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UTILISATION OF SOLAR TUNNEL GREENHOUSE AS A SOLAR DRIER FOR DRYING SEEDLES GRAPES:
I: THERMAL PERFORMANCE ANALYSIS OF SOLAR DRIER

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ABSTRACT

In this research work an attempt has been made to analyse the thermal performance of solar tunnel greenhouse which can be utilised as a solar drier for seedless grapes. Three identical solar tunnel greenhouse driers (STGD) were used under the climatic conditions of El-Mansoura city, Egypt (latitude and longitude angles of 31.05ºN and 31.37 ºE, respectively), during August 2009. The thermal performance analysis of the solar driers (active or dynamic drier) based on the energy balance equations was evaluated. The three active solar driers were operated under three different mass flow rates of 0.122, 0.183, and 0.259 kg/s. The obtained results revealed that, the daily average solar energy available outside the solar driers was 16.727 kWh of which 12.572 kWh was available inside the drier with an average effective transmittance of 75.16%. The daily average solar energy available inside the three solar tunnel greenhouse driers during the experimental period was 12.572 kWh of which 6.993, 7.699, and 6.687 kWh, respectively, converted into useful heat gain. These solar energy available inside the three solar driers resulting in increase the inside air temperatures above the outside (31.6°C) by 21.9, 12.5, and 9.4°C, and reduce the air relative humidity under the outside (40.6%) by 9.0%, 3.1%, and 5.1%, respectively. The daily average overall thermal efficiencies of the three solar tunnel greenhouse driers during the experimental period were 55.62%, 61.24%, and 53.19%, consequently, 44.38%, 38.76%, and 46.81% of the solar energy available inside the solar driers was lost, respectively. The predicted heat energy for the three solar driers was validated well with that measured during the experimental period by 0.995, 0.991, and 0.998, respectively, which gave an excellent agreement.

Keywords*:* solar tunnel greenhouse drier; thermal performance analysis.

INTRODUCTION

Drying process is one of the most common applications of solar energy in the sunny countries. Egypt as a developing country and its geographical location has a great amount of natural energy such as solar energy and heated air by solar energy can be utilized for either heating or drying different agricultural products (Abdellatif and Helmy, 1993). Therefore using solar can considerably reduce energy costs. The efficiency of a solar dryer depends on its type and model as well as on the rate of heat loss during operating (Timoumi et al., 2004).

One of the great important potential applications of solar energy is the solar drying of agricultural products (grapes, apricots, bananas, tomatoes, and green beans). Radiant energy from the sun can be used in two ways: either heating up ambient air in a solar air heater and drying the agricultural products with heated air or heating up the products directly through absorption of solar radiation by the wet product. The second method is more economic and easier, since no heat transfer losses occur. But, while drying the vegetables containing higher amount of vitamin A and other several medicinal and herbal products these must not be exposed to direct solar radiation (Joshi *et al*., 2004). Furthermore, any direct exposure to the sun during high temperature day might cause hardening, where a hard shell develops on the outside of the agricultural products, trapping moisture inside. Therefore, the employment of solar drier taps on the freely available solar energy while ensuring good product quality via judicious control of the radiative heat (Sharma *et al.,* 2009).

Solar driers can generally be classified into two broad categories depending upon the mode of heating or the mode of their operation; active and passive solar driers. Passive driers or static driers use only the natural movement of heated air without mechanical agitation of drying air or product. They can be constructed easily with inexpensive, locally available materials such as wood is readily available (El-Sebaii *et al*., 2002). Passive drying is a well-known food preservation technique that reduces the moisture contents of agricultural products, and prevents deterioration within a period of time regarded as the safe storage period. Considerable losses occur during this drying process because of influences such as birds, insects, rodents, rain, and microorganisms. The quality of dried product can be seriously degraded so it sometimes becomes inedible. To overcome these problems, an active solar drier or dynamic drier is commonly used. Active solar dryers are designed incorporating external means, such as fans or pumps, for moving the solar energy in the form of heated air from the collector area to the drying beds. An advanced and alternative method to the traditional techniques is greenhouse drying in which the product is placed in trays receiving solar radiation through the plastic cover, while moisture is removed by natural convection or forced air flow (Condori and Luis, 1998 ; Kumar and Tiwari, 2007). This double function, greenhouse and drier, improves the rate of the initial investment (Condori *et al*., 2001), thus maintaining the good quality, increasing the storage capacity and reducing the wastage of the crop simultaneously (Tiwari, 2003). The thermal efficiency of solar drying systems can be evaluated either based on the thermal performance or drying rates of the agricultural products.

The main goal of this research work was to utilize the solar tunnel greenhouse as a solar air heater for drying seedless grapes during August of 2009. The objectives of this study are to analysis the thermal performance of solar tunnel greenhouse including, air temperature rise, overall thermal efficiency, and energy balance on the solar tunnel.

MATERIALS AND METHODS

1. Experimental set-up and procedure

Three identical solar tunnel greenhouse driers were constructed and installed on the roof of the Agricultural Engineering Department at El-Mansoura University. The latitude angle and longitude angle, and altitude of the Department above the sea level, respectively, are 31.045 ºN and 31.37 ºE, and 19.05 m. They were orientated in East-West direction, where the southern longitudinal direction faced into the sun's rays as shown in Fig. (1). The geometric characteristics of each solar tunnel greenhouse drier are as follows: eaves height 0.605 m, width 1.06 m, length 2.05 m, length of arc 1.55 m, net drying surface area 2.0 m^2, and internal volume 0.710 m^3 as shown in Fig. (2). The experimental set-up apparatus is constructed to study the thermal performance of the solar tunnel. Each solar tunnel was covered with single layer of polyethylene sheet 200µ thick. Each tunnel is equipped with a blower driven by a 0.5 hp electric motor at 3000 rpm, and 220 V. It was controlled by vertical gate to provide three different air mass flow rates of 0.0277, 0.04306, and 0.07692 kg/s in order to assess the required level of air for drying process. Drying air was cycled through the tunnel which continuously had a hot air heated by solar energy. Therefore, the drying air was continuously introduced from the top and leaves through the bottom as revealed in Fig. (2).

Fig. (1): Solar tunnel greenhouses (Quonset type) used as an active solar dryers during the experimental period.

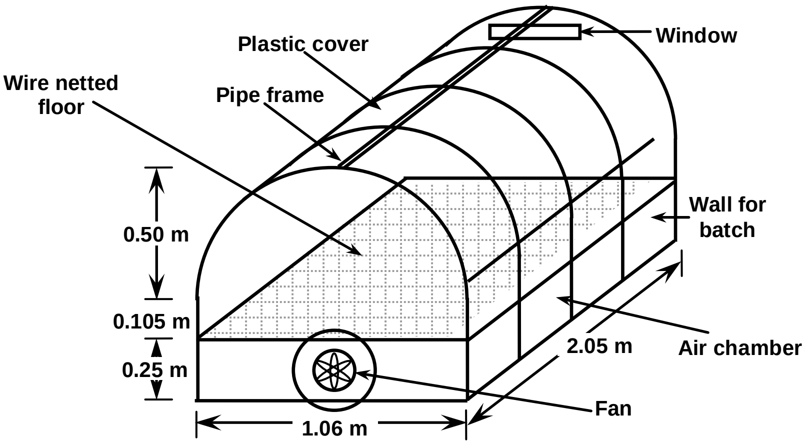

Fig. (2): Schematic diagram of the active and passive solar dryers.

2.Instruments and data acquisition

The meteorological data included solar radiation flux incident on a horizontal surface (pyranometer), dry-bulb air temperature (shelter and vented thermistor), wind speed and its direction (cup anemometer and wind van), and air relative (hygrometer) were obtained from the meteorological station (WatchDog, model 550, USA) which installed 3.0 m above the solar dryers. To measure the solar radiation flux incident on a horizontal surface inside the solar drier, another pyranometer was situated inside the first tunnel and connected with the meteorological station. The data were displayed on the video screen and updated by a scan of all the sensors every one minute. The mean of 15 scans was recorded on a hard-disk every 15 minutes using a data logging program (space ware 6.02). A 12 channels data-logger (Digi-Sense Scanning Thermometer Type, USA) was also used for measuring and storing air temperatures at different locations using Thermocouples (K-type with an accuracy of ± 0.2ºC). The vertical air temperature distribution was determined at the centre of each solar tunnel drier at heights of 12.5, 25, and 50 cm above the bottom of air chamber. In addition, the temperature of just leaving the drier (exhaust air) was also measured. The time interval for data recording was 15 minutes with data acquisition every one minute for integrated measurements.

3.Mathematical modeling

The three solar tunnel greenhouse driers were operated under quasi steady-state conditions as an air heating solar collectors. In these circumstances, the thermal performance of a solar tunnel greenhouse drier is described by an energy balance that indicates the distribution of incident solar energy into useful energy gain (Q_u), and thermal losses (Q_{loss}), **(Duffie and Beckman, 1991 ; Bargach, et al., 2000 ; Shanmugam and Natarajan, 2006 ; Hossain and Bala, 2007).** The heat energy balance can be computed as follows:-

$$Q = Q_u + Q_{loss}, \quad \text{Watt} \qquad (1)$$

The solar energy available inside the solar tunnel greenhouse (Q) could be calculated in terms of solar radiation penetrated the tunnel cover and the net surface area of the drier as:

$$Q = R\ A_d, \quad \text{Watt} \qquad (2)$$

Where, R, is the solar radiation flux incident on a horizontal surface inside the tunnel greenhouse drier (W m^{-2}), and, A_d, is the net surface area of the drying box (m^2). The useful heat gain by a dryer can be expressed as:

$$Q_u = m_a\ C_P\ (T_{ao} - T_{am}), \text{Watt} \qquad (3)$$

Where, m_a, and, C_P, respectively, are the air flow rate (kg s^{-1}), and the specific heat of air (J kg^{-1} $^oC^{-1}$), T_{am}, is the inlet air temperatures (ºC), and T_{ao}, is the outlet air temperature (exhaust air) of the solar drier (ºC). A measure of thermal performance of the greenhouse type solar dryer is the overall thermal efficiency (η_o), defined as the ratio of useful heat gain over any time period to the incident solar radiation over the same period.

$$\eta_o = \frac{Q_u}{R\ A_d} \times 100, \quad \% \qquad (4)$$

The total heat losses from the inside solar drier into the outside by conduction and convection, air exchange, and thermal radiation can be computed from the following formula:-

$$Q_{loss} = q_c + q_e + q_r, \quad \text{Watt} \qquad (5)$$

The heat losses from the greenhouse by conduction and convection can be determined by limiting the heat transfer to conduction and convection, if the overall heat transfer coefficient (U_o) in Wm $^{-2}$ °C $^{-1}$ total surface area of the solar tunnel cover (A_c) in m^2, and the air temperature difference between inside (T_{av}) and outside ambient air (T_{am}) in °C are known or measured. The procedure does not require the separation of the conduction and convection components. It can be calculated from the following equation:

$$q_c = U_o \; A_c \; (T_{av} - T_{am}) \,, \qquad \text{Watt} \qquad (6)$$

The heat energy loss by forced air exchange (q_e) could be calculated by determining the rate of extracting fan discharge (V) in m^3 s^{-1}, density of air (ρ) in kg m $^{-3}$, specific heat of air at constant pressure (C_P) in J kg $^{-1}$ °C $^{-1}$, and temperature difference between the inside air (T_{av}) and the air just leaving the solar tunnel (T_{ao}) in °C, as follows:

$$q_e = V \; \rho \; C_p \; (T_{av} - T_{ao}) \,, \qquad \text{Watt} \qquad (7)$$

The heat energy loss by thermal radiation (q_r) can be computed by the mean emittance factor of the inside substances (ε), average transmissivity coefficient at long wave radiation (τ), *Stefen-Boltzmann* constant (σ) in W m $^{-2}$ k $^{-4}$, and absolute temperature difference between the inside air and the sky (T_{sky}) in °K, as:

$$q_r = \varepsilon \; \tau \; \sigma \; A_f \left(T_{av}^4 - T_{sky}^4\right) , \qquad \text{Watt} \qquad (8)$$

$$T_{sky} = 0.0552 \; (T_{am})^{1.5} \,, \qquad {}^{o}\text{K} \qquad (9)$$

The normalized temperature rise (D_T) of the solar tunnel drier is the difference between the average air inside and outlet air temperatures divided by solar radiation flux incident. It can be computed by the following relation:-

$$D_T = \frac{(T_{av} - T_{ao})}{R} \,, \qquad m^2 \, {}^{\circ}C \, W^{-1} \qquad (10)$$

A computer model has been developed and used for computing the thermal performance of the solar tunnel greenhouse drier using the previous equations. The model was implemented as a stand-alone program running on IBM compatible microcomputer. The developed mathematical model has been solved with the help of computer program based on MATLAB. The program requires two input files: one contains the simulation parameters and the other contains the input data. Table (1) lists all inputs data required to run the program together with the parameter values used for the simulation runs. The program outputs data are also listed in Table (1). Simplified flowchart of the developed program is shown in Fig. (3).

Data were measured and stored in microcomputer files and statistically analysed using Excel program. Once a computer model is tested and found to be accurate, it can be used to predict the results which could otherwise be obtained with extensive and costly experimentation. Significance level of 0.05 was conventionally taken as the minimum level of significance. Though where higher levels of significance were found these values were included in the text ($P \leq 0.01$ and $P \leq 0.001$). For the rest of this manuscript the three solar tunnel greenhouse driers are referred to as STGD1, STGD2, and STGD3, respectively.

Table (1): Parameters and variables required as input and variables output by MATLAB program.

Configuration of file inputs:	**Value**
Floor surface area of solar drier (A_d), m^2	2.00
Overall heat transfer coefficient (U_o), W m^{-2} °C^{-1}	7.20
Specific heat of operating fluid, (C_P), J kg°C^{-1}	1006.6
Cover surface area of solar drier (A_c), m^2	3.100
Transmissivity coefficient at long wave radiation (τ), decimal	0.43
Mean emittance factor of the tunnel cover (ε), decimal	0.77
Stefen-Boltzmann constant (σ), W m^{-2} k^{-4}	5.67×10^{-8}
Data file inputs:	
Solar radiation flux incident inside the solar drier (R), W m^{-2}	
Inlet air temperature into the solar drier (T_{am}), °C	
Outlet air temperature from the solar drier (T_{ao}), °C	
Average air temperature inside the solar tunnel (T_{av}), °C	
Mass flow rate of air (m_a), kg s^{-1}	
Data outputs:	
Solar energy available inside (Q), Watt	
Useful heat gain, (Q_u), Watt	
Heat energy losses by conduction and convection (q_c), Watt	
Heat energy losses due to air exchange (q_e), Watt	
Sky temperature (T_{sky}), °K	
Heat energy losses by thermal radiation (q_r), Watt	
Total heat losses from the solar drier (Q_{loss}), Watt	
Overall thermal efficiency, (η_o), %	
Normalized temperature rise (D_T), m^2 °C W^{-1}	

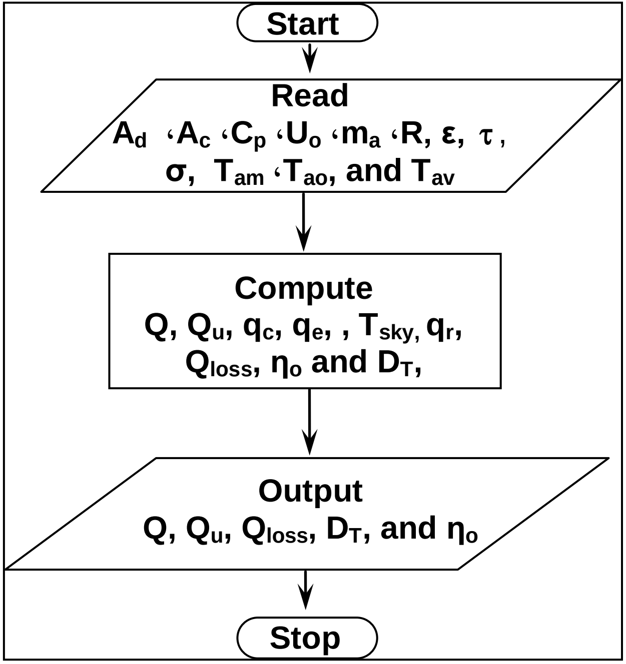

Fig. (3): Simplified flowchart for MATLAB program.

RESULTS AND DISCUSSION

1.Solar Radiation Inside and Outside

During the experimental work, the solar tunnel greenhouse driers were operated satisfactorily for five days (29/7/2009 to 2/8/2009) without any malfunction. Because the three solar driers used the same orientation and polyethylene cover under the same climatic conditions, there was no difference in the solar energy available inside the driers. The thermal efficiency of solar drying systems can be evaluated either based on the thermal performance analysis or drying rates of the products. The thermal performance analysis of the solar tunnel greenhouse driers depends upon the geometric characteristics of the drier, mass flow rate of operating fluid, and the climatic conditions surrounding the drier. The climatic conditions were associated with the intensity of solar radiation, ambient air temperature, and wind speed. During the experimental period, there were 65 hours of bright sunshine of which 45 hours were used in the thermal performance analysis. The hourly average solar energy flux incident outside and inside the solar tunnel greenhouse drier during the experimental period is plotted in Fig. (4). It evidently showed that, the actual solar radiation ranged from near zero to about 1000 W m^{-2} within the day length of 13 hrs. The lowest values during the experimental period were in the range of 15-100 W m^{-2}, which occurred just after sunrise and prior to sunset. They varied from hour to another and during the experimental period due to the sky cover (clouds) solar altitude angle, and solar incident angle as shown in the sixth day in Fig. (4). Therefore, the experiments during drying process were run only through nine hours (from 8 am to 4 pm, solar time). The actual solar radiation recorded inside the solar drier was lower than that outside because of, the reflectance, absorptance, and transmittance of the drier covering material. The hourly average solar radiation recorded outside and inside the solar drier, respectively, was 643.4 and 483.6

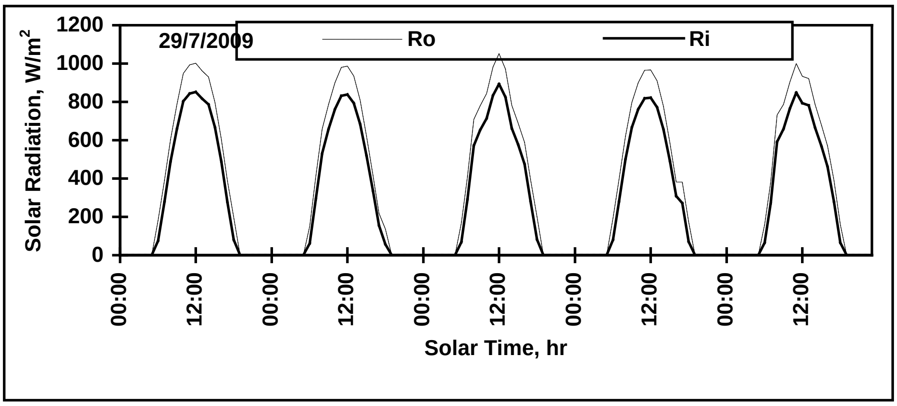

Fig. (4): Hourly average solar radiation flux incident outside and inside the solar tunnel greenhouse drier during the experimental period

Wm^{-2} with plastic cover effective transmittance of 75.16%. To determine the solar radiation penetrating the solar tunnel drier cover (R_i) as a function of the actual solar radiation flux incident outside (R_o), all the data recorded during the experimental period were plotted in Fig. (5). Regression analysis revealed a highly significant linear relationship (r = 0.9968 **;** $P \leq 0.001$) between these parameters. The regression equation for the best fit was:-

$$R_i\ (STGD) = 0.7516\ (R_o) \qquad (11)$$

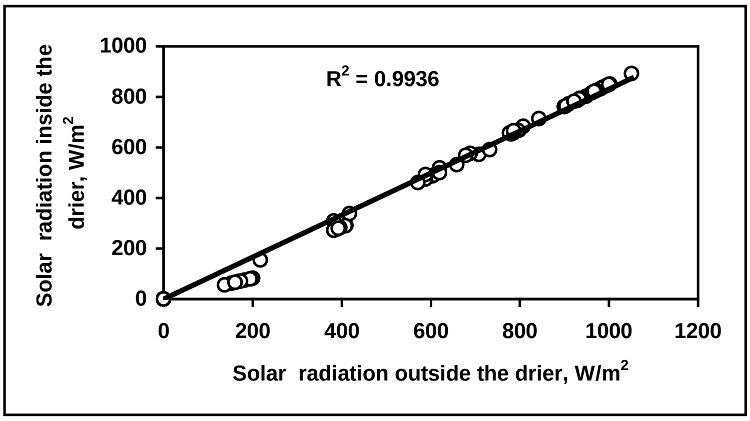

Fig. (5): Hourly average solar radiation flux incident inside the solar drier versus solar radiation outside.

2.Solar Energy Available Inside the Solar Drier

The daily average solar energy available inside the solar tunnel greenhouse drier during the experimental period was 12.572 kWh. There were obvious differences in solar energy available for the days recorded due to effect of the climatic conditions during the experimental period. Since, the solar energy available inside the solar drier is the main source of energy used in the drying process of agricultural products; it had the main effect on increasing the temperatures of drying air which may be considered as a very important parameter affecting the drying process. The hourly average air temperatures inside the three solar driers (STGD 1, 2, and 3) were 53.5, 44.1, and 41.0°C, respectively, while the outside air temperature was 31.6°C. Accordingly, the complied data showed that, the solar tunnel greenhouses drier increased the air temperatures by 21.9, 12.5, and 9.4°C, and reduce the air relative humidity under the outside (40.6%) by 9.0%, 5.1%, and 3.1%, respectively. These differences in air temperatures can be attributed to the variations in mass flow rates of air during the experimental period. It can be observed a sinusoidal variation of the air temperature with solar time. The air temperature in the solar driers varied from 29.5 to 65.0°C. The diurnal variation amplitude under solar tunnel greenhouse driers was more significant. The maximum air temperatures during the experimental period for the three solar driers reached 65.0, 51.5, and 46.8°C, respectively which occurred at and around noon. At nighttime the air temperatures inside the solar driers were almost fit with the outside air temperature. While, during the daylight the air temperatures were usually greater than that outside the driers.

3.Useful Heat Gain

The daily average useful heat gain for the three solar tunnel greenhouse driers during the experimental period was 6.993, 7.699, and 6.687 kWh, respectively. These differences in useful heat gain can be attributed to the variations in mass flow rates of air during the experimental period which effect on the exchange rate of air. The useful heat acquire varied from hour to another and during each day of the experimental period due to the variations in solar energy available, ambient air temperature surrounding the solar driers, and wind speed. As the ambient air temperature is increased, the difference in temperature between the hot air inside and the air passing through the solar drier is reduced and useful heat gain is thus reduced. Useful heat gain during the experimental period (Q_C) was plotted against the solar energy available (Q) for the three solar driers (Fig. 6). Regression analysis revealed a highly significant linear relationship ($r = 0.9493$; $P \leq 0.001$) between these parameters. The regression equations for the best fit were:-

$$Q_C \text{ (STGD 1)} = 0.5562 \text{ (Q)} \tag{12}$$
$$Q_C \text{ (STGD 2)} = 0.6124 \text{ (Q)} \tag{13}$$
$$Q_C \text{ (STGD 3)} = 0.5319 \text{ (Q)} \tag{14}$$

The regression analysis also showed that, the slopes of the regression equations are equaled to the daily average overall thermal efficiency of the solar tunnel greenhouse driers during the experimental period. The useful heat gain was also affected by the mass flow rate of air, thus some scatter in the data occurred particularly in the STGD 1 due to it used the lowest mass flow rate.

The daily average total heat losses from the three solar tunnel greenhouse driers during the experimental period were 5.579, 4.873, and 5.885 kWh, respectively. Consequently, the STGD 3 lost heat energy greater than the STGD 1 and STGD 2 by 5.48% and 20.77%, respectively. The daily average heat losses by conduction and convection for the three solar driers were 2.945, 1.397, and 1.119 kWh, respectively. While, the heat energy lost due to air exchange by extracting fan were 1.428, 2.631, and 3.958 kWh, respectively. The daily average heat losses by thermal radiation during the experimental period were 1.206, 0.845, and 0.808 kWh, respectively. They varied from hour to hour and day to another due to the ambient air temperature, wind speed, and temperature difference between inside and outside the solar driers. As the air temperature inside the solar drier is increased above the ambient air temperature, the air temperature difference between inside and outside is increased and heat losses are thus increased and vice versa.

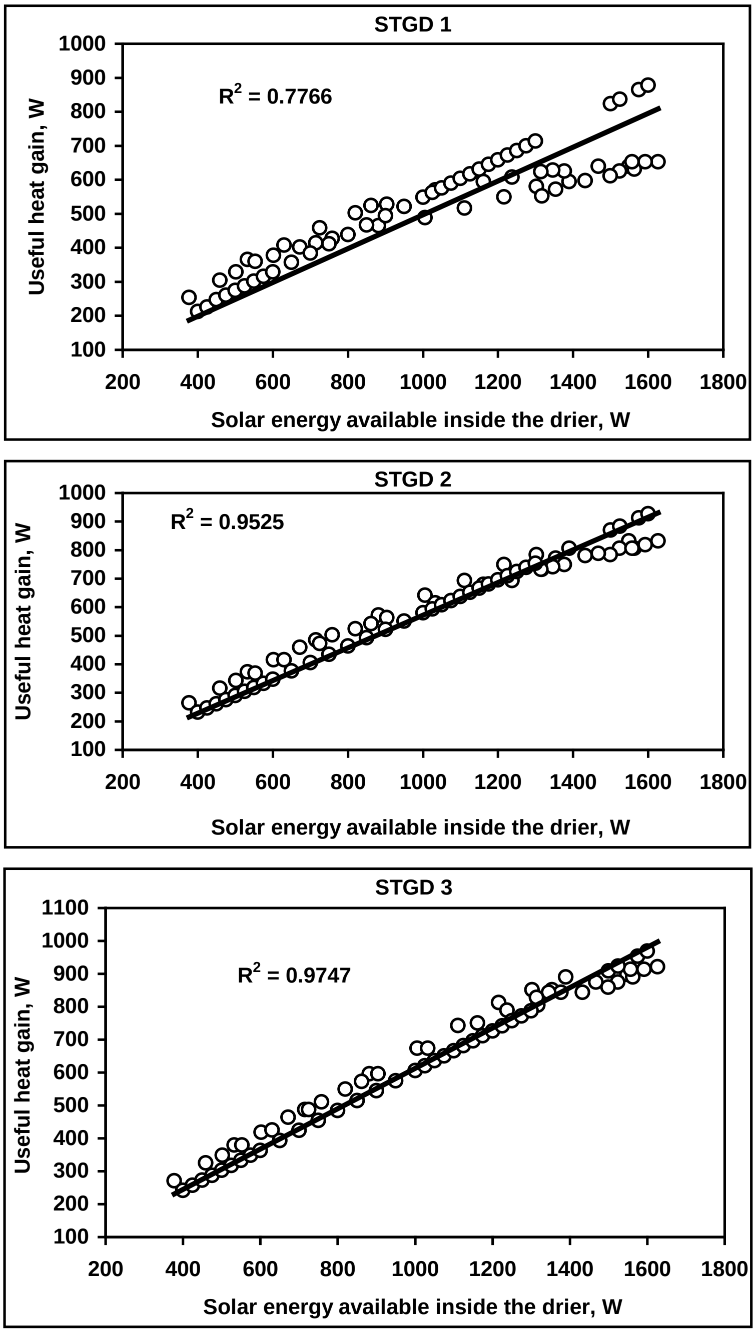

Fig. (6): Useful heat gain versus solar energy available for the three solar tunnel greenhouse driers during the experimental period.

4.verall Thermal Efficiency

The overall thermal efficiency is the ratio of useful heat gain to the solar energy available. The daily average overall thermal efficiencies of the three solar tunnel greenhouse driers during the experimental period were 55.62%, 61.24%, and 53.19%, consequently, 44.38%, 38.76%, and 46.81% of the solar energy available inside the solar driers was lost, respectively. The overall thermal efficiency (η_o) for three solar tunnel greenhouse driers was plotted against the normalized temperature rise (D_T) as shown in Fig. (7). Regression analysis revealed a highly significant linear relationship (r = -0.993 ; P≤0.001) between these parameters. The regress ion equations for the best fit were:

$$\eta_o\ (\text{STGD 1}) = 0.7351 - 6.7751\ (D_T) \qquad (15)$$
$$\eta_o\ (\text{STGD 2}) = 0.7333 - 6.5439\ (D_T) \qquad (16)$$
$$\eta_o\ (\text{STGD 3}) = 0.7865 - 7.3717\ (D_T) \qquad (17)$$

The regression analysis also showed that, the overall thermal efficiency of solar tunnel greenhouse drier can be expressed as:

$$\eta_o = \frac{Q_u}{Q} = F_R\ (\eta_{op}) - F_R\, U_O\, \frac{(T_{av} - T_{ao})}{R} \qquad (18)$$
$$\eta_o = F_R\ (\eta_{op}) - F_R\, U_O\ (D_T) \qquad (19)$$
$$\eta_o = a - F_R\, U_O\ (D_T) \qquad (20)$$

Regression equation is definitely the numerical expression of equation (19). The y-intercept (a) is equaled to the product of heat removal factor (F_R) and optical efficiency (η_{op}). The slope is equaled to the product of heat removal factor and overall heat transfer coefficient (U_O). The plot of overall thermal efficiency versus normalized temperature rise was a straight line with y-intercept F_R (η_{op}) and slope ($-F_R\, U_O$). It is clear that U_O is a function of temperatures difference between inside air and outside, mass flow rate of air, and wind speed. Also heat removal factor is a weak function of overall heat transfer coefficient. And, some variations of the relative proportions of beam and diffuse components of solar radiation occurred. Therefore, some scatter in the data particularly in STGD 3 was expected because of temperature dependence and mass flow rate effects as shown in Fig. (7). The previous obtained data are in agreement with the data published by Duffie and Beckman (1991) and ASHREA (2005).

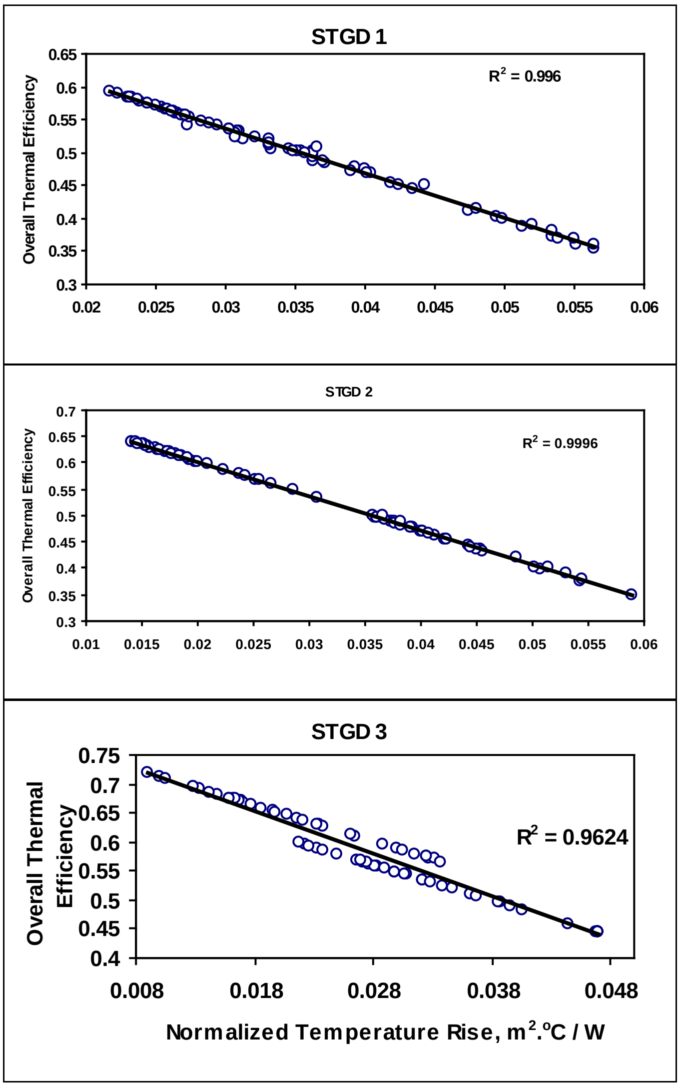

Fig. (7): Overall thermal efficiency versus normalized temperature rise for the three solar tunnel greenhouse driers.

5.Heat Energy Balance on the Solar Driers

The mathematical model of heat energy balance on the solar tunnel greenhouse driers which was used to predict the solar energy available inside the solar drier in terms of the summation of useful heat gain and total heat losses. There are many factors affecting heat energy balance on solar drier during daylight. These factors and their effects on heat energy balance were; solar radiation available inside that converted into useful heat gain, forced convection heat transfer coefficient, variation in the air temperatures in the solar driers, and ambient air temperature surrounding the solar drier.

Therefore, it is imperative to determine the solar energy available to check whether there are differences between the actual heat energy gained and lost, and the heat energy required to increase the drying air temperature inside the solar tunnel greenhouse drier. The predicted heat energy gained and lost was plotted as a function of the measured heat energy acquired and lost for the three solar tunnel greenhouse driers as shown in Fig. (8). The predicted heat energy for the three solar driers was validated well with that measured during the experimental period by 0.995, 0.991, and 0.998, respectively, which gave an excellent agreement.

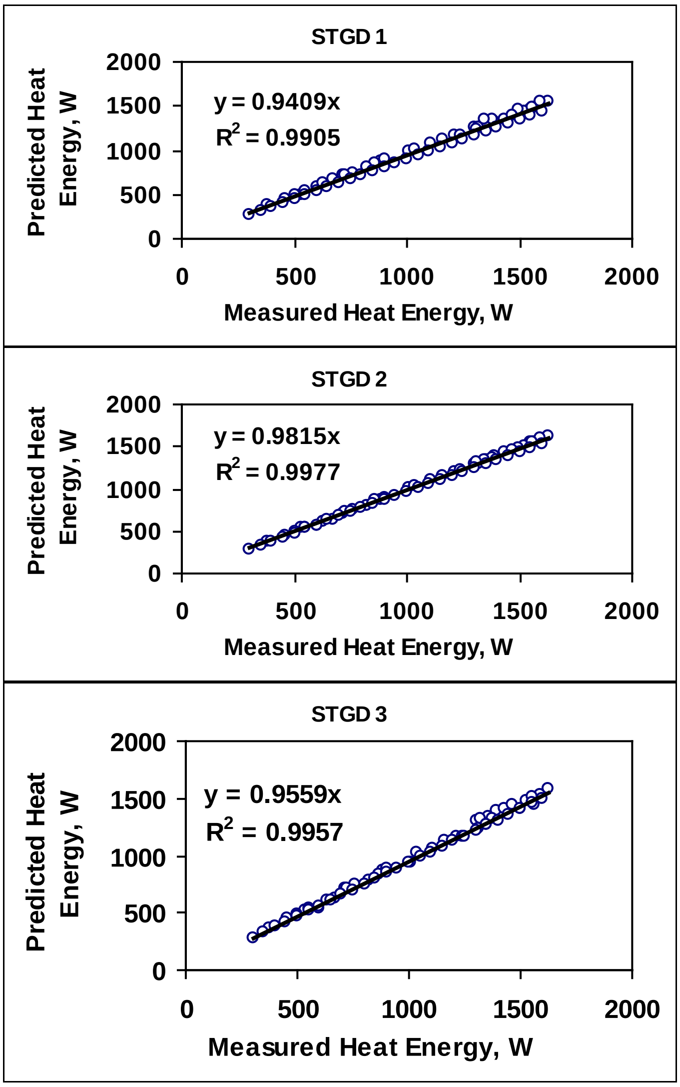

Fig. (8): Predicted heat energy gained and lost versus that measured for the three solar tunnel greenhouse driers.

CONCLUSION

The primary objective of this solar tunnel greenhouse drier is to increase the solar radiation converted into useful heat gain and investigate effective uses of that heat gain in increase the drying air temperature. For the duration of this research work the solar energy available was considered as the most important parameter affecting thermal performance of the solar tunnel greenhouse drier. The useful heat gain, and normalized air temperature rise were found to be affected mainly by the solar energy available and the mass flow rate of the drying air. The daily average solar energy available inside the three solar tunnel greenhouse driers during the experimental period was 9.721 kWh of which 5.485, 6.003, and 5.294 kWh, respectively, converted into useful heat gain. The daily average overall thermal efficiencies of the three solar tunnel greenhouse driers during the experimental period were 55.62%, 61.24%, and 53.19%, consequently, 44.38%, 38.76%, and 46.81% of the solar energy available inside the solar driers was lost, respectively. The predicted heat energy for the three solar driers was validated well with that measured during the experimental period by 0.995, 0.991, and 0.998, respectively, which gave an excellent agreement.

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إستغلال البيوت المحمية كمجفف شمسى لتجفيف العنب البناتـى:

1: تحليل الإداء الحرارى للمجفف الشمسى

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يتناول هذا الجزء من البحث إجراء تجارب بغرض تحليل الأداء الحرارى لبيت محمى على شكل نفق يستخدم كمجفف شمسى لمحاصيل الفاكهة وإمكانية استغلاله كمجفف شمسى للعنب البناتى. تم استخدام ثلاثة مجففات أنفاق متشابهة فى الشكل والأبعاد تحت الظروف الجوية لمدينة المنصورة عند زاوية خط عرض 31.05° شمالاً وزاوية خط طول 31.37° شرقاً وذلك فى شهر أغسطس عام 2009.

إعتمد تقييم الأداء الحرارى للمجففات الشمسية (المجفف النشط أو الديناميكى) على معادلات إتزان الطاقة على المجفف. تم تشغيل المجففات الثلاثة تحت ثلاثة معدلات سريان وزنى مختلفة لهواء التجفيف هى 0.122، 0.183 و 0.259 كجم/ث. أظهرت النتائج المتحصل عليها أن المتوسط اليومى للطاقة الشمسية المتاحة خارج المجففات كانت 16.727 كيلووات.ساعة بينما المتوسط اليومى للطاقة الشمسية داخل المجفف الشمسى 12.572 كيلووات.ساعة بمعامل نفاذية مقداره 75.16%. المتوسط اليومى للطاقة الشمسية المتاحة داخل مجففات الأنفاق الثلاثة أثناء فترة التجربة كانت 12.572 كيلووات.ساعة والتى منها 6.993، 7.699 و6.687 على الترتيب تحولت إلى طاقة مستفادة. أدت الطاقة الشمسية المستفادة إلى رفع درجة حرارة الهواء الداخلى عن الخارجى (31.6 م°) بمقدار 21.9، 12.5 و9.4 م°، بينما إنخفضت الرطوبة النسبية لهواء التجفيف (40.6%) إلى 9.0%، 5.1%، 3.1% على الترتيب لكل مجفف. كان المتوسط اليومى للكفاءة الحرارية الكلية للمجففات الثلاثة أثناء فترة التجربة 55.62%، 61.24% و53.19% وبالتالى فإن 44.38%، 38.76% و46.81% من الطاقة الشمسية المتاحة داخل المجففات تم فقدها عل الترتيب. إتزان الطاقة الحرارية على المجففات الشمسية الثلاثة أوضحت أن الطاقة الحرارية المتوقعة للمجففات الثلاثة كانت متوافقة جيداً مع تلك التى تم قياسها خلال فترة التجربة بمعدل تطابق مقداره 0.995، 0.991 و0.998 على الترتيب.

قام بتحكيم البحث

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