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Postharvest treatment of dates

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Abstract

Purpose of review: The increasing demand for high quality dates that are not chemically treated and the phase out of methyl bromide (MB), which is used in fumigation and disinfestation of dates, have created the interest for preparing this review.

Recent findings: Reports in recent studies include: (1) improved practical techniques for the application of solar energy in the maturation and drying of dates in the open and close to date gardens; (2) new data related to the moisture content, water activity and equilibrium relative humidity (ERH) of dates; (3) initial data on the relationship between the level of ERH and the market appropriate texture of Medjool dates; (4) the importance of harvesting Medjool dates at 65% ERH; (5) a novel approach to the integration of the heat disinfestation method in the date drying process (this approach has the potential to fully replace the fumigation treatments with MB at the receipt stations for the Medjool variety); (6) the emigration of pests from fruits by using heated air (50^{o}C) that also controls the pests within an exposure time of 2 h after the date reaches the target temperature; (7) storage methods based on the use of modified atmospheres to replace refrigerated storage.

Directions for future research: Additional work is needed to define the feasibility of the heat disinfestation method on the quality of date varieties other than Medjool. The potential of heat to cause emigration of insects when dates are handled in bulk should be elucidated.

Keywords: date; disinfestation; storage

Abbreviations

a_w	Water Activity
CA	Controlled Atmosphere
EMC	Equilibrium Moisture Content
ERH	Equilibrium Relative Humidity
MA	Modified Atmosphere
MB	Methyl Bromide
PH_3	Phosphine

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Introduction

Phoenix dactylifera L., the date palm, has been in the Middle East and North Africa as a staple food for thousands of years. The largest date production in the world is concentrated in a few countries in this region. In 2001, the top 10 date-producing countries were Egypt, Iran, Saudi Arabia, Pakistan, Iraq, Algeria, the United Arab Emirates, Sudan, Oman and Morocco, accounting for about 90% of the total world production of dates. The world production of dates has increased from about 1.8 million tonnes in 1961 to 2.8 million in 1985, and to 6.9 million in 2005 [1]. Trade figures indicate that about 93% of date harvested is consumed locally and the majority of these palms are not of the well-known export varieties. Although the date palm is a traditional crop in many countries, it has only recently been introduced in modern plantations in the USA, Israel and the southern hemisphere [2].

Date fruit has a single seed, is oblong in shape, and becomes sweet when ripe. Dates are a high-energy food due to the high content of carbohydrate and other nutrients. For the interested reader, further information on the propagation, production and protection of date palm is given in several publications [3–5]. The diversity of the date crop, date derived products and palm products in particular have also been described [5].

In spite of the importance of this crop, most of the handling and storage methods remain traditional [7–11]. This article reviews new approaches and original data related to date maturation, moisture content, drying, storage and disinfestation methods. In view of the phase out of methyl bromide (MB) [12], particular emphasis is placed on non-chemical disinfestation methods including heat treatment.

Date varieties

Dates can be classified according to their physiological development to reach maturation and storage conditions, which is reflected in their characteristic appearance and texture. There are primarily four types: Fresh (must be consumed as fresh, typically Barhee variety), Wet (maturation occurs at low temperatures and can be stored under refrigeration, typically Hayany variety), Semi-dry (typically Deglet Noor and Medjool varieties) and Dry (typically Halawy, Khadrawy, Zahidi, Ameri and Thoory varieties) [3–6, 13].

Treatments before storage

Dates distinguish themselves from most other fruits by their botanical maturity characterised by at least three distinct commercial maturity levels; the sweet Khalaal (physiologically mature, yellow or red, with 50–85% moisture content), the Rutab (partially browned, with 30–45% moisture content) and the Tamr (amber to dark brown, with moisture content <25% down to 10%). Fruit harvested at the Tamr stage is non-perishable since micro-organisms cannot grow on it [3].

Not all fruits in a cluster and all clusters on a palm ripen at the same time. A number of pickings may have to be made over a period of several weeks. High-quality dates are picked individually by hand, but most are harvested by cutting off the entire cluster. In some countries, the harvesters climb the palms and use forked sticks or ropes to lower the fruit clusters, or they may pass the clusters carefully down from hand to hand (North Africa). In California and Saudi Arabia, the growers use various mechanised means such as harvesting-saddles, extension ladders or mobile towers with catwalks for harvesting [9].

Maturation (curing)

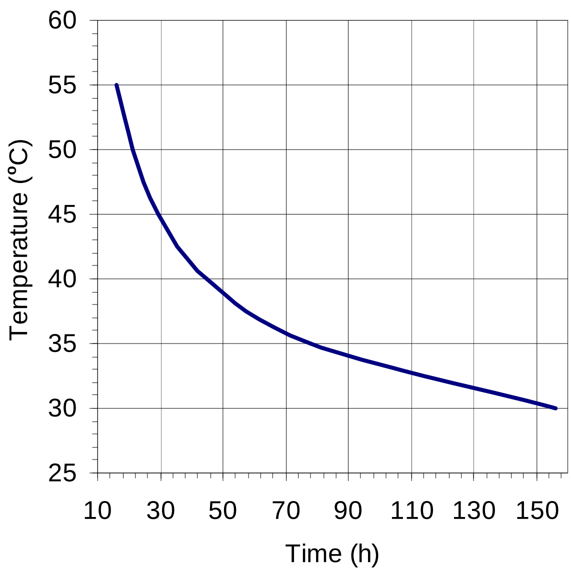
When ripening is not completed entirely on the palm or early rains threaten to damage the crop, maturation can also be achieved by artificial heat treatment. Artificial maturation consists of imitating the optimum conditions for ripening on the palm. The process requires rooms in which temperature, humidity and air ventilation can be controlled. Maturation is quite often accompanied by removal of moisture. The optimal temperature for Deglet Noor should not exceed 35°C, but most other varieties will permit higher levels, though not exceeding 50°C. Relative humidity also varies according to variety and the need to remove moisture or not. Because of these moderate conditions, the time required is usually rather long, a matter of days rather than hours. Artificial maturation is therefore a delicate, time-consuming process, and very variety-specific. In modern packing houses, prematurely-harvested dates are ripened in controlled atmospheres (CAs), the degrees of temperature and humidity varying with the nature of the cultivar [6].

A common practice for the Medjool date variety is to collect the dates that fall to the bottom of the net, which covers each cluster at each picking. Since not all fruits in a cluster ripen at the same time, it is very common to harvest a significant portion of immature dates particularly at the first pickings. A common practice developed in the Jordan Valley (Israel) is to separate these immature fruits for ripening using solar energy. Laboratory work carried out has demonstrated the relationship between the temperature and time necessary for ripening of immature Medjool dates (Figure 1) [14]. This relationship indicates that at the lowest tested temperature of 30°C, maturation required as much as 156 h, whereas at 50°C maturation time was 21 h. It should be noted that at the highest temperature tested (55°C), date appearance significantly changed and skin separation (blistering effect) from the fruit occurred. The relationship shown in Figure 1 can be plotted in an equation that leads to a constant value expressed as:

$$K = T. \ln(t)$$

Where T = temperature in °C and t = time in h. The calculated constant value (K) in the specific case of Medjool matu-

Figure 1. Time necessary for ripening of immature Medjool dates at various temperatures. Adapted from Kanner *et al.* [14].



ration shown in Figure1 is 152.2. Alternatively, based on this constant and knowing the maturation temperature, the time necessary for maturation can be calculated using the following equation:

$$\ln(t) = 2K/((\Sigma(t_{max})/n) + 30)$$

Where $\Sigma(t_{max})/n$ = average maximum daily temperature inside the maturation pallet. For example, if the average maximum daily temperature is 40°C, then the equation will result in 77.4 h, the time needed to reach maturation of the Medjool variety in the pallets. The time 77.4 h is the cumulative time when the maturation temperature is above 30°C.

Field tests using shrink film to cover the pallet containing trays with immature Medjool dates gave excellent results. The principle with this type of maturation is based on the use of solar energy by exposing the pallets to solar heat in the open. Calculations showed that the energy required for field maturation is cumulative and predictable using the above equations. In field conditions, covering the pallets with the shrink film may cause slight condensation. To overcome this phenomenon, a ventilation window (shown in Figure 2) must be left open to prevent excessive accumulation of moisture at the top layers of the shrink film covered pallet.

Moisture content

The enzyme invertase determines the speed and level of transition from disaccharide to two monosaccharide, fructose and glucose. The level of fructose and glucose influences the speed of drying, the activity of the polygalacturonase and cellulase, and the relationship between the moisture content and the water activity (a_w); a_w is the ratio of the vapour pressure of water in a product or solution to that of pure water at the same temperature [5].

Figure 2. Two types of shrink film covered pallets for ripening Medjool dates using solar energy. Note the small ventilation opening to prevent condensation on trays located at the top layer.

Equilibrium relative humidity (ERH) and a_w are numerically equivalent but ERH is expressed as a percentage; thus, a_w 0.65 = 65% ERH [15]. Dates are hydroscopic and lose or gain moisture until equilibrium is reached with the relative humidity of the surrounding air. This relationship is expressed in terms of equilibrium moisture content (EMC) or in terms of ERH. The EMC defines the levels of moisture content on wet basis in terms of the ERH with which the commodity is in equilibrium. The ERH defines the level of the air relative humidity surrounding the commodity with the corresponding commodity moisture content on wet basis.

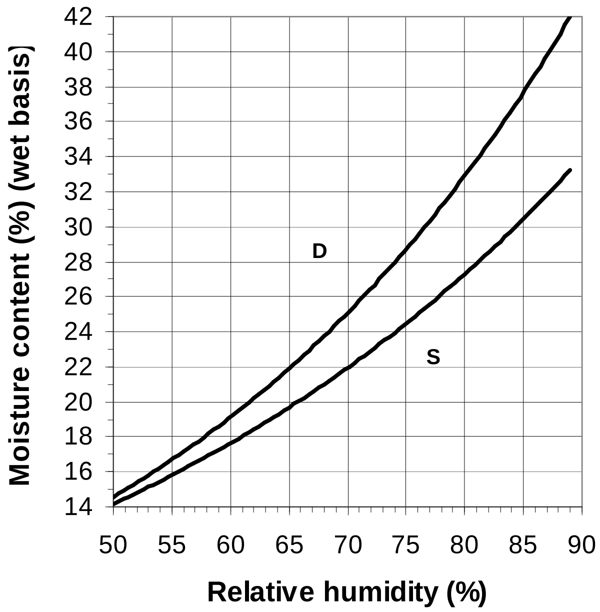
The intensity of microbiological activity in a stored crop is largely determined by the a_w. At an a_w slightly >0.65, *Aspergillus restrictus* and species of the *A. glaucus* group grow slowly. Different products with the same a_w may have very different water contents [15]. For example, commodities with high sugar content have a lower a_w than cereals and oil seeds. Dates with lower sugar content (eg, immature dates) will increase the a_w. This poses a technical difficulty for dates with moisture content in the border line of their storability, which might deteriorate due to microflora activity because of the high a_w. Since a_w reflects the availability of water for metabolic processes under the influence of different levels of sugar content, a_w (or ERH) is a more useful parameter than moisture content, particularly in dates. Therefore, the most accurate criterion for deciding on the storability of dates is the a_w.

It is very important to appreciate the practical significance of the ERH. It is not possible to dry dates to a moisture content lower than the ERH associated with the temperature and humidity of the drying air; eg, the data in Figure 3 show that dates can only dry to a moisture content of 21% (desorption) when exposed to air at 26°C and 65% relative humidity. If dates at moisture content less than 21% are required, then either the humidity of the drying air has to be reduced or the temperature increased.

An important aspect to consider is the initial moisture content of the dates, whether they were at the high level, immediately after harvest, in a drying process (desorption), or they were already dry and were subjected to higher humidity levels in the hydration process (sorption) as indicated for the Medjool variety at 26°C (Figure 3). Temperature also plays an important role in determining the ERH values of each commodity. Therefore, each ERH should indicate for which specific temperature value the isotherm is valid.

The harvesting method is planned in such a way as to ensure that the fruit has the appropriate texture when it reaches the market. It must be soft and elastic, so it can be packed and preserved without changing shape. Its moisture should be 20–26% (when fresh), with ERH of not more than 65%. Consequently, dates of <65% ERH ensure resistance to microbiological factors such as mould, yeast and bacteria that attack the fruit. Therefore, harvesting should take place while the

Figure 3. Equilibrium relative humidity values for sorption and desorption isotherms expressed by the relationship between the air relative humidity and moisture content (%) (wet basis) of Medjool date variety at 26°C.



Abbreviations: D, desorption; S, sorption

fruit has a relatively high water content in order to prevent the fruit from losing water and becoming hard in texture.

Data on ERH values for Bikraari dates reported by Dowson and Aten [5] (indicated in EMC values) were significantly different from those reported by Glasner *et al.* [3] and Kanner *et al.*, [14] (indicated in a_w values). Care should be taken in developing such data to indicate whether the values represent the sorption or desorption isotherm and the temperature at which the data were generated.

Texture

Texture depends mainly on the moisture content, but also on normal ripening which activates enzymes that soften the fruit. Moisture must be appropriate for market requirements and storage conditions [3]. A correlation was found between the moisture content and the texture of Medjool variety dates (unpublished data). Elevated temperature makes it very difficult to estimate the level of dryness of Medjool dates achieved and, therefore, it is difficult to decide when to stop exposure to the sun. Sun drying at ambient temperature that reaches 40°C or higher causes mature dates to soften, making it difficult to decide when to stop exposure. When the dates reach the ambient temperature of the room, the texture also changes from very soft to harder, depending on the moisture content. An alternative could be to take frequent samples to determine moisture content, particularly when the dates reach acceptable moisture content. However, moisture content determination in field conditions posed a serious barrier. Laboratory tests at 25°C showed that Medjool dates with ERH values of 50, 60, and 65% had corresponding texture values (measured in Shear Press Units) of 3.1, 2.7 and 1.7 Kg (f)/g (dry weight). Therefore, it was decided that overdrying should be avoided for the Medjool variety . A practical approach adopted in the Jordan Valley has been to frequently test the ERH values of the Medjool dates, particularly at the time the dates dry close to 65% ERH and then stop the drying process by removing the dates from the dryer or preventing further exposure to the sun.

Drying

Where there is low atmospheric humidity outdoors and adequate sunshine, harvested dates are sun dried whole or cut in half. In California, for fresh shipment, the normally ripe, harvested fruits are carried to packing plants, weighed, inspected by agents of the United States Department of Agriculture, fumigated, cleaned, graded, packed, stored under refrigeration and released to markets according to demand. Saudi Arabia has constructed a number of extra-modern processing plants for fumigation, washing, drying and packing of dates prior to cold storage.

Known methods of drying consist of solar drying and mechanical drying. Recently a hybrid solar and mechanical dryer was developed and successfully implemented in the Jordan Valley. A major advantage of this hybrid dryer is its ability to integrate heat disinfestation to its functionality, and will be described in the section on date disinfestation methods.

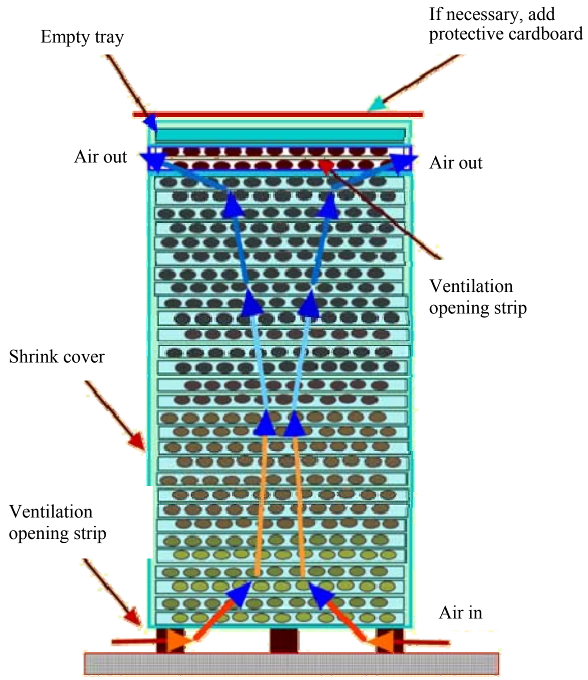
Conventional sun drying methods consisted of exposing trays containing dates to direct solar irradiation. In this method, the dates are exposed to occasional strong winds that cause dust to deposit on the dates, which reduces their appearance and quality because of the difficulty in separating the dust by washing them. A method found useful for sun drying, which eliminates the necessity to spread the trays on the ground for exposure to sun drying is to expose the entire pallet covered by shrink film, but leaving a strip at the top and bottom layer to permit ventilation. Figure 4 is a schematic presentation of this type of solar dryer found particularly suitable for Medjool dates. Using this method of drying, data on average moisture contents to reach 65% ERH in the Jordan Valley is shown in Figure 5. Accordingly, from ERH values of dates at about 76% to reach 65% takes about 7 days for dates positioned at the top layers of the dryer, and 8 days at the bottom layer.

Disinfestation

Fumigation

Field infestations of nitidulid beetles in all date varieties pose a serious contamination problem. Until now, this problem has

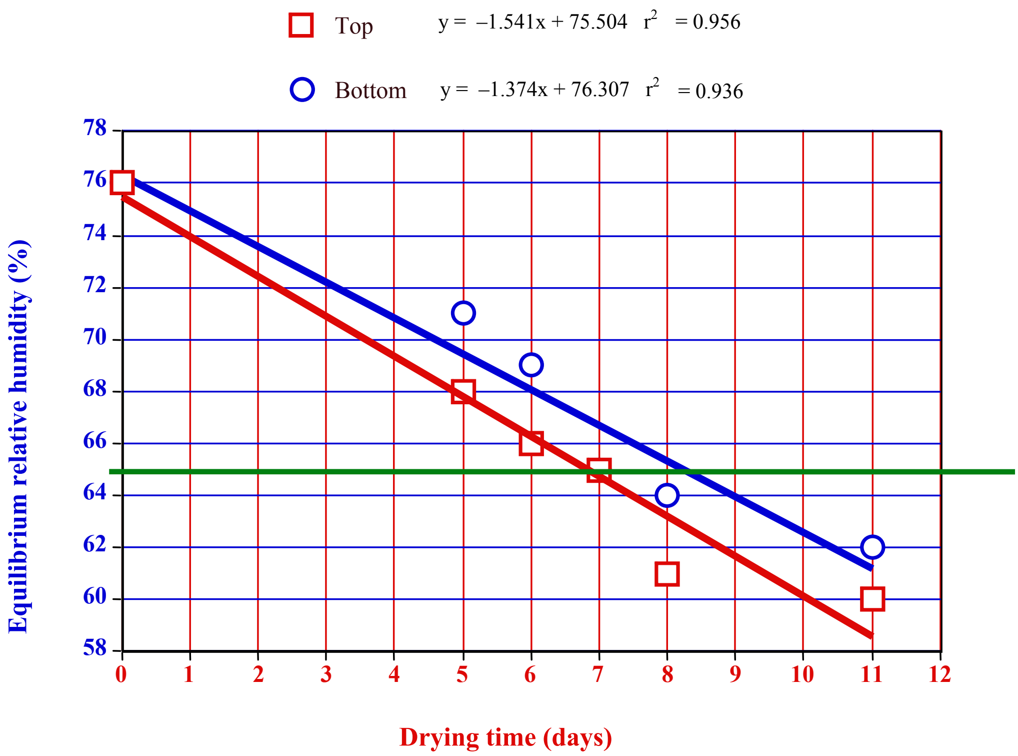
Figure 4. Schematic presentation of the sun dryer for Medjool dates. The pallet contains trays of dates covered by shrink film with a strip at the top and the bottom to permit ventilation.



been addressed successfully using MB. Its use has been mandatory to the date industry, particularly because it causes a high proportion of larvae and adults to emigrate from the fruit before they succumb. This emigration phenomenon is no less important than the toxic effect of the treatment. However, MB is now associated with depletion of the Earth's ozone layer and, under the terms of the Montreal Protocol, was phased out in January 2005 for Non-Article 5 (developed) countries, and will be phased out in 2015 for Article 5 (developing) countries, excepting for quarantine and pre-shipment fumigations. Nevertheless, the Methyl Bromide Technical Options Committee of the United Nations Environment Programme recognises the problem of MB phase-out in Non-Article 5 countries and, consequently, has recently published a handbook on Critical Use Nominations for MB [16]. This is to help parties submit requests for exemptions on a yearly basis under circumstances where no technically or economically feasible alternative treatment to MB yet exists. However, the parties that submit these nominations must demonstrate to the evaluation panel that they are making intense efforts to search for suitable alternatives.

Fumigation must not be carried out when the fruit is fresh, harvested at the Khalal stage, (Barhee, Khalas, Zaghlool and Hayany varieties) or when stored under deep refrigeration. The time recommended for fumigation is 12–24 hours. The temperature must be above 16°C. It is important for the air to

Figure 5. Time (days) necessary for sun drying of Medjool dates in 2 m high pallets covered by shrink film with ventilation strips at bottom and at top.



circulate within the fumigation chamber so that it spreads uniformly within the chamber.

The only other universally available fumigant for control of durable commodities is phosphine (PH_3). Regrettably, although PH_3 is a very useful fumigant, it is slow acting, has not been shown to cause insects to emigrate from the dates (disinfestation) and insects in various countries have developed resistance to this gas [17]. Other treatments have been examined for their disinfestation effect including the use of high carbon dioxide concentrations, low oxygen concentrations and low pressures. Although all three treatments cause high levels of disinfestation, they are not readily suitable for practical application at the point of entry into date packing houses [18].

Heat disinfestation treatments

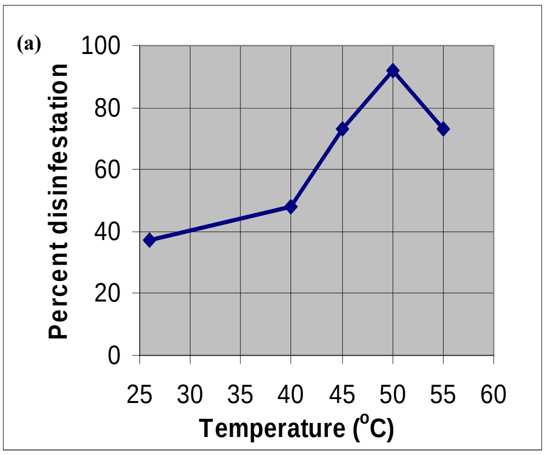
In the drying processes of the date industry, temperatures are usually kept moderate (35–55°C) to avoid discolouration and a blistering effect that separates the skin from the flesh of the fruit. The possibility that heat treatment may be effective in producing both emigration and control of nitidulid beetles in dates was tested in laboratory experiments using *Carpophilus hemipterus*, followed by field trials to integrate this technology into the existing date-drying procedures in Israel [19, 20]. Test insects were *C. hemipterus* larvae reared on a synthetic food medium and held at 26°C and 75% relative humidity. Artificial feeding sites destined to simulate the dates were prepared consisting of cardboard rectangles placed on food medium contained in Petri dishes. Exposure times of 2 h after the feeding sites reached the target temperature were employed. Temperatures of 40, 45, 50 and 55°C were tested. Disinfestation was greatest (92.3%) at 50°C (Figure 6a). At 50 and 55°C, 100% mortality was obtained (Figure 6b).

Commercial application of heat disinfestation: The drying facility consisted of a polyethylene clad hothouse 40 m long x 10 m wide x 3 m high, specially prepared for large-scale commercial drying of dates (Figures 7–9) [21, 22]. The hothouse can accommodate up to 12 rows of stacked dates positioned in parallel across the hothouse and covered over their top and sides with polyethylene liners to form drying ducts. Each row consists of 10 pallets, arranged five pallets lengthwise and two pallets across. Each pallet holds crates stacked 20 layers high with five crates (40 x 60 x 10 cm) per layer. Each crate holds 3 kg of dates, one layer deep of the variety Medjool. Thus, a standard row consisting of 10 pallets holds 3 tonnes of dates.

Since drying temperatures for most date varieties are between 45 and 50°C, and because percent disinfestation and control were most effective at 50°C, these findings were examined at a commercial drying facility. It was shown that between 1–2 h were required for the dates to reach the set temperature of 50°C. During the following 2 h, dates were exposed to heated air (50°C), after which an examination of infested dates inserted into the drying ducts, and natural infestations showed that successful emigration and control were obtained. This method produced results comparable with those obtained with MB fumigation, and was suitable as a replacement strategy for infestation control. The drying facility served for heat disinfestation of 650 tonnes of Medjool during the season of 2005, to the full satisfaction of the processors.

Integration of heat treatment in the disinfestation processes of dates: The conventional handling practice for dates, when disinfestation is based on fumigation, permits the use of small fumigation chambers. The raw dates follow the sequence of receipt of dates at the packing stations, first fumigation, and then storage, sorting and drying. The initial quick

Figure 6. (a) Percent disinfestation of *C. hemipterus* larvae from artificial feeding sites at various temperatures for 2 h of exposure after the test temperature was reached. (b) Percent mortality of *C. hemipterus* larvae exposed to various temperatures for 2 h after the test temperature was reached [19].



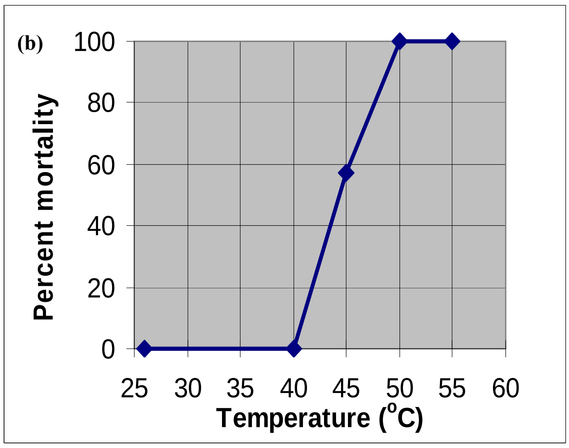


Figure 7. Schematic diagram of the date drying hothouse: (a), drying ducts; (b), open face of a row; (c), axial fan; (d), opposite open face of a row; (e), heater; (f), hot air supply duct; (g), outlets from supply duct [21].

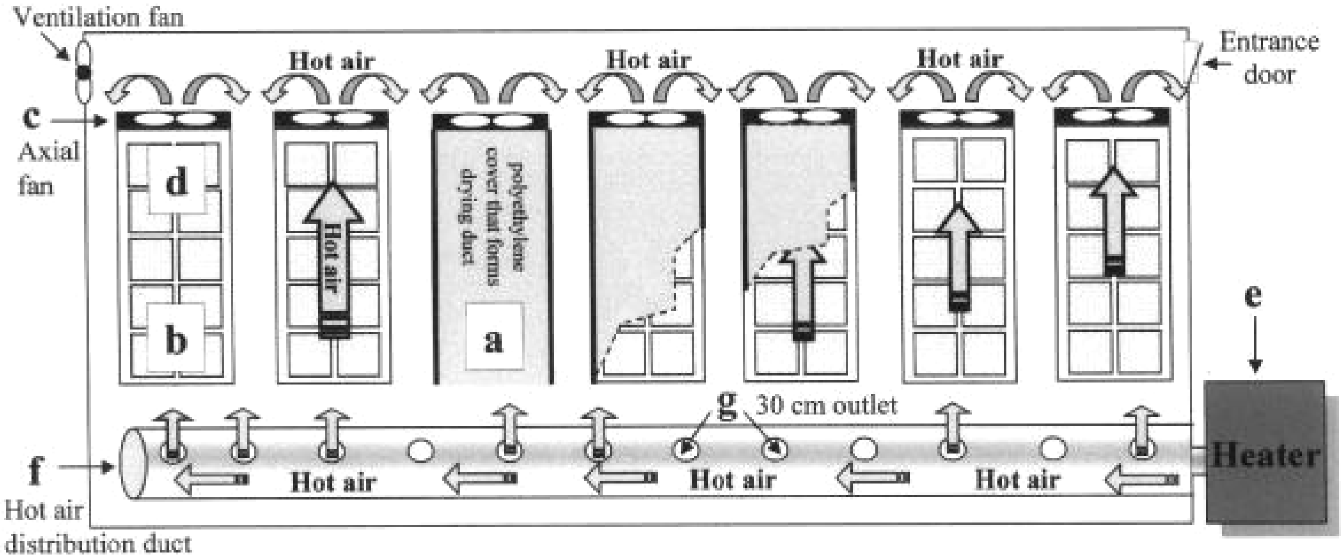


Figure 8. Internal view of the dryer, dates containing pallets, direction of heated airflow, and location of the axial fan [22].

Figure 9. General view of the dryer used for disinfestation of dates [22].

disinfestation based on MB precedes the storage and drying for two main reasons: to prevent insect contamination in the dates and the packing station, and the limited size of drying facilities. Drying time may be extended to a few days depending on the initial moisture content and the selected drying temperature. In the attempt to integrate heat treatment for disinfestation, the conventional sequence should be reversed to incorporate first the disinfestation in the drying process and then storage whether at ambient or cold storage (depending on the variety and moisture content).

An aspect that will necessitate further research and development is related to the application of heat on date varieties other than Medjool. So far the feasibility of heat treatment was demonstrated for only Medjool variety [20–22]. Further laboratory and field trials should concentrate on finding solutions for the even distribution of heat in large crates other than those trays used for the Medjool variety. The other types of handling and storage facilities consist of large crates of 200 or 450 kg capacity. For a successful heat disinfestation treatment, these crates need to be adapted to permit even distribution of heat.

Modified atmosphere storage of dates

In Israel, the conventional method of date conservation after harvest is cold storage at –18°C. This is the most suitable method for the sensitive soft-fruit cultivars, but it is highly energy consuming. In contrast to studies carried out in MAs for insect disinfestation, only very limited work has been carried out to determine the influence of MAs on date quality. Studies under laboratory conditions [23] and in field tests at ambient temperatures [24, 25] showed that CO_2 significantly delayed browning and sugar formation on dates, and extended shelf-life. On the basis of these earlier studies aimed at providing a non-toxic alternative to MB fumigation at ambient temperatures and to extending the shelf-life of dates, the application of MA technology to date storage on a commercial scale was studied, using a gastight plastic liner specially designed for the MA storage of dates in Israel.

A MA of 60–80% CO_2 was used within a 151 m^3 plastic chamber partially filled with 30 tonnes of dates stacked in crates on pallets [26, 27]. The dates were stored in the chamber in bulk (in boxes of 10 kg or crates of 400 kg on pallets) or packed (250 g capped plastic cups) on pallets containing dates of varieties Halawy, Khadrawy, Zahidi, Thoory and Ameri. Dates were sampled before closing the chamber, after one month and after 4.5 months at the end of storage. Presence of insects and moulds, skin sloughing, sugar formation, a_w and colour changes (only on Zahidi variety) were investigated. At the initial purge phase, the desired CO_2 concentration was obtained in the chamber within 1 h by introducing the gas under high pressure. An intermittent maintenance phase was then applied for 4.5 months using approximately 0.8 kg CO_2 per day. At the end of storage, quality of the treated dates was compared to controls stored at –18°C. No significant difference was found between the treated dates and controls. The insect population was effectively controlled. This technology is proposed for treating stored dates to control pests and maintain quality.

The current market demands fruit with higher moisture content. Preservation is ensured by storage under low temperatures. The temperature at which the fruit is stored is adapted to the time lag until the next treatment or until marketing. Low temperature must ensure the continued extermination of insects that have survived fumigation. Refrigeration must not influence properties, such as texture, moisture and colour.

The temperature and the speed of refrigeration also affect physiological phenomena, such as sugar crystallisation. Sugar crystallisation is caused by the breaking of cell walls or the tearing of the skin, facilitating the movement of water inside the fruit or out of it. This is related to the amount of moisture in the fruit. The risk increases when the amount of moisture rises above 20% (also at low temperatures). Today, the temperature commonly used for long-term preservation of dates of several varieties including Medjool is –18°C. This temperature decreases the sugar crystallisation and skin separation phenomena.

Conclusions

Ripening of immature Medjool dates using solar energy in shrink covered pallets was demonstrated as a practical solution. Ripening times could be estimated using the equations provided for Medjool dates. To estimate the storability of dates, a_w and equilibrium relative humidly are the most reliable parameters regardless the actual moisture content; this is because of the difficulty of relating the moisture content to a state of sorption or desorption isotherm. A reliable critical limit for market acceptable texture of dates is 65% ERH at 26°C.

A practical solar dryer based on shrink film-wrapped pallets that replaces the conventional spreading of the date trays in the field demonstrated drying times of approximately 7–8 days. Heat disinfestation during the drying process of Medjool dates was described; disinfestation was greatest and mortality of nitidulid beetles was highest at 50°C. A hybrid solar dryer consisting of a hothouse was described as useful in the application of heat disinfestation process. MA storage using CO_2 was shown to be effective in controlling pests during storage of dates.

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