4-a). This is because of thickness of silicon which plays as a thermal isolation layer.

Figure (4-c) illustration relationship between the productivity and temperature.

4. *Productivity comparison of solar stills during May and June.*

Productivity of solar stills was increased during the period 1st June to 9th June compared with 17th May to 25th May (Fig 5-a and 5-b). This is due to high solar radiation and others climate factors which was clear weather, no cloud and dust during June. Because of high temperature during June, the productivity of solar still was high on 9th of June.

5. ***The effect of reflection mirror on productivity of solar still with black-coated basin covered with black cloth and charcoal powder*.**

By using two reflection mirrors (0.40 m ×1.15m), the productivity of solar still was increased compared to the same solar still but without reflection mirrors (Fig 6-a).

The highest productivity was achieved on 14th June due to high solar radiation, high temperature (48 °C), and low wind speed (5 m/s).

6. ***Calculation of thermal efficiency for solar still.***

Thermal efficiency of solar still was calculated (18) and indicated in Table 1.

$$E = P \times L / I \times Ab$$

P = daily productivity (Liter).

L = potential heat for water evaporation (MJ/L).

I = daily intensity of solar radiation (MJ/M^2).

Ab = area of solar still basin for square meter.

Table 1: The highest values of thermal efficiency for solar still.

Solar still type	Productivity (Ml/M^2/day)	Solar Radiation (w/M^2)	Thermal Efficiency (%)
solar still with black-coate basin and covered with black cloth	**3500**	**9050**	**24.70**
***solar still with black-coated basin covered with black cloth and charcoal powder* (during May 2017)**	**3800**	**9050**	**26.82**
solar still with black silicon-coated basin	**1250**	**9500**	**8.40**
solar still with black-coated basin covered with black	**4200**	**4800**	**32.11**

cloth and charcoal powder **(during June 2017)**			
solar still with black-coated basin covered with black cloth and charcoal powder + **reflection mirrors**	**5500**	**10000**	**35.13**

7. *Chemical and physical properties for sample of the water before and after distillation*.

The chemical and physical properties of low salt water used for distillation was investigated (Table 2). The total dissolved solids (salts) (TDS) before distillation was 404 ppm and reduced to 35.3 ppm after distillation. Also after distillation, Electrical conductivity (EC) value of the water was reduced from 811µ.s/cm to 70.4 M.s/cm which is proportional with the TDS. However, turbidity and pH values were also measured and revealed reduction after distillation from 16.14 NTU to 3.33 NTU and 7.68 to 7.21 respectively.

In comparison with the standard properties of drinking water (Table 3) (19), the results indicated that the produced water was fresh water for drinking and other usage. The target of the project was to design a solar still and produced fresh water from salty or low salt water.

Table 2. chemical and physical properties of the water before and after distillation.

Properties / Sample	pH	T (°C)	Turbidity (NTU)	EC µs/cm	TDS (ppm)
After Distillation	**7.21**	**26***	**3.33**	**70.4**	**35.3**
Before Distillation	**7.68**	**21.7**	**16.14**	**811**	**404**

* Temperature was measured after a while.

Table 3. standard properties for drinking water.(19)

Property	Iraqi properties 1998	Iraqi properties 1974	WHO properties 2004
TDS (ppm)	1000	1000	1000
SO_4 (ppm)	250	400	200
pH	6.5-8.5	6.5-8.5	7.5-8.5

Conclusions

1. Modification of double slope solar still such as black cloth, charcoal powder, and reflection mirrors led to increase the productivity. The highest productivity was 5.5 L.
2. The highest heat efficiency was 35.13% in presence of reflection mirrors and others modifications.

3. The influence of climate factors was clear and effective on the productivity of the solar still. The Productivity was directly proportion with solar radiation and maximum temperature and reversibly with wind speed. The best direction for the solar still was south-west.
4. The productivity increased when the depth of the water on the solar still basin was low.
5. The chemical and physical properties of the used water completely changed after distillation. The water became fresh and drinkable. Left behind salt could be used for other purposes (table salt).

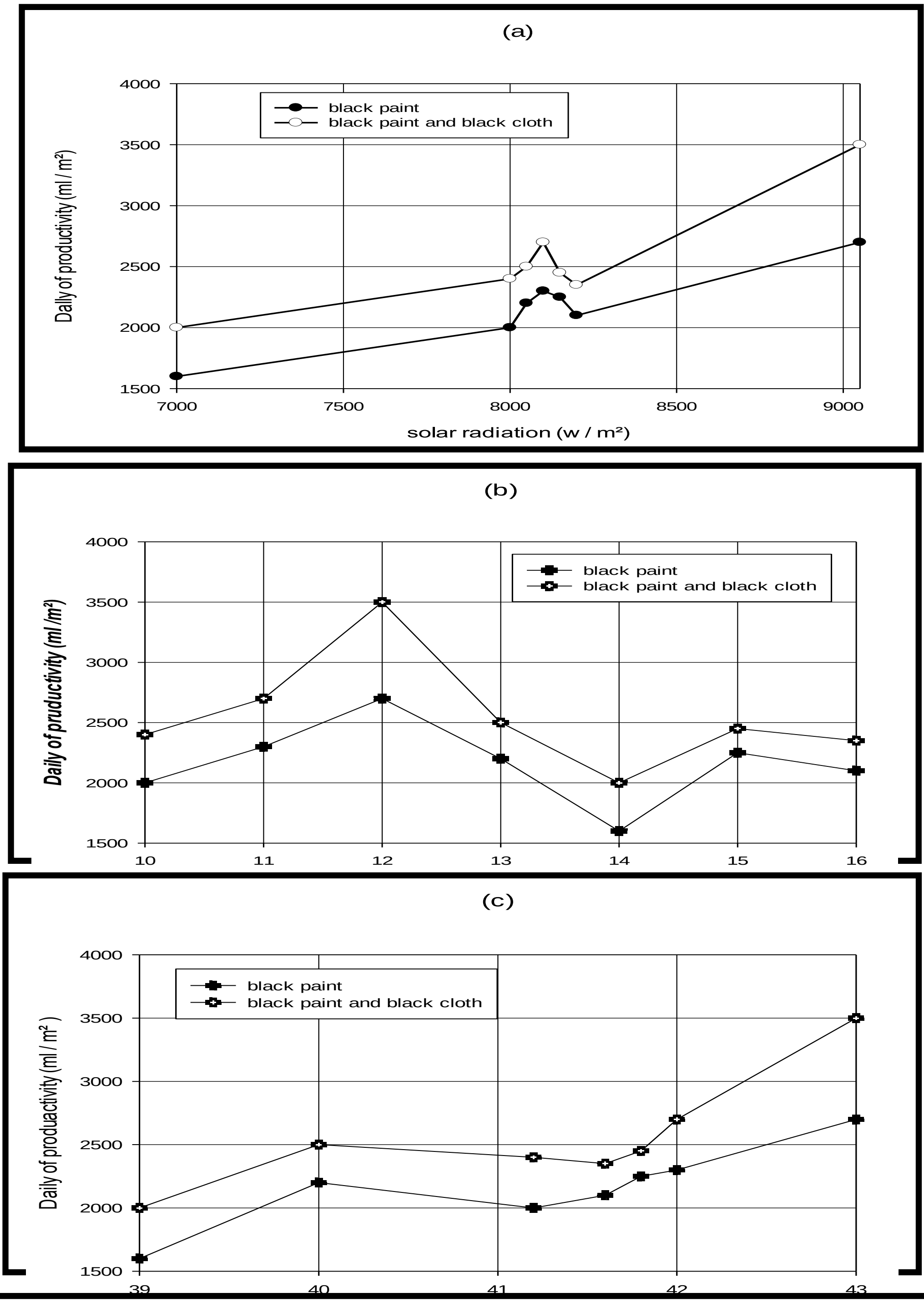
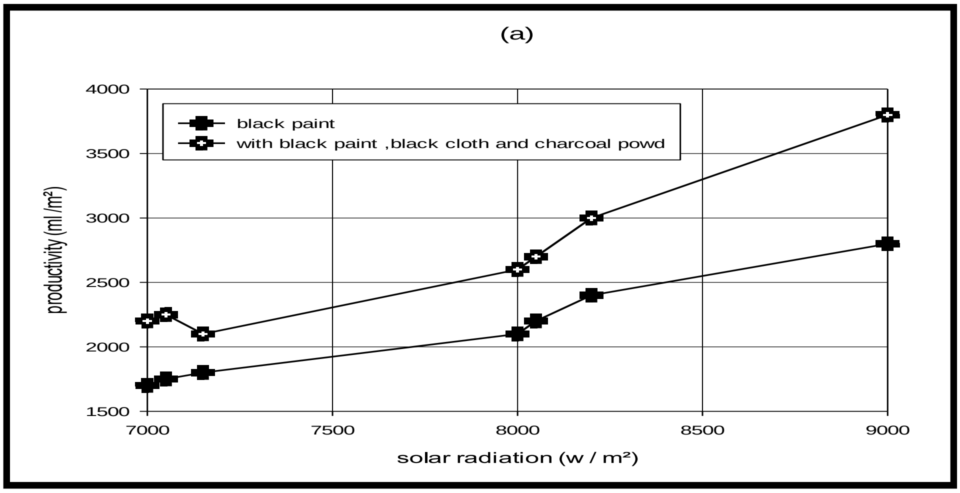
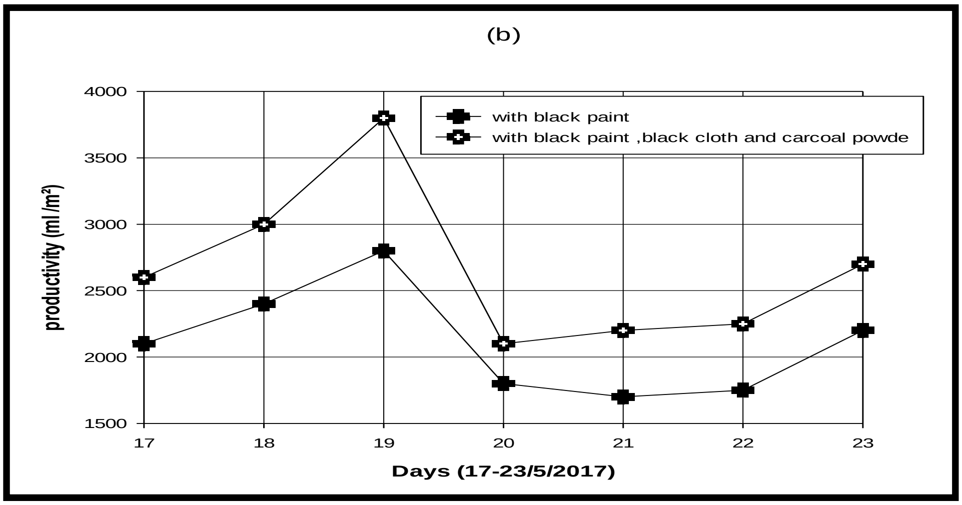


Fig.2: (a) Show relationship Between daily production of the two double slope solar still and solar radiation .
(b) The productivity with the days of the test . (c) the productivity with Temperature of the test days .


(a)
black paint
with black paint ,black cloth and charcoal powd
productivity (ml /m²)
4000
3500
3000
2500
2000
1500
7000
7500
8000
8500
9000
solar radiation (w / m²)


(b)
with black paint
with black paint ,black cloth and carcoal powde
productivity (ml /m²)
4000
3500
3000
2500
2000
1500
17
18
19
20
21
22
23
Days (17-23/5/2017)

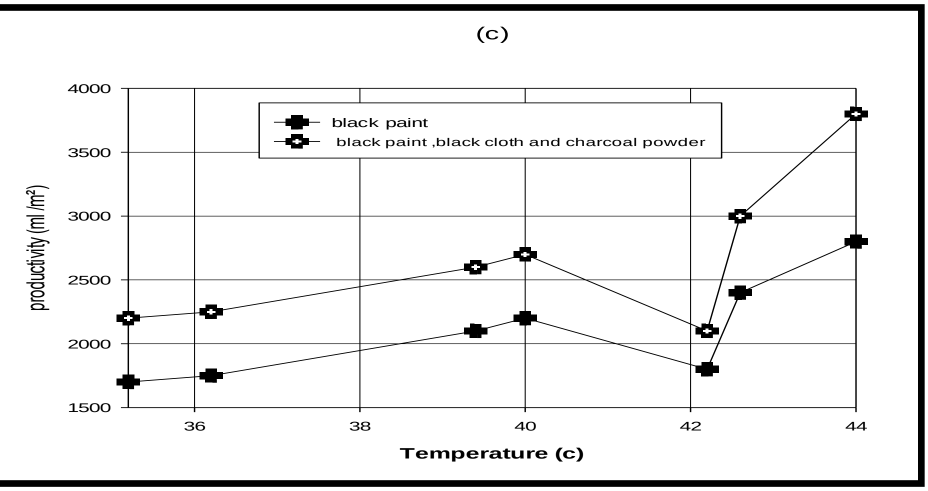
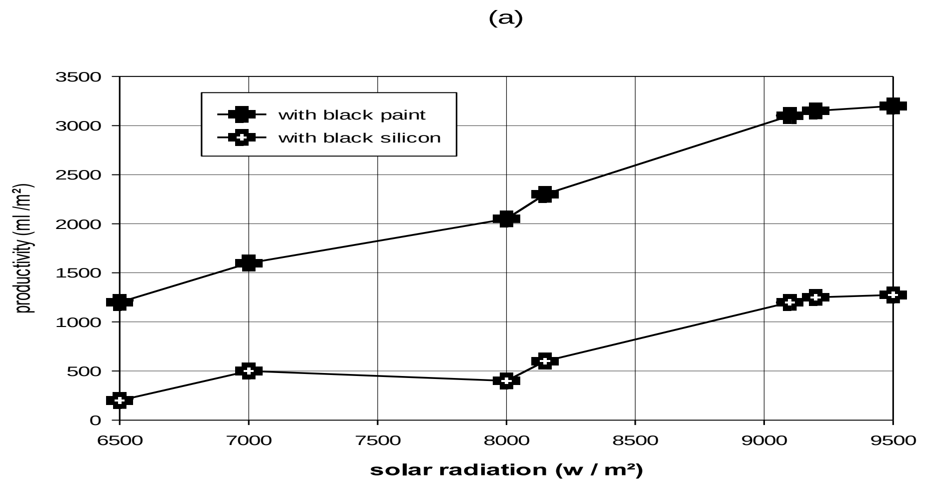
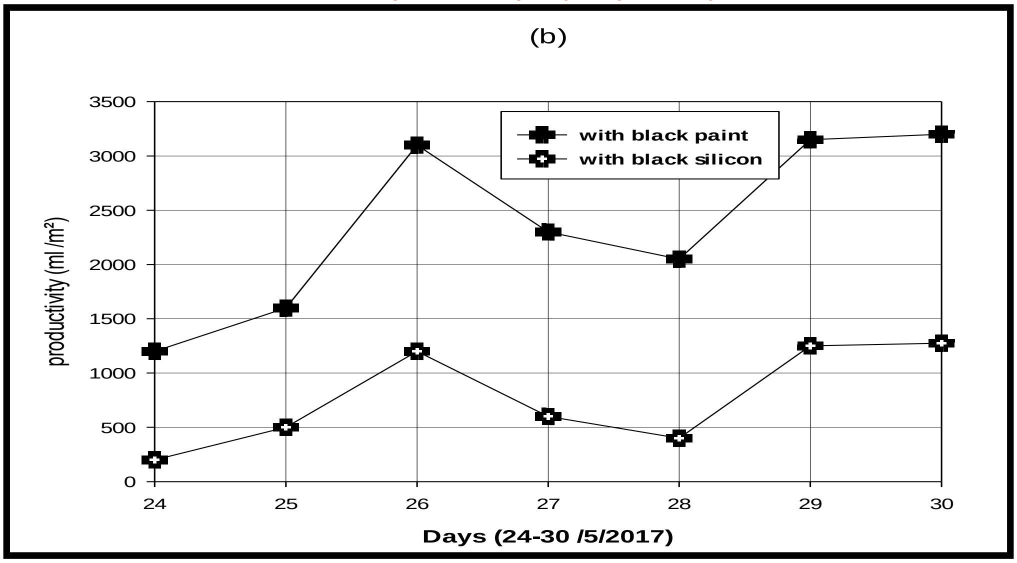


Fig 3: (a) daily production of the two double slope solar still and radiation During (17-23/5/2017).
(b) The productivity with the days of the test . (c) the productivity with Temperature of the test days .





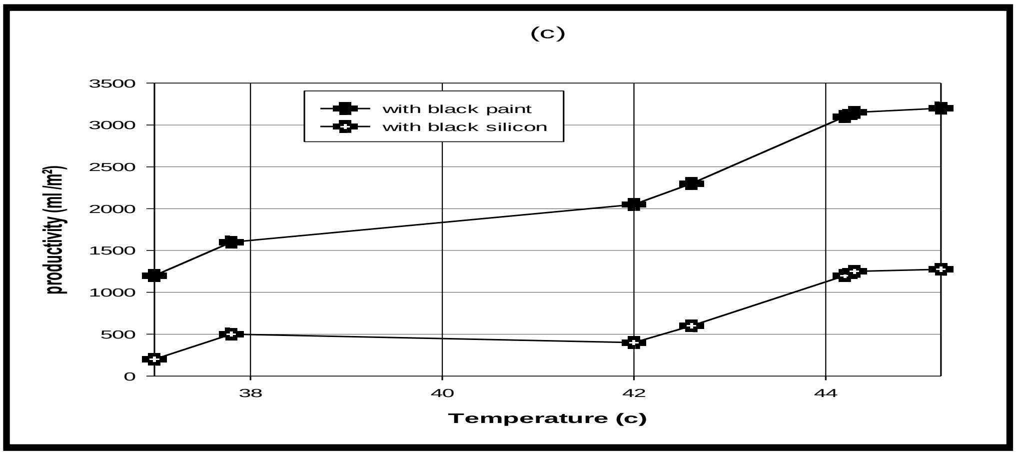
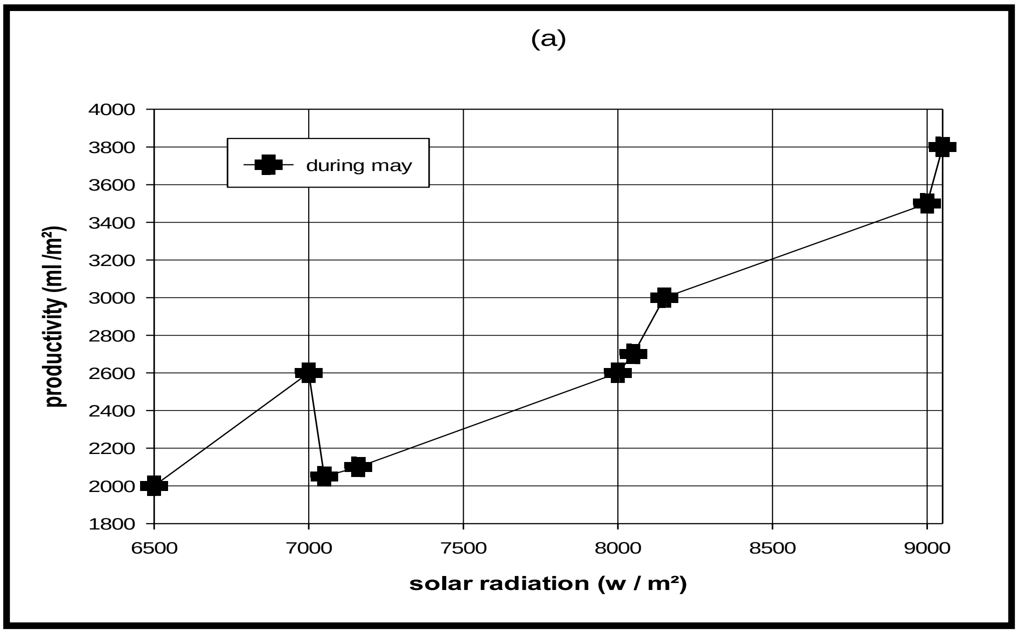


Fig 4: (a) daily production of the two double slope solar still and solar radiation During (24- 30 /5/2017). (b) The productivity with the days of the test . (c) the productivity with Temperature of the test days .



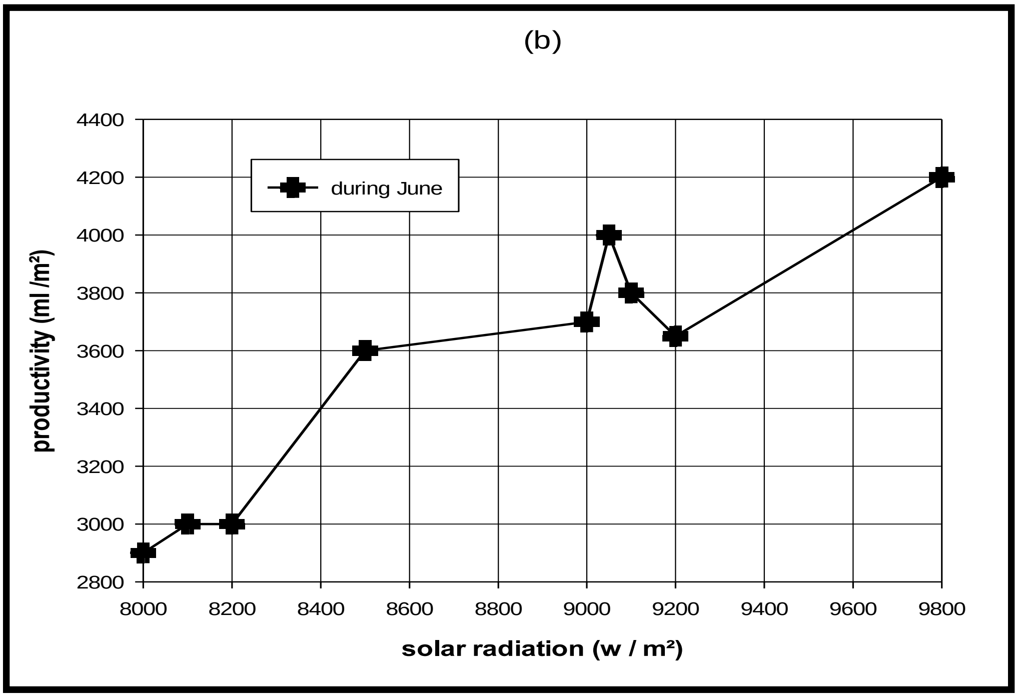


Fig 5: (a) daily production of the two double slope solar still and solar (During May, June 2017).
(b) The productivity with the days of the test .

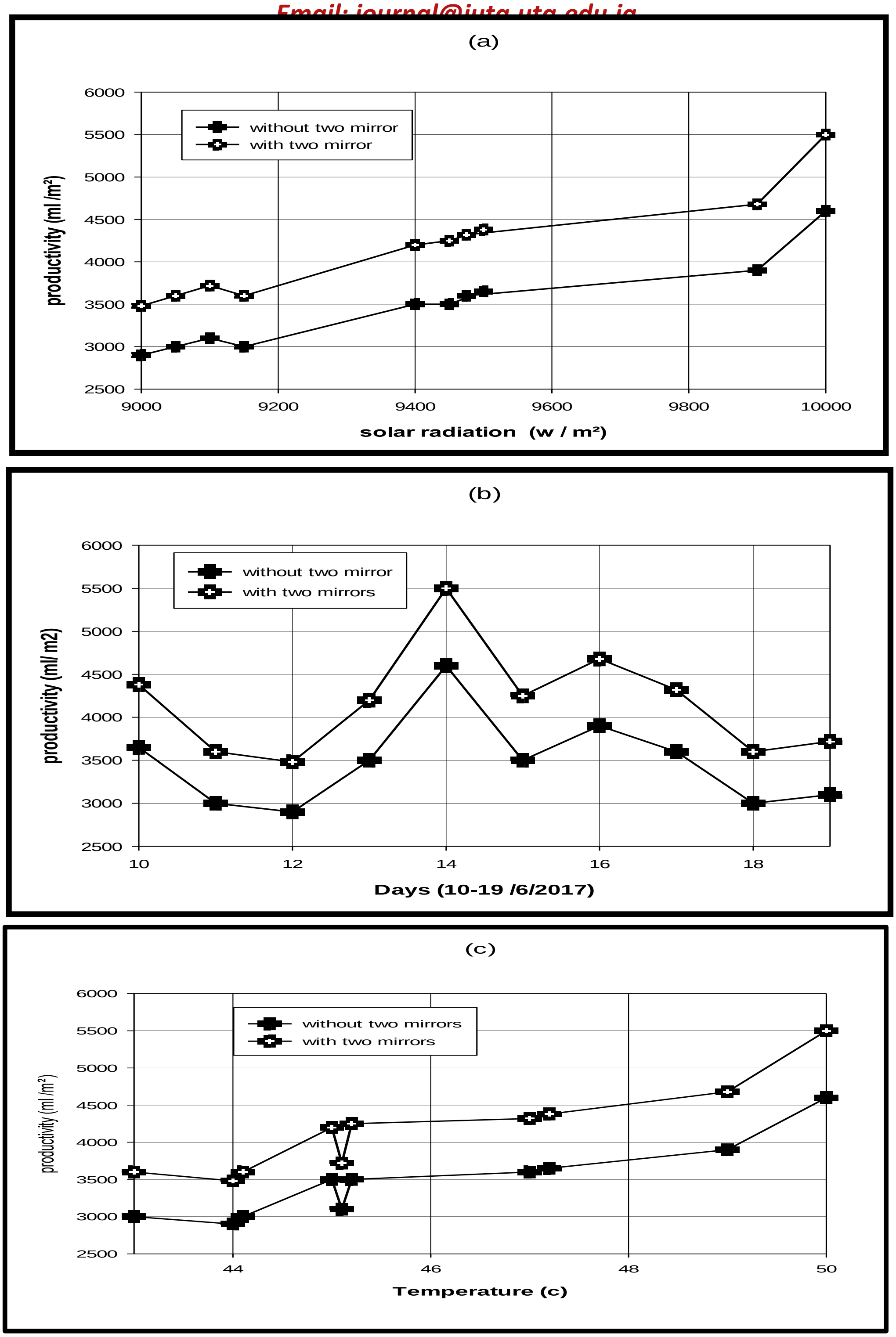


Fig 6: (a) daily production of the two double slope solar still and solar During (10- 19 /6/2017).
(b) The productivity with the days of the test . (c) the productivity with Temperature of the test days .

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