

## **UTILIZATION OF SOLAR ENERGY FOR DRYING SUNFLOWER SEEDS**

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### **ABSTRACT**

A study was carried out to test and evaluate the possibility of using greenhouse type solar dryer for drying sunflower seeds and the effects of the drying process on seeds quality and fungal load count. The experimental treatments included three different levels of air velocity (0.5, 1.0, and 1.5 m/sec), and three different types of solar collector absorber plate (perforated aluminum sheet, perforated iron sheet, and plastic wire net). The changes in seeds moisture content was monitored versus time until reaching the moisture content of about (9% w.b.). Solar radiation flux incident, bulk temperature of seeds, air temperature and relative humidity inside and outside the solar drier, drying efficiency of the dryer, fungal load and the final quality of seeds in terms of oil stability were measured and determined. The results showed that, the hourly average available solar radiations ranged from 476.6 to 586.6 W/m<sup>2</sup> during the experimental work. Also, the solar collector of the dryer could increase the air temperature by about 11.8, 14.8 and 19.1<sup>o</sup>C and decreased the air relative humidity by about 25.2, 28 and 30.6% based on the type of solar collector absorber plate. The reduction in moisture content of sunflower seeds was varied and increased with the increase of drying air temperature and velocity inside the solar drier. The greenhouse type solar dryer having perforated aluminum absorber plate operated at air velocity of 1.5 m/sec achieved the minimum drying time of 9 hr in comparison with 10 and 25 hr for the perforated iron sheet and the plastic wire net, respectively. The corresponding drying time for the traditional drying method was about 58 hours. Meanwhile, the percentage of free fatty acids of the extracted oil ranged from 1.74 to 3.97% which means no rancidity of seeds. The drying efficiency of the solar dryers increased with the increase of drying air temperature and air velocity and it was ranged from 28.18 to 40.61%.

### **INTRODUCTION**

Sunflower is one of the main crops for oil production, followed by soy, cotton and rape seeds (Acko, 2008). Sunflower seed is not used only for the industrial production of table oil or bio diesel, but also for the production of cold pressed table oil, husked seeds, roasted or fresh, that could be used whole or grounded for different foods (Jereb, 2004).

Drying is one of the common techniques for preservation of food and other products. The major advantage of drying process is the reduction of moisture content to a safe level that allows to extend the storage of dried products. The removal of water from foods provides microbiological stability and reduces deteriorative chemical reactions. Also, the process allows a substantial reduction in terms of mass, volume, packaging requirement, storage and transportation costs with more convenience (Okos et al., 1992).

In Egypt, natural sun drying is one of the most common ways to conserve agricultural products. Considerable losses may occur during natural

sun drying due to various influences, such as rodents, birds, insects, rain, storms and microorganisms. The quality of the dried products may also be lowered significantly (Lutz et al., 1987). Artificial drying can be done faster and in a controlled fashion. In addition, a better-quality product is obtained (Abd El-Moteleb et al., 2009).

Dryers can be classified on the basis of methods of supplying heat, type of drying equipment, method of transporting the product, nature state of feed, condition of the operation, and residence time (Fellows, 1990).

In recent years, the unpredictable availability of fossil fuels has caused researcher's to stress on more effective use of energy or using the renewable sources of energy. In this respect, Egypt is one of the countries, which have solar energy in abundance. It lies within the tropical and sub tropical regions. It has a value of about 5 to 8 kWh of solar energy per square meter per day and that sun-shine duration per year extends to about 4000 hours (El-Awady et al., 1993).

Solar dryers seems to be a promising way since the available amount of solar energy is sufficient to provide the heat requirements for small dryers. The solar drying system for crops drying depends on a temperature rise of only a few degrees in order to dry the crops in an extended period of time. Most of the solar drying systems depend on a forced or a natural convection air for reducing the moisture content of the product (Tayel and Wahby 1989).

Studying the possibility of utilizing solar energy for heating air inside a greenhouse and the use of that heated air in drying some agricultural crops under Egyptian conditions has been investigated by many researchers (Kamel 1991, Abdellatif and Helmy, 1992, Abd- Ellatif et al., 2010).

The use of solar dryers significantly reduces drying time and prevents mass losses; it collects the sun's rays and elevates the temperature to about 11 to 17° C higher than the unaided sun. Furthermore, product quality can be improved compared with traditional sun drying methods (Lutz and Muhlabauer, 1986).

Othieno (1986) reported that, the drying rate of any product depends on the air relative humidity used for drying; a good solar dryer must significantly reduce the air relative humidity and at the same time produce a high air flow. Natural convection solar dryers can significantly reduce the relative humidity of air through heating, but many of them cannot achieve high airflow.

Gebreil (2008) reported that, an improved technology in utilizing solar energy for drying of grains is the use of solar dryers where the air is heated in a solar collector and then passed through grain bed. The greenhouse type which is facilitated with metal frame covered with plastic film, wire netting for the floor, fans and duct for air suction to give a required airflow rate was investigated under Egyptian conditions and it was considered a more economic method for artificial drying of agriculture crops.

Leon et al. (2002) noted that an increase in air-flow in a collector increased the efficiency of the conversion of solar energy into more usable forms of energy at the expense of a drop in air temperature.

The present study aims to test and evaluate the possibility of using greenhouse type solar dryers for drying sunflower seeds and to test its effect on seeds quality, oil stability, and fungal load.

## **MATERIALS AND METHODS**

The present work was carried out at the Agricultural Engineering Department, Fac. of Agriculture, Mansoura Univ., during the sunflower harvesting season of 2010.

### **Testing Crop**

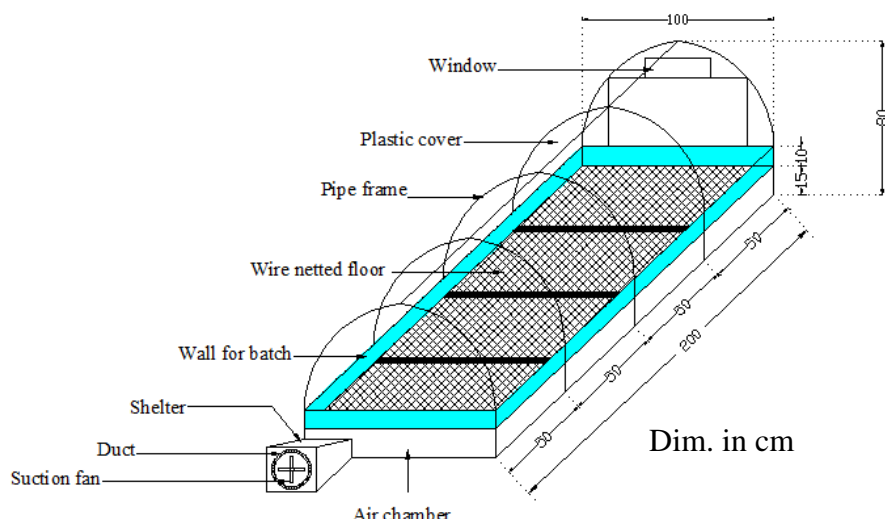
Sun flower seeds of variety (Sakha-35) were harvested and transported to the experimental laboratory of the Agriculture Engineering Department, Fac. of Agric., Mansoura University. The harvesting and threshing process of sunflower heads was done manually at initial moisture content of 30% (w.b).

### **The Greenhouse Type Solar Dryer:**

Fig. (1) shows the structure feature and a general view of the greenhouse type solar dryer used during the experimental work. Three identical dryers were built at the workshop of Rice Mechanization Center, Agric. Eng. Res. Institute, Kafr El-Sheikh Governorate. They installed on the roof of Agric. Eng. Dept, Faculty of Agric., Mansoura University. The dimensions of the vinyl house (solar dryer) are 100 cm wide, 200 cm long and 80 cm high. The dimensions of the drying chamber are 100 cm wide, 200 cm long and 9 cm high. The dryer constructed of iron pipes frame installed on the circumference of four walls forming a batch and the pipe frame was covered by a clear plastic film. Wire netting constitutes a floor at the bottom of the batch and a plenum chamber is constructed under the wire netted floor. An axial type suction fan and a duct for air suction were fixed at one side of the dryer and a window for air inlet (30 x 6 cm) was opened at the other side. A front door (70 x 45 cm) was located at the front side of the dryer for loading, unloading and collecting samples of sunflower seeds. Whenever the fan is rotated, the window must be opened suspending with strings. To protect the direct exposure of the sunflower seeds to sunrays and to increase the collection efficiency of solar radiation, a black plastic wire net, a black perforated iron sheet and a black perforated aluminum sheet were used separately as a solar absorber for covering the surface of the drying chamber.

### **The Traditional Drying Method:**

The traditional drying method used in this study was similar to the method used by farmers to dry sunflower seeds in the field. The freshly harvested sunflower seeds were spread on the floor inside an open wooden frame of 1 m<sup>2</sup> surface area and turned several times until it reaches the desired moisture content. During the night time the wooden frame was covered by a plastic sheet to prevent moisture reabsorption.



**Fig. (1): Schematic diagram of the experimental scale greenhouse type solar dryer.**

**Experimental Treatments:**

The experimental treatments of the drying process included two different drying methods (forced convection solar drying and traditional sun drying), three different types of black painted solar collector absorber plates (perforated aluminum sheet, perforated iron sheet, and plastic wire net sheet) and three different air velocities (0.5, 1.0 and 1.5 m/s).

**Test Procedure and Measurements:**

Three identical forced convection solar dryers were used during the experimental work. Before each experimental run, the initial moisture content of sunflower seeds was determined and a sample of 78 kg seeds was divided into three equal sub-samples. The three dryers were operated for 30 minutes before seeds loading. After making sure that the dryers working at stable condition, the dryer's beds were loaded with seeds samples at capacity of 26 kg/batch and distributed uniformly in thin layer of 3 cm over the surface of the perforated wire net of each drying chamber. The required air velocity for each experimental run was adjusted using a hot-wire anemometer model (ATESCO 40S-V1). The three types of absorber plates (plastic wire net, perforated iron sheet and perforated aluminum sheet) were installed at the top surface of the drying chamber of each dryer. Thermocouples were fixed at different locations of the dryer to measure the temperature of (inlet air, inside air, outlet air, and seeds bulk). The air relative humidity was measured at adjacent points of temperature measurements. The sunflower seeds moisture content was determined every 20 min. during the early stage of experiments and then determined each one hour. The drying process was kept running until the moisture content almost ceased to approach the final moisture content of seeds around (8 to 9% w.b). At the end of each experiment, sub samples were collected for oil analysis and fungal count.

**Experimental measurements and measuring instruments:**

**Moisture content of sunflower seeds:**

ASAE standard (2003) for sunflower seeds moisture measurement was used for determining the seeds moisture content during each drying run. Ten grams of sunflower seeds were placed at 130°C for 3 h, and then it was kept in a desiccator at room temperature. The dried samples were weighed again using an electronic digital balance and the moisture content of sunflower seeds was calculated on wet basis.

**Solar energy flux incident:**

A solar radiation sensor, Model (H-201) was used for measuring solar radiation flux incident on a horizontal surface. It was connecting to a chart recorder Model (YEW 3057) to convert the voltage signal to an equivalent reading in W/m<sup>2</sup>. The desk solarimeter was calibrated with standard pyranometer under clear sky conditions. The solar radiation was measured and recorded during the period started from 8 a.m to 6 p.m.

**Air temperature and relative humidity:**

The universal digital measuring system (Model Kaye Dig. 14) connected to 32 channels scanning box with thermocouple sensors (type k) distributed at different points inside and outside the solar dryers in order to measure the air temperatures. The relative humidity meter (Model Extech) was used to measure the air relative humidity at adjacent points of air temperature measuring points.

**Seeds bulk temperatures:**

thermocouples of the universal digital measuring system (Model Kaye Dig. 14) were also used to measure the bulk temperature of sunflower seeds at one hour intervals. The thermocouples used were type (K) with accuracy of ± 0.1°C.

**Air velocity:**

A hot type anemometer (Model ATESCO 40S-V1) was used to measure the air velocity at the surface of each drying bed in m/sec.

**The overall thermal efficiency of the solar dryer:**

The thermal efficiency of the solar dryers was determined using the following relationship (ASHREA, 2005):

$$\eta = \frac{W_w L}{3.6 R A_d} \times 100 \dots\dots\dots(1)$$

Where:

- η = thermal efficiency, %
- W<sub>w</sub> = water evaporated from seeds, kg
- L = latent heat of vaporization of water, kJ/kg
- R = solar energy flux incident on the dryer, W/m<sup>2</sup>.
- A<sub>d</sub> = Surface area of solar drier, m<sup>2</sup>

**Quality evaluation tests of sunflower seeds:**

**1-Fungal count over the surface of sunflower seeds:**

The spread plate method recommended by Flannigan (1977) was used to determine the change in fungal colony count of sunflower samples. Potato dextrose agar (PDA) at 3.9% concentration was used as a culture

medium. Plates were incubated at 37°C for 4 days and the counts of fungi were determined as colonies/g.

**2- Acid value (A.V.) of sunflower oil:**

Acid value was determined according to the method described by A.O.A.C. (1991). A known weight of the melted sample (ca 2.5 g) was dissolved in 25 ml of petroleum ether alcohol mixture (1:1, v/v). The contents of the flask were heated on a steam bath for 2 min. then titrated with alcoholic potassium hydroxide (0.1 n) in the presence of phenolphthalein as an indicator. The acid value was calculated according to the following equation:

$$\text{Acid value} = \frac{V.N.56.1}{W} \dots\dots\dots(2)$$

Where:

V : Volume of alkali required to naturalize the free fatty acids.

N : Normality of KoH.

W : Weight of sample, g.

**3- Peroxide value (P.V) of sunflower oil:**

Peroxide value was measured according to the method described by A.O.A.C. (1991). Five grams of melted lipid samples were dissolved by 50 ml of acetic acid chloroform mixture (2:1, v/v). One ml of saturated potassium iodide solution was added, then the mixture allowed to stand with occasional shaking for exactly 1 min and 30 ml of distilled water were added. The contents of flask were titrated with 0.1 N sodium thiosulphated solution until the yellow color had almost disappeared. Starch solution indicator (0.5 ml) was added and titration was continued until the blue color had just disappeared. The following equation was used to calculate the peroxide value of lipid samples under study.

$$\text{Peroxide value} = \frac{S.N.1000}{W} \dots\dots\dots(3)$$

Where:

S : Titration of sample, ml;

N : Normality of sodium thiosulphate, dimensionless and

W : Weight of lipid sample, g.

**4- Free fatty acids (FFA%) of sun flower oil:**

Oil samples were extracted from sunflower seeds by soaking the crushed samples at n-hexane solvent for 24-48 hrs under room temperature. The solvent was completely re-gained by evaporation using a heated water bath at 85 °C and condensing it using a condensation unit. The remained oil samples were filled in glass bottles and used for the required measuring tests. The FFA % of oil samples were calculated as oleic acid using the corresponding acid value of each sample according to the A.O.A.C. (1991) as follows:

$$FFA\% = \frac{282 \chi 100 \chi \text{ Acid Value}}{56.1 \chi 1000} \dots\dots\dots(4)$$

$$FFA\% = \frac{A. V}{1.99} \dots\dots\dots(5)$$

Where:

A.V : Acid value

The values 282 and 56.1 refer to the equivalent weight of oleic acid and the potassium hydroxide (KOH) respectively. It should be mentioned that, to get true results of the free fatty acids, the laboratory tests were conducted after 15 days of samples storage under room condition.

## RESULTS AND DISCUSSION

### Solar radiation:

The hourly average solar radiation flux incident during the period of experimental work (sept. 2008) in Mansoura area were measured and recorded. The hourly averages solar radiation were 586.55, 520.31 and 476.6 W/m<sup>2</sup> during the periods of experimental work at air velocity of 0.5, 0.1 and 1.5 m/sec, respectively. Fig. (2) shows the measured solar energy flux incident as related to day time. In general, the solar radiation gradually increased from sunrise till it reached the maximum value at noon, it then decreased gradually until it reaches the minimum value at sunset. The observed variation in solar energy available during the drying period affected the dryer effectiveness in heating air and the differences in air temperature and relative humidity inside and outside the solar drier.

### Air temperature and relative humidity:

As air passes through the dryer it was first heated in the solar collector (greenhouse), then it was cooled and humidified as it passes through the drying bed containing the sunflower seeds. Following this, the air moves downwards through the wire net of the drying bed and exhaust out of the dryer through the suction fan. Figs. (3) through (5) present the temperature and air relative humidity profiles outside and inside the solar dryer of the greenhouse type during the experimental period at air velocity of 0.5, 1.0 and 1.5 m/sec, respectively. As shown in the figures at air velocity of 0.5 m/sec the average ambient air temperature was 33.1<sup>o</sup>C while the air relative humidity was 44.7%. As the air passes through the solar drier the air temperature increased to 52.3, 47.9 and 44.9<sup>o</sup>C while the air relative humidity decreased to 20.5, 21.9 and 26% for the dryers having perforated aluminum, perforated iron and plastic net absorber plates, respectively. At air velocity of 1.0 m/sec the average ambient air temperature during the experimental period was 31.8<sup>o</sup>C and the outside air relative humidity was 48.1%, while the corresponding temperature values inside the solar drier increased to 50.3, 46.3 and 43.6<sup>o</sup>C and the air relative humidity decreased to 22.5, 24.2 and 27.2%.

Fig2



Fig3

Fig4

Fig5

Meanwhile, during the experimental period at air velocity of 1.5 m/sec the average ambient air temperature was 30.7°C and the outside air relative humidity was 55%, while the recorded values of air temperature inside the three solar dryers were 48.3, 44.6 and 41.7°C and the air relative humidity decreased to 24.4, 26.9 and 29.7% for the perforated aluminum sheet, the perforated iron sheet and the plastic wire net sheet, respectively. The above mentioned results revealed that, the air temperature and relative humidity inside the solar driers obviously affected by the type of the solar absorber plate and the air velocity inside the solar drier.

**Bulk temperature of sunflower seeds:**

Bulk temperature of sunflower seeds was measured at different positions of the drying bed. In general, the bulk temperature of all studied treatments steadily increased with time till approaching the drying air temperature inside the solar drier. Then, it was decreased with the drying time due to the evaporative cooling of seeds. Following this stage and near the end of the drying process a noticeable increase of bulk temperature was observed as the moisture content of seeds decreased and approached the final moisture content as shown in Figs. (6) through (8). At the minimum air velocity of 0.5 m/s the recorded averages bulk temperature of sunflower seeds were 45.7, 42.7, and 40.3°C for the dryers having solar drier having perforated aluminum, iron and plastic net absorber plates, respectively. The corresponded values at air velocity of 1.0 m/sec were 44, 42.4, and 39.6°C, respectively. While at the maximum air velocity of 1.5 m/s the recorded averages bulk temperature were 41.5, 38.6, and 38°C, respectively.

**Seeds moisture content:**

Figs. (9) through (11) illustrate the change in seeds moisture content as related to drying time at different levels of drying air velocity and different types of solar absorber plate. As shown in the figures, the reduction in moisture content of sunflower seeds was varied and increased with the increase of air velocity, and the drying air temperature inside the solar drier.

At the air velocity of 0.5 m/s the recorded drying time for the sunflower seeds dried within the dryers having perforated aluminum, perforated iron and plastic net absorber plates were 25, 27, and 29 h, respectively. The corresponded times for the treatments dried at air velocity of 1.0 m/sec were 24, 25, and 27 h, respectively. While, at air velocity of 1.5 m/s the recorded drying times were 9, 10, and 25 h, respectively. This means that, the type of absorber plate greatly affected the properties of drying air inside the solar drier and thereby affecting drying rate and the total drying time. In general, the greenhouse type solar dryer with solar drier having perforated aluminum absorber plate operated at air velocity of 1.5 m/sec showed the minimum drying time of (9 hr ) in comparison with 11 and 25 hours for the perforated iron sheet and the plastic wire net, respectively. While, the traditional drying method has been taken about 58 hours.

Fig6

Fig7

Fig8

Fig9



Fig10

Fig11

**Drying efficiency of the solar dryer:**

To evaluate the overall performance of the solar dryer, the drying efficiency was determined for actual drying tests using different types of solar absorber plates and different levels of air velocity. The obtained results are presented in Table (1). As shown in the table, the dryer efficiency increased with the increase of drying air velocity and the drying air temperature inside the solar drier and it was ranged from 28.18 to 40.61%. In general, the drying efficiency of the proposed solar dryer could be considered satisfactory for general use.

**Table (1): Drying efficiency (%) of the solar dryer at different drying air velocities.**

Air velocity m/s	Type of absorber plates		
	Aluminum sheet	Iron sheet	plastic sheet
0.5	29.81	28.18	28.32
0.1	34.3	32.63	32.36
1.5	40.61	39.72	36

**Quality evaluation tests:**

The presence of lipase enzyme in sunflower oil hydrolysis it into free fatty acids and glycerol. Also oxidation of free fatty acids leads to produce various off odor compounds such as aldehydes and ketons. The free acids tests were conducted only for the samples which approached the safe storage moisture content of sunflower seeds in the range of (8-9 % w.b). Table (2) illustrates free fatty acids, oil, acid value and peroxide value of dried sunflower seeds. The obtained results showed that, the free fatty acids, acid value and peroxide value was in the safe level of less than 5% as reported by Hendawy (2009).

**Table (2): Percent of free fatty acids, oil, acid value and peroxide value as related to air velocity and type of solar collector.**

collector absorber	Air velocity, m/s.	Oil, %	F. F. A., %	Acid Value	Peroxide Value
Aluminum	0.5	47.3	2.81	5.62	6.25
Aluminum	1	47.4	1.81	4.62	20.83
Aluminum	1.5	48	1.74	4.08	12.14
Iron	0.5	47.1	3.09	6.18	20
Iron	1	47.8	2.83	5.66	12.9
Iron	1.5	46.6	2.84	5.68	11.53
Plastic	0.5	47.8	3.82	7.64	26.78
Plastic	1	47.8	3.97	7.94	8.06
Plastic	1.5	46.9	2.69	5.38	7.4

**Fungi colony count :**

Fig. (12) illustrates the effect of drying process using different types of solar absorber plates on fungal mortality level at the end of the drying process. As shown in the figure, the fungal count recorded levels ranged from 982 to 1623 colonics/g for the solar dried samples in comparison with 2639

colonics/g as initial count. On the same time, the fungal count for the natural dried seeds approached about 2951 colonics/g, which mean an increase of fungal activity during the early stage of natural sun drying process which taken longer time to reach the safe level for retarding the fungi mortality on the surface of seeds.

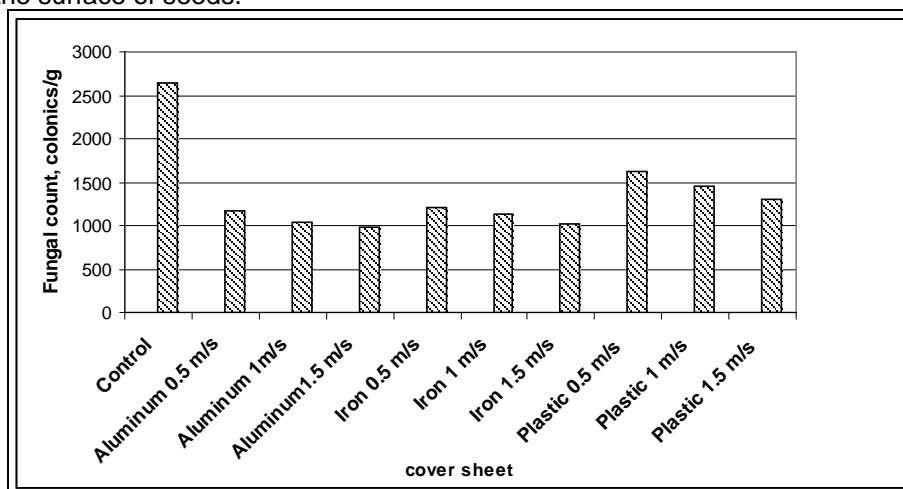


Fig. (12): The effect of drying process using different types of solar collector on fungal mortality level at the end of the drying process

## CONCLUSION

- 1-The hourly averages solar radiations flux incident on the horizontal plane were 586.6, 520.31 and 476.6  $W/m^2$  during the experimental period at air velocity of 0.5, 1.5 and 1.5 m/sec, respectively.
- 2-The solar dryers having perforated aluminum, iron and plastic net absorber plates could increase the average air temperature by about 19.1, 14.8 and 11.8 $^{\circ}$  C and decreased the average air relative humidity by about 24.2, 22.8 and 18.7%, respectively.
- 3- The reduction in moisture content of sunflower seeds was varied and increased with the increase of drying air velocity, and air temperature inside the solar drier.
- 4- The greenhouse type solar dryer having perforated aluminum absorber plate operated at air velocity of 1.5 m/sec achieved the minimum drying time of 9 hr in comparison with the natural drying method which has been taken about 58 hours.
- 5-The drying efficiency of the solar dryers increased with the increase of drying air temperature and air velocity and it was ranged from 22.96 to 31.57 %.

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**استخدام الطاقة الشمسية في تجفيف بذور عباد الشمس**  
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**(3) قسم هندسة التصنيع والتداول - معهد بحوث الهندسة الزراعية**

أجريت هذه الدراسة لاختبار وتقييم إمكانية استخدام المجففات الشمسية من النوع Green-house type لتجفيف بذور عباد الشمس وتأثيرها على جودة البذور والعد الفطري وكذلك خصائص الجودة للزيت المستخلص متمثلاً في نسبة الأحماض الدهنية الحرة. وشملت المعاملات التجريبية ثلاث أنواع من السطح الماص للمجمع الشمسي (الألومونيوم المطلي المثقب – الصاج المطلي المثقب – البلاستيك الأسود المثقب)، ثلاث سرعات لهواء التجفيف (5، 1 – 1,5 م/ث). بينما شملت القياسات التغير في المحتوى الرطوبي للبذور، كمية الطاقة الشمسية الساقطة، درجة حرارة كتلة البذور، درجة حرارة الهواء ورطوبته النسبية داخل وخارج المجفف، كفاءة التجفيف للمجفف، العد الفطري للبذور، جودة وثبات الزيت المستخلص من البذور المجففة.

أظهرت النتائج المتحصل عليها أن متوسط الطاقة الشمسية الساقطة أثناء فترة التجارب قد تراوحت بين 476,6 إلى 586,6 وات/م، كما زاد أيضاً متوسط درجة حرارة هواء التجفيف بما يعادل 11,81، 14,81، 19,14 م بينما انخفضت رطوبته النسبية بما يعادل 25,24، 28,06، 30,55% حيث كان الاختلاف في تلك القيم يعتمد على الاختلاف في طبيعة السطح الماص للأشعة الشمسية وكذلك سرعة هواء التجفيف.

كما اختلف أيضاً معدل الفقد في المحتوى الرطوبي لبذور عباد الشمس وذلك باختلاف طبيعة السطح الماص وسرعة هواء التجفيف. وبصفة عامة أعطى المجفف الشمسي ذو السطح الماص المصنوع من الألومونيوم المثقب والمطلي باللون الأسود أعلى معدل فقد للرطوبة وأقل فترة للتجفيف عند سرعة هواء 1,5 م/ث مقارنة بالأسطح الأخرى حيث وصلت فترة التجفيف إلى 9 ساعات مقارنة ب 10 ساعات، 25 ساعة للسطح المصنوع من الصاج المثقب والبلاستيك الأسود المثقب على التوالي عند نفس سرعة الهواء. من ناحية أخرى وصلت فترة التجفيف بالطريقة التقليدية إلى حوالي 58 ساعة. كما أظهرت النتائج أن كفاءة المجمع الشمسي تراوحت بين 28,18% إلى 40,61% حيث اختلفت قيم الكفاءة باختلاف نوع السطح الماص وكذلك سرعة هواء التجفيف وما نتج عنهما من تغيرات في درجة حرارة هواء التجفيف. أيضاً أظهرت نتائج تحليل الزيت المستخلص للبذور المجففة أن نسبة الأحماض الدهنية الحرة في المعاملات المختلفة قد تراوحت بين 1,73 – 3,97% مما يعني عدم تعرض الزيت للتزنخ في جميع المعاملات.

**قام بتحكيم البحث**

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