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Use of Solar Energy for Disinfesting Stored Dates

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Abstract: A solar heat exposure or solarization trial was carried out during November 2007 at Shambat Research Station, Sudan. The Objective of the study was to control the date moth *Ephestia calidella* (Guen.) and the saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) in stored dates. Black iron and polyethylene solar heat collectors were constructed and exposed to the sun. The results showed considerable variation in the mean temperature between the iron heat collector, polyethylene heat collector and control treatments; they were 41.5°C, 53.7°C and 57.4°C, respectively, while the ambient mean temperature and relative humidity were 33.1°C and 52.9%. Six and 12 hours were enough to control *E. calidella* in the iron heat and polyethylene heat collectors, respectively, and 18 and 24 hours to control *O. surinamensis*. Exposing the ripened dates to a mean temperature of 57.4°C for 24 hours did not lead to high significant change in the chemical composition, except that some sucrose was inverted to reducing sugars.

Key words: *Ephestia calidella; Oryzaephilus surinamensis*; stored dates; solar collectors

INTRODUCTION

Dates in Sudan are usually packed in jute bags and stacked on ridges over old date palm stems out-doors or inside traditional stores. A major concern after harvest is to prevent or control insect infestation. Stored dates are commonly infested concurrently by the date moth *Ephestia calidella* (Lepidoptera: Pyralidae) and the saw-toothed grain beetle *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) (El-Nazir 2004). The date moth commences the infestation of fruits while on the tree or once they are harvested and left to dry; it may also fly to stores or carried on the products (Cox 1975). The saw-toothed grain beetle infests the crop in the stores, but has not been recorded in the field (Hussain 1969; Anonymous 1985).

Exposing infested stored products to the sun to minimize insect infestation is a common practice in rural communities in Sudan. There are several reports on field studies regarding the possible exploitation of solar energy for the protection of stored products against insect pests (Agona and Nahdy 1998; Lale and Ajayi 2001; Assiry 2009). This method is based on the well-known principal that insects are killed upon heating to 50°C-60°C (Howe 1965; Al-Azawi *et al.* 1983; Field 1992). There is some information in the literature on the sensitivity of stored-date insects to high temperature (Al-Azawi *et al.* 1983; Barreveld 1993; Navarro *et al.* 2004; Navarro 2006). Assiry (2009) used solar energy, as an alternative method to fumigation, to destroy date insects.

The objectives of this study were (i) to develop a simple low-cost technology to use solar energy for controlling store pests in dates, and (ii) to determine the optimum exposure period to solar radiation to control *E. calidella* and *O. surinamensis*.

MATERIALS AND METHODS

The colonies of insects used in the experiment were established from cultures of *E. calidella* and *O. surinamensis* which had been raised for several generations on date fruits in the Storage Insects Research Unit, Shambat Research Station, Agricultural Research Corporation, Sudan. The above mentioned insects were reared individually on dates at 30°C in a thermostatically controlled Gallenkamp cooled incubator; a number of stock cultures were made in 2.5 litres glass jars, each culture contained about 500 g of dates. Nine 65-kg sacks (1x 0.5x 0.25 m) of the common date Barakawi cultivar were artificially infested with *E. calidella* eggs and *O. surinamensis* mixed aged adults and left for six months (May-October, 2007). The heavily infested jute-bagged date was used..

Solar heaters were constructed by laying a black iron sheet (1 x 2 m) and a black polyethylene sheet (1 x 2 m) on the ground exposed to the sun. On each iron or polyethylene sheet, one jute sack of the artificially infested date was laid. A translucent polyethylene sheet was laid over the bag and secured at the edges with paper clips, as an inexpensive solar heat collector. Another bag was laid on the bare ground, exposed to solar heat as a control. The solar heat collectors were exposed to solar energy during the period 3 to 6 November, 2007. A thermohygrograph was used for recording the ambient conditions (temperature and relative humidity). Temperature inside the solar heaters was monitored by max-min thermometers every two hours and recorded.

Random samples of dates (500 g) were collected before the treatment (control samples). In the laboratory, each date fruit was cut into two halves using a pair of scissors, and the number of *O. surinamensis* adults and immature stages of *E. calidella* were counted and recorded.

The sacks were exposed to the solar heat for 24 hours (6 hours daily and consecutively); every two hours random samples (500 g) were collected from each sack and immediately examined in the laboratory for surviving adults of *O. surinamensis* and immature stages of *E. calidella*. The treated and untreated samples were then incubated in glass jars under laboratory conditions for up to six weeks to allow any immature survivor to develop and emerge as an adult. Adult insects emerging from these incubated samples were counted and removed every two weeks. The efficacy of the treatment was assessed by the mortality of *E. calidella* and *O. surinamensis* adults and their immature stages. Three replicates were set up for each treatment in a randomized complete block design and means were separated by the Duncan's Multiple Range Test.

To determine the effect of high solar temperatures on the chemical components of dates, 15 kg of newly harvested date (Barakawi) were divided into three replicates, placed in small jute bags of 50 x 30 cm and enclosed in the iron heat collector envelopes. One sample was kept in the laboratory, as a control, and the other three were returned to the laboratory after 8, 16 and 24 hours. The chemical analysis was done immediately after the termination of the experiment and repeated after four months of storage at the Chemistry Laboratory of the Food Research Centre, Shambat. The chemical components determined were moisture content (according to Dowson and Aten 1962), total sugars, reducing sugars and sucrose (Schnieder 1979), total protein and ash (AOAC 1975) and titrable acidity (Ragana 1977). Data were subjected to analysis of variance and means were separated by the Duncan's Multiple Range Test.

RERULTS AND DISCUSSION

Regular emergence of adult insects of *O. surinamensis* and *E. calidella* from the control samples, during weekly counts throughout the incubation period, provided evidence that all developmental stages of insects were adequately represented in the dates used in the experiment.

The ambient mean temperature was 33.1°C and R.H. was 52.9%. There was considerable variation in the mean temperatures of the control, plastic heaters and iron heaters treatments (41.5°C, 53.7°C and 57.4°C, respectively).

Table 1 shows the effect of temperatures attained in solar Iron and Polyethylene heat collectors on the survival of *E. calidella* and *O. surinamensis* developmental stages. There were highly significant ($P < 0.01$) differences between the three treatments for the two species. For *E. calidella*, 6 hours exposure period inside the iron heat collectors achieved complete mortality, while inside the plastic heat collectors 12 hours were needed to kill all the developmental stages. The time required for complete mortality of *O. surinamensis* was 18 and 24 hours in iron and plastic heat collectors, respectively.

The highest intrinsic rate of natural increase for *E. calidella* when reared on Barakawi was recorded during October to January (El-Nazir *et al.* 2007); so for securing of the newly harvested date, the control should be done immediately after harvesting, drying and before storage, which is the peak-time for *E. calidella*.

When the dates were subjected to 57.4°C mean temperature in iron heat collectors for 24 hours (Table 2), protein and titrable acidity were not significantly ($P > 0.05$) affected, ash was significantly ($P < 0.05$) affected and the moisture content, reducing sugars and sucrose were highly significantly ($P < 0.01$) affected.

Date fruits are hygroscopic, and so the moisture content was considerably affected by the ambient relative humidity during storage. Barakawi is a hard cultivar, because of the high sucrose content, and hence it has low moisture content (El-Nazir 2004). Dowson and Aten (1962) reported that soft dates contain little sucrose, while the sugar content of the dry dates is about one third sucrose and two thirds reducing sugars, and semi-dry dates occupy a position between the two groups. It seems that the high temperature with reasonable amount of moisture content sufficiently reactivated the invertase enzyme which inverted sucrose to reducing sugars. Barreveld (1993) mentioned that the typical conditions for Deglet Noor hydration in California is 4 to 8 hrs at 60°C (with steam) for reactivation of the invertase enzyme, which is responsible for the inversion of sucrose to glucose and fructose to improve texture and pliability.

Navarro (2006) stated that since drying temperatures for most date cultivars are between 45°C and 50°C, disinfestation of insects is greatest at 50°C (92.3%), and at 55°C 100% mortality is obtained. Barreveld (1993) recommended 65°C and relative humidity of over 40% (but should not exceeding 60%) for reasonable drying of dates without affecting the basic quality. He concluded that heat treatment of dates, at a maximum of 60°C-65°C, may have the combined beneficial effect of destroying insect life, reducing the microbial count and creating a product with a prolonged storage life. Assiry (2009) constructed and tested a small flat rectangular (40x40x8 cm) solar heat collector, consisting of wood and glass cover; in which the air temperature approached about 80°C after 40 minutes. He concluded that solar energy can be used to destroy insects with little change of date quality.

Table 1. Effect of temperatures attained in solar Iron and Polyethylene heat collectors on the survival of *Ephestia calidella* and *Oryzaephilus surinamensis* developmental stages in 500 g samples of dates (ambient conditions were 33°C and 52.9% R.H.)

Treatment	Mean temp. (°C)	Exposure period (hours)												
		0	2	4	6	8	10	12	14	16	18	20	22	24
								Ephestia calidella* (larvae, pupae and adults)						
Iron heat collectors	57.4	(5.4) 2.4abc	(4.0) 2.1cde	(1.5) 1.6gh	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i
Polyethylene heat collectors	53.7	(4.2) 2.2bcd	(3.6) 2.1cde	(2.5) 1.9efg	(1.5) 1.6gh	(1.0) 1.4h	(1.0) 1.4h	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i	(0.0) 0.7i
Control	41.5	(5.7) 2.5ab	(6.0) 2.6a	(4.6) 2.3abcd	(3.8) 2.0def	(2.5) 1.9efg	(2.0) 1.7fgh	(1.5) 1.6gh	(2.0) 1.7fgh	(2.0) 1.7fgh	(1.6) 1.6gh	(1.6) 1.6gh	(2.6) 1.9efg	(1.7) 1.6gh
SE±								0.11						
CV %								9.7						

Table 1. Cont.

Treatment	Mean temp. (°C)	Exposure period (hours)												
		0	2	4	6	8	10	12	14	16	18	20	22	24
		Ephestia calidella* (larvae, pupae and adults)												
Iron heat collectors	57.4	(91.5) 9.6a	(62.5) 7.9b	(46.0) 6.8bcdeg	(47.1) 6.9bcdefg	(29.5) 5.8efghi	((24.0) 5.0ghij	(23.0) 4.9hij	(13.0) 3.7jkl	(3.1) 1.8kl	(0.0) 0.7m	(0.0) 0.7m	(0.0) 0.7m	(0.0) 0.7m
Polyethylene heat collectors	53.7	(63.0) 7.9b	(58.0) 7.7bcd	(60.5) 7.9b	(50.5) 7.2bcdef	(28.0) 5.4fghij	(26.8) 5.3fghij	(24.3) 5.0ghij	(18.0) 4.4ijk	(17.3) 4.3ijk	(11.5) 3.4jkl	(5.5) 2.5jkl	(3.0) 1.8lm	(0.7) 1.3 m
Control	41.5	(60.0) 7.7bcd	(58.7) 7.7bcd	(56.6) 7.6bcd	(45.4) 6.8 bcdefg	(34.0) 5.9cdefghi	(32.2) 5.7 efghij	(33.7) 5.9cdefghi	(21.2) 4.7ij	(32.0) 5.8defghi	(34.1) 5.9cdefghi	(21.3) 4.7ij	(18.6) 4.4ijk	(13.4) 3.7jkl
SE±								0.55						
CV								14.2						

*The count was done during 6 weeks incubation period under laboratory conditions.
The actual data (in parenthesis) were transformed to $\sqrt{x+0.5}$.
Means within a column followed by the same letter(s) are not significantly different at P=0.05, according to Duncan's Multiple Range Test.

Table 2. Chemical composition of ripened Barakawi date fruits subjected to 57.4 °C mean temperature in iron heat collectors for different exposure periods

Exposure period (hours)	Moisture content (%)	Sugars (%)			Titrable acidity (%)	Crude protein (%)	Ash (%)
		Total	Reducing	Sucrose			
0	11.60b	63.73cd	44.63g	44.63g	0.98a	2.66ab	2.64b
8	11.33c	63.90c	44.76f	44.76f	0.95a	2.67a	2.78a
16	11.30c	64.20bc	45.21e	45.21e	0.90ab	2.61bc	2.56bc
24	12.40a	63.64cd	54.11b	54.11b	0.90ab	2.56c	2.53c
0*	8.24e	64.53a	49.74c	14.47b	0.97a	2.70a	1.81d
8*	8.21e	64.56a	49.27d	49.27d	0.91ab	2.70a	1.88d
16*	7.72f	64.35ab	49.72c	49.72c	0.83b	2.61bc	1.87d
24*	9.47d	63.57d	54.63a	54.63a	0.97a	2.67c	1.69e
SE ±	0.05	0.11	0.04	0.04	0.03	0.02	0.03
CV%	1-8	0.9	1.0	1.4	5.7	1.2	2.5

*Chemical analysis was performed after four months storage period.
Means in a column followed by the same letter(s) are not significantly different at P=0.05, according to Duncan's Multiple Range Test.

CONCLUSIONS

Application of solar energy as a replacement to direct use of insecticides appears an encouraging solution for treatment of stored dates to control insects, with no harmful residues or chemical by-products.

Raising of temperature to lethal limits by exposing either black iron sheets or polyethylene ones to solar energy to control stored date insects is a simple, feasible technique. It is low costing and suitable for long term storage in rural areas. Six and 12 hours are enough to control *E. calidella* in the iron heat and polyethylene heat collectors, respectively, and 18 and 24 hours to control *O. surinamensis*.

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إستخدام الطاقة الشمسية لمكافحة حشرات التمور المخزونة

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المستخلص: أجريت تجربة في محطة بحوث شمبات، هيئة البحوث الزراعية ، في نوفمبر عام 2007، لمكافحة حشرتي فراشة التمور المخزونة *Ephestia calidella* (Guen.) وخنفساء الحبوب المنشارية *Oryzaephilus surinamensis* (L.) التي تصيب التمور المخزونة. استخدمت مجمعات لحرارة الشمس سوداء اللون من الحديد والبلاستيك وعرضت لحرارة الشمس . أظهرت النتائج أن هناك تبايناً كبيرا ً بين الشاهد الذي وضع على الأرض مباشرةً معرضا ً لحرارة الشمس ومجمعات الحرارة التي صممت من البلاستيك ومن الحديد، فقد كان متوسط درجة الحرارة 41.5°م و 53.7°م و 57.4°م علي التوالي، بينما كان متوسط درجة الحرارة 33.1°م والرطوبة النسبية المحيطة 52.9 % . وجد أن 6 ساعات و 12 ساعة كانت كافية لمكافحة حشرة فراشة التمور في مجمعات الحديد والبلاستيك على التوالي ، أما لخنفساء الحبوب المنشارية فقد كانت 18 ساعة و 24 ساعة على التوالي . تعريض البلح الى متوسط درجة حرارة 57.4°م لمدة 24 ساعة لم تؤدي الى تغيير كبير في مكوناته الكيميائية ولكنه أدى الى تحول جزء من السكروز الى سكريات بسيطة .