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Effect of air flow rate and plant type on the cost and efficiency of the performance of the indirect solar dryer

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Key words: Solar, Drying, Medicinal plants, Mint

Abstract

The solar dryer is designed and manufactured to dry some medical plants at the Research Center for Energy and Environment of the Ministry of Industry and Minerals. This experiment was included two factors, where three levels speeds for the fan and three kind of medical plants. Factorial experiment within CRD with three replications was used to study the effect of the dried substance type ,air flow rate and their overlap with studied parameters. The results indicated that the increased intensity of the fallen solar radiation resulted in a lower efficiency of the solar dryer from 17.95 % to 12.18 %. Increased air flow rates reduce the water mass from 0.21 kg to 0.185 kg during the day as a result of lower temperatures within the drying room and thus a decrease in the efficiency of the dryer. Increasing speed leads to lower temperatures, which in turn reduces the extraction of moisture from the plant and thus decreases the moisture mass of the vaporist. The binary overlap between substance type and air flow rate has had a moral effect on most of them efficiency drying room, rate of drying, efficacy of the medicinal plant and daily costs. The alcohol extract of ginger was more effective against the growth of *E. coli* bacteria than the rest of the extracts where the diameters ranged 20-25 mm. The alcohol extract of the pepper was effective against the growth of the *Staphy.aureus* bacteria better than the rest of the extracts where the diameters ranged (11-17) mm.

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Introduction

Solar energy is one of the renewable power sources that are not ending in human life. The solar energy can be supplied with the expected energy and, at the same time, it has a highly technical potential compared with the sources of other renewable energy (biomass, irrigation, hydroelectricity, thermal) etc. (Khudair *et al.,* 2011). Medicinal plants are the main source of many medicinal drugs used for various therapeutic purposes, particularly in the treatment of many diseases chronic being a source of effective materials for the preparation of a lot of pharmaceutical compounds in the form of abstracts or other forms. (AL-Rawi, Chkravarty, 1998). The drying of herbs and medicinal plants is one of the most important works in the preservation of useful materials in the plant, the prevention of corruption and its preparation for storage. The drying process is aimed at removing water from the plant, because a small fraction of the moisture in the plant may expose it to the storage of fermentation and decay, and spoil and lose its useful properties. And the drying process must take place in the shade without exposing it to sunlight, because the sun causes the plant to be corrupted and its glasses and color are lost. Brightly and little part of their effectiveness. A properly designed solar dryer can mitigate the defects associated with open sun drying (natural solar drying) and improve the quality of the dried product, which in turn causes high benefits to producers. Solar drying systems must be properly designed to meet special needs for specific crop drying and to give satisfactory performance in terms of energy needs (Sreekumar *et al.,* 2008). The aims of this study to evaluate the performance of the solar thermal collector, find the rate of drying, maintain the active material of the medicinal plant and calculate cost.

Materials and methods

Descriptions of solar dryer and work location

The solar drying plant was designed and manufactured and the experiment was carried out to dehydrate some medicinal plants in the Industrial Research and Development Authority- Renewable Energy Research Center of the Ministry of Industry and Minerals, Al-Jadriya, located 33.27 North latitude and 44.38 East longitude, 32 meters above sea level. Drying for the period from 15/2/2017 to 25/4/2017.

In the experiment, two operators were selected. Three propeller velocities (0.056 m3/s, 0.065 m3/s, 0.101 m3/s) were selected and represented by the main factor. Three types of medicinal plants are mint, pepper and ginger. The studied qualities are: - Daily theoretical efficiency of the solar collector (%), daily practical efficiency of solar collector (%), efficiency of drying room (%) and medicinal plant efficacy. The experiment was carried out according to Complete Randomized Design and three replicates. The Statistical Analysis System (SAS, 2012) used data analysis to study the effect of the type of dryer material and the airflow rate and their overlap in the studied characteristics according to the complete random design (CRD). The differences between the averages with less significant difference (LSD). indirect solar drying system consists of two separate units, the first one being the solar collector (Solar water heater) ,The second unit is the dryer (the dehydrating room), which consists of a box containing a set of shelves on which the material is to be dry Delivering hot air to fan drying room. The objective of this study is to design an indirect solar dryer as the samples are drying by air passing through a radiator containing hot water received from a evacuated tube solar collector with a vacuum tube type of air. The materials used to build indirect solar dryer are inexpensive and easily accessible in the domestic market. Figure 1 shows the main components of the dryer. It consists of the solar collector (water heater) and the drying room containing three drying depots.

Mathematical models used in the experiment

The efficiency of the drying room

It is the ratio between the energy required to evaporate the moisture and the energy entering the drying chamber and is calculated from the following mathematical relationship (Senadeera *et al.,* 2004).

$$\eta_d = \frac{m_w h_{fg}}{I_c A_c}$$

Mw: Vaporized water mass of food (kg).

$h_{fg=2260}$

I_c: Solar radiation

Rate of drying

Is the ratio between the mass of the fumigating water from the material to be dried to the total time of drying and calculated from the following equation (El-Amin *et al.,* 2006).

$$M_{dr} = \frac{m_w}{T_d}$$

Cost accounting (ID/kg) (Atia, 2016)

$$T_C = \frac{\left(\frac{c}{L \times 12} + \frac{r \times c}{12} + OS\right)}{q_m}$$

C: System Price

r: Annual rate of repairs and maintenance (estimated at 3.5 of the initial price (c)

L: Average life of the device per year (estimated about 15 years)

OS : Worker's wages

q_m : Product Quantity

Solar collector Area (Khalil *et al.,* 2007).

$$Ac = \frac{\mathbf{mw}\, h_{fg}}{\mathbf{IT}(\tau\acute{\alpha})tAc\eta c}$$

QL Is the sum of the losses caused by convection and radiation heat transfer and can be written in another form as received from (Fudholi *et al.,* 2015).

QL= UL Ac (Tc-Ta)

Tc: Surface temperature of the absorbent part (K).

Ta: Ambient temperature (K).

The total energy needed to dry out a certain amount of nutrients can be estimated using the basic energy balance formula for evaporation of water **(**Bolaji, B.O**.,**2005) and **(**Youcef-Ali *et al.,* 2001).

mw Lv = ma Cp (T1 – T2)

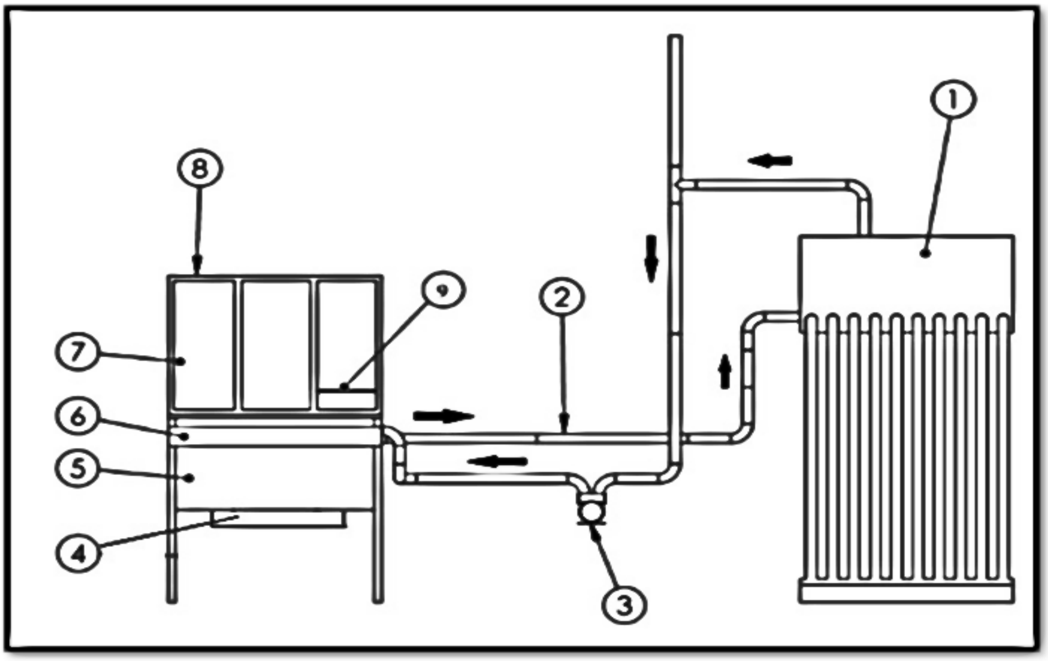

Fig. 1. An occasional section in a solar power dryer of the indirect type.

1= Tubular sun heater\no. of tubes 10\length of tube 180 cm\tube diameter 6.3.

2= Connecting Tubes.

3= Rotating pump.

4= Fan.

5= Tube to guide the air towards the radiator.

6= Radiator.

7= Dehydrating Room.

8= Sandwich Panel (5 cm).

9= Metallic buckle.

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mw Lv = ma Cp (T1 – T2)

Results and Discussion

Efficiency of the drying room (%)

Table 1 shows the effect of the type of material and the rate of air flow and the interplay between them in the efficiency of the solar dryer. It was noticed that there was a significant effect of the type of substance between pepper and ginger, where the efficiency decreased from 17.95 to 12.18 by a decrease of 32.14% and increased by mint to 16.17 by increase of 24.67%. The decrease in efficiency is due to the increase in the intensity of the solar radiation falling on the absorbent board. These results are consistent with that of (Joshi *et al.,* 2005) and (Usub *et al.,* 2007). The mean overlap between the material type and the air flow rate was significant, with the highest efficiency of the dryer and its percentage (26.9%), resulting from the overlap of type (pepper) and velocity (0.056). Pepper) and speed (0.101) and the amount (7%).

Table 1. Effect of material type and air flow rate in drying efficiency.

Type of dehydrated substance	Air flow rate (m3/s)			Average
	First velocity (0.056)	Second velocity (0.065)	Third velocity (0.101)	
Pepper	26.97	19.88	7.00	17.95
Ginger	16.80	11.53	8.21	12.18
Mint	19.35	16.30	12.85	16.17
The average	21.04	15.91	9.36	---

LCD Values: to substance type: 1.273 *, to Air flow rate: 1.273*, to the overlap: 2.546*

Medical plant efficiency

Table 2 shows the effect of the alcohol extract of ginger, peppers and mint on the diameter of the inhibition area of the *E. coli* bacteria. It was found that the alcohol extract of the ginger is more effective against the bacterial growth than the rest of the extracts. The diameters ranged from 20-25 mm. Increases the production of dermicidin in sweat, a substance that protects the adhesion and growth of *E. coli*. As for peppers, the diameters ranged 12-17 mm and the least affected mint on *Staphy aureus* bacteria where the diameters ranged between 12-14 mm. This may be due to the plant extracts themselves, which may contain compounds that inhibit or inhibit the growth of some microorganisms, but some of them may lose their inhibitory ability during extraction or storage methods. In addition, this activity is already reduced in some plant extracts or during certain reactions. And its concentration is an important and influential factor in the inhibitory action of each extract.

Table 2. Effect of alcohol extracts of ginger, peppers and mint on the diameter of the inhibition area (mm) of *E. coli* bacteria.

Third velocity (0.101)	Second velocity (0.065)	First velocity (0.056)	Type of dehydrated substance
22	25	20	Ginger
17	13	12	Pepper
14	13	12	Mint

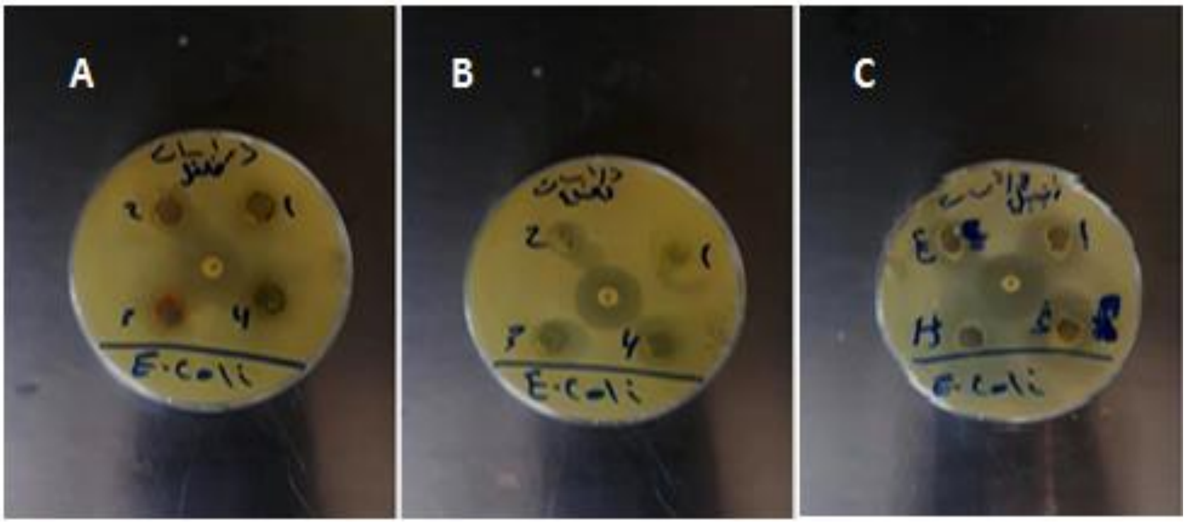

Fig. 2. A: Effect of the alcohol extract of the pepper on the *E. coli* bacteria., B: Effect of the alcohol extract of the mint on the *E. coli* bacteria, C: Effect of the alcohol extracts of the ginger on the *E. coli* bacteria.

Table 3 shows the effect of the type of material and the rate of air flow and their interaction on *E. coli* bacteria (inhibition diameters). There was a significant effect of the material type on the diameters of the bacteria inhibition of the intestinal. This is due to the difference in the active substances found in these plants as well as the difference in their concentrations.

The double interference between the material type and the air flow rate has a significant effect. The highest diameter of the inhibition of 25 mm, (Ginger) and speed (0.065). The lowest diameter of the inhibition was obtained from the double interference between the peppers, peppermint and speed (0.056) and the amount of (12) mm. There was no significant effect of the air flow rate on diameters.

Table 3. Effect of material type and air flow rate on E. coli bacteria.

Type of dehydrated substance	Air flow rate (m3/s) First velocity(0.056)	Second velocity (0.065)	Third velocity (0.101)	Average
Pepper	12	13	17	14.00
Ginger	20	25	22	22.33
Mint	12	13	14	13.00
The average	14.67	17.00	17.67	---

LCD Values: to substance type: 3.079 *, to Air flow rate: 3.079*, to the overlap: 6.183*

Table 4. Effect of alcohol extracts of ginger, peppers and mint on the diameter of the inhibition area (mm) of the *Staphy aureus* bacteria.

Third velocity (0.101)	Second velocity (0.065)	First velocity (0.056)	Type of dehydrated substance
11	11	11	Ginger
11	17	15	Pepper
10	10	10	Mint

Table 4 shows the effect of the alcohol extract of ginger, peppers and mint on the diameter of the inhibition area of the *Staphy aureus* bacteria. It was found that the extract of the peppers is more effective than the rest of the extracts. The diameters ranged from 11-17 mm to contain the capsaicin which affects the bacteria. The peppers had diameters of 11 mm and mints 10 mm.

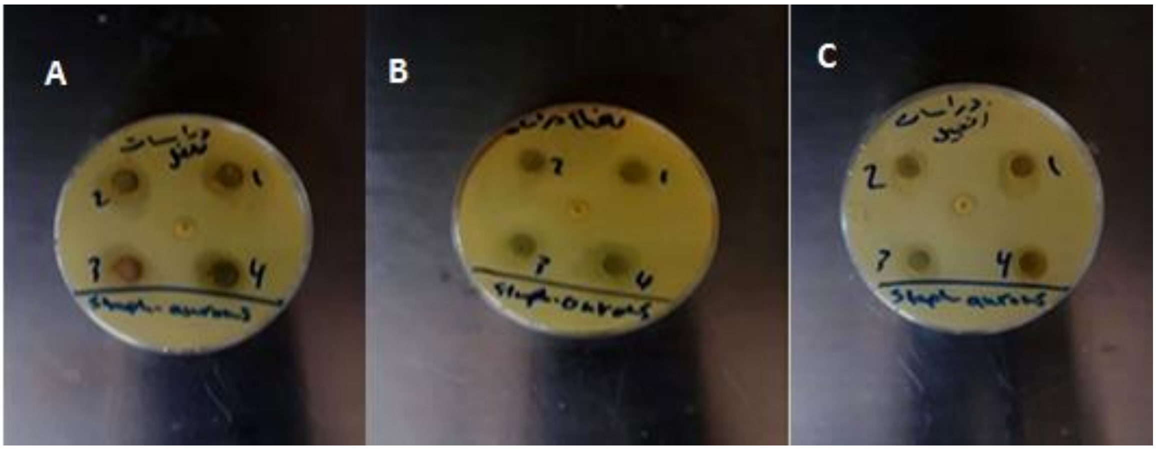

Fig. 3. A. Effect of the alcohol extract of the pepper on the *Staphy aureus* bacteria, B: The effect of the alcohol extract of the mint on the *Staphy aureus* bacteria, C: The effect of the alcohol extract of the ginger on *Staphy aureus* bacteria.

Table 5 shows the effect of the type of material and the rate of air flow and their interaction on the *Staphy.aureus* bacteria (diameters). There was a significant effect of the type of material on the diameters of the bacteria inhibition of the bacteria. This effect is due to the difference in the active substances in these plants as well as the difference in concentrations.

The binary interference between the material type and the airflow rate has a significant effect, with the highest diameter of 17 mm, (Pepper) and speed (.0650). The lowest diameter of the inhibition was obtained from the double interference between the type (mint) and the first, second, and third velocity (10). There was no significant effect of the air flow rate on the diameters.

Table 5. Effect of material type and air flow rate on *Staphy aureus* bacteria.

Type of dehydrated substance	Air flow rate(m3/s) First velocity (0.056)	Second velocity (0.065)	Third velocity (0.101)	Average
Pepper	15	17	11	14.33
Ginger	11	11	11	11.00
Mint	10	10	10	10.00
The average	12.00	12.67	10.67	---

LCD Values: to substance type: : 2.263 *, to Air flow rate: 2.263 *, to the overlap:4.294*

Table 6 shows the effect of the substance type and the air flow rate and the overlap in the rate of solar drying. It was noted that there was no moral effect on the type of substance and the rate of air flow in the drying rate. The bilateral overlap between the substance type and the air flow rate had a moral effect, with the highest drying rate and its amount (% 10). Resulting from the interference of type (pepper) and speed (.0560), the lowest rate of drying has been obtained by the binary overlap between the type of substance (pepper) and velocity (0.101) and its amount (% 2.53).

Table 6. The effect of plant type and air flow rate in the rate of drying (%)

Type of dehydrated substance	Air flow rate (m3/s) First velocity (0.056)	Second velocity (0.065)	Third velocity (0.101)	Average
Pepper	10.04	7.51	2.53	6.70
Ginger	4.96	3.43	8.22	5.54
Mint	5.31	4.90	3.98	4.73
The average	6.77	5.28	4.91	---

LCD Values: to substance type: 2.822, to Air flow rate: 2.822, to the overlap: 4.8884*

Vaporizes moisture mass (kg water)

Table 7 shows the effect of air flow rates in the mass of moisture and three samples of pepper, ginger and mint respectively. We note that temperatures were somewhat high at the initial velocity, resulting in an increase in the vaporated moisture mass of the substance, which is consistent with the results obtained (Dilip, 2007) and (Akpinar, 2010)

As the air speed increases, we note that the average moisture mass dropped from 0.21 kg to (0.185 kg) by a decrease of 11.9%. For Pepper and from (0.122 kg) to 0.084 kg (31.1%) For Ginger, and from 0.13 kg to 0.12 kg, with a decrease of 7.6%.

For mint material, because increasing speed leads to lower temperatures, which in turn reduces the moisture extraction of the plant, and these results are consistent with what it got (Bukola *et al.,* 2008) and (Morad *et al.,* 2017).

*Daily costs (*ID /day)*

Table 8 shows the effect of the substance type and the air flow rate and the overlap between them on the daily costs. It was observed that there was a moral effect of the type of substance on the daily costs. The binary interference between the type of material and the air flow rate had a moral effect, with the highest and largest costs 3876 ID /day.

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Table 7. The effect of the plant type and the air flow rate in the vaporizes moisture mass (kg water).

Vaporizes moisture mass (kg water)	Air flow rate (m3/s)	Type of dehydrated substance
0.21	0.056	Pepper
0.185	0.065	
0.047	0.101	
0.122	0.056	Ginger
0.084	0.065	
0.075	0.101	
0.13	0.056	Mint
0.12	0.065	
0.098	0.101	

Resulting from the overlap of the type (ginger) and velocity (0.101), the less costs have been obtained from the interference the binary between the type of substance (ginger) and (mint) and velocity (0.065) and its amount 3120 ID /day. There was no moral impact of the air flow rate on daily costs.

Table 8. Effect of material type and air flow rate on daily labour costs (*ID /day)

Type of dehydrated substance	Air flow rate (m3/s)			Average
	First velocity (0.056)	Second velocity (0.065)	Third velocity (0.101)	
Pepper	3488	3337	3416	3413.67
Ginger	3351	3120	3202	3224.33
Mint	3475	3708	3876	3686.33
The average	3438.00	3388.33	3498.00	---

LCD Values: to substance type: 162.09 *, to Air flow rate: 162.09 *, to the overlap:317.44

*ID = Iraq dinar

Conclusion

The results indicated that the increased intensity of the fallen solar radiation resulted in a lower efficiency of the solar dryer. Increased air flow rates reduce the water mass during the day as a result of lower temperatures within the drying room and thus a decrease in the efficiency of the dryer. Increasing speed leads to lower temperatures, which in turn reduces the extraction of moisture from the plant and thus decreases the moisture mass of the vaporist.

The binary overlap between substance type and air flow rate has had a moral effect on most of them efficiency of the drying room, the rate of drying, the efficacy of the medicinal plant and the daily costs. The alcohol extract of ginger was more effective against the growth of *E. coli* bacteria than the rest of the extracts where the diameters ranged 20-25 mm. The alcohol extract of the pepper was effective against the growth of the *Staphy.aureus* bacteria better than the rest of the extracts where the diameters ranged (11-17) mm.

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