PENETRATION CURVES OF SOLAR HEAT INTO DATE FRUITS AS A MEAN TO CONTROL INSECTS

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ABSTRACT

The annual palm date production in Saudi Arabia approached 800 thousands tons in 2004. One of the most important processes in the date industry is fumigation which is based in chemical treatment to destroy insects. Previous studies indicate that insects are very sensitive to temperature rise and can be destroyed instantly if exposed to 64ºC. The harvesting period of date fruits in the Riyadh region of Saudi Arabia extends from June till the beginning of September. During the summer months, the standard day temperature in the Riyadh area ranges from 35 to 45ºC. Therefore, this study is an attempt to develop a procedure to utilize the solar energy to destroy date insects as an alternative method to the fumigation process. Thus, the goal of this research was to study the heat penetration curves of solar energy into three varieties of date fruits (Sefri, Seri and Khudari). Temperatures of three locations were recorded during solar exposure (inside the date fruits, inside the solar collector and the surrounding atmosphere temperature). Mathematical models were developed for the heating curves. Fruit color and moisture content before and after solar heating were determined as quality parameters. The heat penetration rates and quality parameters depend on the date variety as well as the surrounding temperature. Kinetic models were applied to indicate the effectiveness of solar energy in the destruction of *Oryzaephilus surinamensis: Silvanidae* insects inside date fruits. Modeling results indicate that solar energy can be used to destroy the insects with little change of date quality.

Keywords: Solar energy, heat penetration, palm date, insect control.

1. INTRODUCTION

Dates are considered to be one of the most important national products in Saudi Arabia. The annual production of palm date in Saudi Arabia approached 800,000 tons by 2004. The date processing industry has been growing steadily during the past few years. The number of licensed date processing factories is 42, however, there are only 26 factories in real production. Mainly these factories process 70,000 tons of dates annually. The final stage of fruit maturation is the "Tamr" stage when the fruit is left on the tree if climatic conditions are favorable. This stage is the brown color, universally known "date" dried fruit, where the moisture content is a self-preserving maximum of 25%. The harvesting period of date fruits in the Riyadh region of Saudi Arabia starts in June and continues till the beginning of September. During the summer months, the stander day temperature in the Riyadh area range from 35 to 45ºC. The first step after harvesting is a fumigation process which is made by exposure of dates to methyl bromide for 4 to 6 hours to kill insects at all stages. Methyl bromide (MeBr) is an odorless, colorless gas that has been used as an agricultural soil and structural fumigant to control a wide variety of pests. However, because MeBr depletes the stratospheric ozone layer and is classified as a Class I ozone-depleting substance (1), there is a great interest to seek an alternative method of insect control which is suitable for palm date producers - especially farmers in remote areas.

Date fruits are subject to insect attack, and one of the most common insects that infect dates *is Oryzaephilus surinamensis: Silvanidae*. The effect of conventional and electrical thermal stresses on the destruction of *Oryzaephilus surinamensis: Silvanidae* inside the fruits of some date varieties has been studied (2). The results indicate that the destruction rate order of the insect can be

described successfully by applying zero order kinetics models in both heating mechanisms: conventional and electrical. In addition, the destruction of the adult insects insures the destruction of all other stages of the insect in the Sefri, Seri and Khudari varieties. Kinetic study indicates that the insect is very sensitive to temperature and can be destroyed by instant exposure to 64 ºC (3). Therefore, this study is an attempt to develop a procedure to utilize solar energy to destroy date insects as an alternative method to the fumigation process. The goal of this research was to study the heat penetration curves of solar energy into three varieties of date's fruits (Sefri, Seri and Khudari) by using a flat solar collector.

2. BACKGROUND

The thermal performance of the solar collector was tested in Riyadh city (Latitude of 23º 34` N Longitude of 46º 43` E and 600 m above sea level. The average daily maximum temperature is approximately 40 ºC from May to September, reaching maximum average highs of 43 ºC, in July. The low average humidity is approximately 15 % to 16 % during June to August indicating low humidity during hot-dry periods.

The kinetic model that describes the destruction of the insect is zero order as shown in the following equation:

$$N_o - N = k\,t$$

The initial number of the insects (No) is reduced to a final number (N) by the rate of (k) when exposed to constant temperature for a certain time (t). The killing rate constants (k) for the adult stage of *Oryzaephilus surinamensis: Silvanidae* were 0.0109, 0.1012 and 0.9143 sec^{-1} at 45, 50 and 55^{o}C respectively. The effect of temperature can be described by the following Arrhenius equation:

$$k = A\,Exp(-Ea/RT)$$

Where; the consistency factor (A) was 1.51 x 10^{61} [sec^{-1}] and the activation energy (Ea) was 3 x 10^{5} [KJ/kg.mole], R is the general gas constant, and T is the exposure temperature in Kelvin.

3. THIS PROJECT

3.1 Materials and methods

The temperature of the date fruits was increased by using a flat solar collector as shown in Figure (1).

Fig. 1. Photo of the date fruits inside the flat solar collector

Figure (2) indicates the dimensions of the solar collector. Where an amount of 500 gm of date fruits was placed inside the solar collector and three thermocouples were inserted inside the center of three fruits selected randomly (T_c). Temperature of the surrounding air inside the solar collector in three locations (T_{in}), the standard air temperature outside the solar collector (T_{out}) and the solar radiation were recorded each minuet by data loggers. The date moisture content was measured before and after exposure to solar heating by using a Halogen Moisture Analyzer (HR73 Halogen, Switzerland). In each experimental run, the color of three fruits was measured before and after heating by using Color Flex (Model No.45/0, USA).

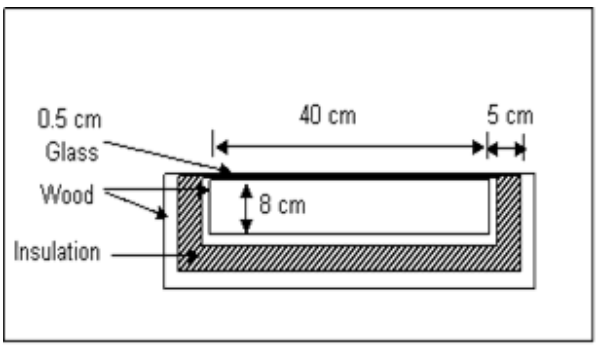

Fig. 2. Dimensions of the solar collector.

3.2 Results and discussions

Figure (3) indicates the air temperature and the solar radiation as an example of the data collected in the test location. It should be noticed that more than 5 hours of a solar radiation during the day was above 600 [w/m^2]. This reflects the possible working hours of the solar exposure with high effectiveness of heating during the harvesting period of date.

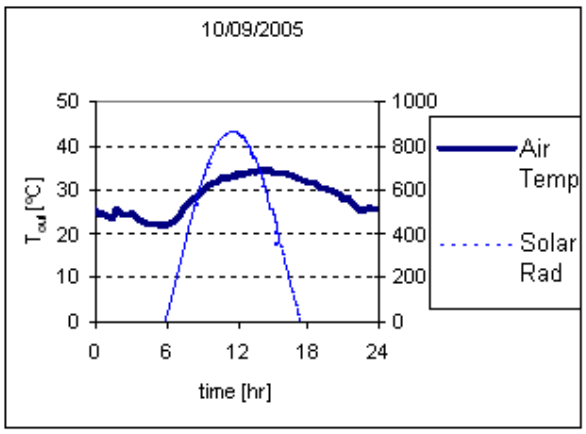

Fig. 3. Example of air temperature and solar radiation during the day in Riyadh.

As the solar collector was exposed to the solar radiation, the average date temperature increased from room temperature gradually as the temperature of the surrounding air inside the solar collector increased as shown in Figure (3). All date varieties (Sefri, Seri and Khudari) followed the same pattern of heat penetration curves with negligible differences although these varieties differ significantly in their fruits volumes as indicated by Figure (4).

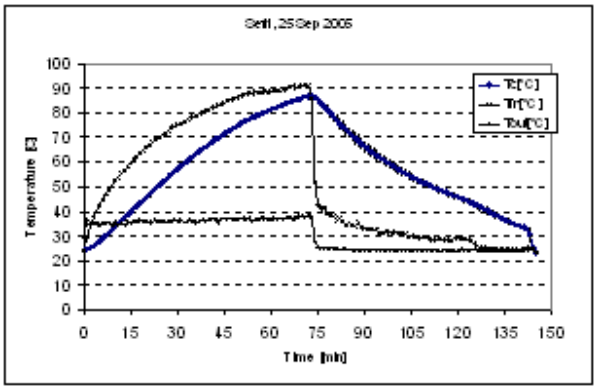

Fig. 4. Typical heat penetration curves of Sefri dates experiment.

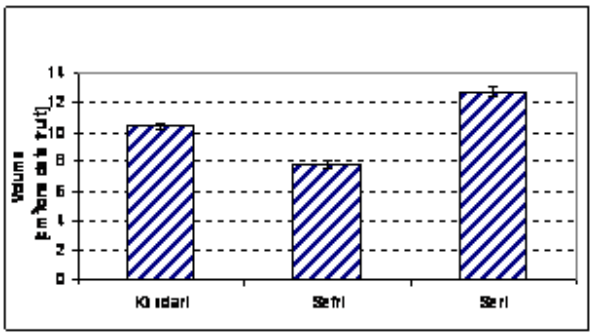

Fig. 5. Average and standard deviation of the date fruits volume.

The required time to reach the lethal temperature range from 37 to 40 minuets as indicated in Table (1) depends on the variety. The air temperature inside the solar collector approached about 80ºC after 40 minutes. At this time-temperature combination any stages of insects is expected to be destroyed as suggested by the kinetic models.

TABLE 1. THE LETHAL TIME REQUIRED TO REACH 64ºC ($T_{T=64}$), THE TEMPERATURE INSIDE THE SOLAR COLLECTOR (T_{IN}), THE STANDARD AIR TEMPERATURE OUTSIDE THE SOLAR COLLECTOR (T_{OUT}) AND SOLAR RADIATION OF THE EXPERIMENTS PERFORMED ON THE DIFFERENT DATE VARIETIES.

Varity	$t_{T=64}$ [min]	T_{in} [ºC]	T_{out} [ºC]	Solar Rad [w/m^2]
Sefri	37	79.86	35.85	887.83
Seri	38	81.71	33.26	809.17
Khudari	40	81.42	32.88	839.28

As the date temperature increased, it is important to determine some of the quality parameters such as color change and moisture loss. Table (2) indicates that during the heating of dates less than 10% change was detected in case of color change and less than.82% losses of moisture. It is clear that the color of the Khudari variety is more sensitive to temperature change.

TABLE 2. THE QUALITY PARAMETERS CHANGES (COLOR AND MOISTURE) DUE TO THE SOLAR HEATING. ?SHOULDN'T THE % COLUMN DELETE DECIMALS?

Varity	% change of color	% loss of moisture
Sefri	0.03	0.82
Seri	2.09	0.38
Khudari	9.65	0.47

The above results can be used to design either batch or continuous solar units to control date insects. A batch unit will be suitable for small and remote date farms, while a continuous unit requires a moving conveyer with a speed 0.25 m/min inside a solar unit (with solar collector area 1x10 m^2). The expected capacity of this unit is 47 kg/hr or 234 kg for 5 working hours per day under the Riyadh climate characteristics. The estimated cost of a batch solar unit is about 600 US$, while the cost of the continuous unit may reach 1500 US$.

4. CONCLUSION

The results of penetration curves indicate that using solar energy can be an effective method to control insects in date fruits with less than 10% of color change and less than.82% of moisture loss. The estimated cost of the solar unit will be in the hand of small farmers and can be improved for industrial applications.

5. REFERENCES

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