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Date (Phoenix dactylifera L.)

E. M. Yahia, Autonomous University of Queretaro, Mexico and
A. A. Kader, University of California, Davis, USA

Abstract: Dates have been an important basic food for several cultures over thousands of years and they are still consumed widely all over the world, especially in the Middle East and North Africa. Date palms grow in several countries, but the industry is still concentrated in the Middle East and North Africa. Over 7 million tons of dates are produced annually, but only about 10% enters world trade. Dates are a nutritious, high-energy food, consumed fresh, dried or in various processed forms. Fruit of some dry date cultivars are not very perishable, and can thus easily be shipped to distant markets and be stored for prolonged periods. In contrast, the shelf life of some moist (soft or syrupy) date cultivars is limited to a few days unless special care is taken to maintain the cold chain between harvest and consumption sites. However, postharvest losses are high due to diverse physical, physiological, pathological and insect problems. Dates adapt very well to very low temperatures, and therefore storage and shipping at low temperatures is the most important method of maintaining quality. Low temperatures significantly reduce losses of colour, flavour, and textural quality; and delay development of sugar spotting, incidence of moulds and yeasts, and insect infestation; and prevent development of syrupiness and souring of soft, moist dates.

Key words: Phoenix dactylifera, postharvest, nutritional quality, health benefits, insects, storage, processing.

4.1 Introduction

Fruits of the date palm, Phoenix dactylifera L., have been a staple food for the population of the Middle East and North Africa for thousands of years (Yahia, 2005). The date palm is thought to have originated in Mesopotamia and its cultivation spread to the Arabian Peninsula (Fig. 4.1), the Middle East and North Africa in ancient times. It has been suggested that the Sumerians were the first to cultivate the date palm. They used its fruits as a staple food in the Tigris–Euphrates valley as early as 4000 bc (Al-Baker, 1972; Hussain, 1974; Ait-Oubahou and Yahia, 1999).
In 2007, world production of dates was about 7 million tons, with the Middle East and North Africa being the major producing regions. The top ten producing countries are Egypt, Iran, Saudi Arabia, United Arab Emirates, Algeria, Pakistan, Iraq, Sudan, Oman and Libya (Table 4.1) (FAO statistics, 2008). The date palm plays an important role in the economic and social life of the Sahara. In the old world, the Near East and North Africa are the region where dates are grown in large quantities. In Europe, the only commercial groves are those at Elche and Orichuela.

Table 4.1 Date production ('000 tons) in some important producing countries in 2007

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (tons)</th>
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<tr>
<td>Algeria</td>
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<td>Egypt</td>
<td>1 326 133</td>
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<td>Iran</td>
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<td>Iraq</td>
<td>440 000</td>
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<td>Libya</td>
<td>175 000</td>
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<td>Oman</td>
<td>255 871</td>
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<td>Pakistan</td>
<td>680 107</td>
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<tr>
<td>Saudi Arabia</td>
<td>982 546</td>
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<tr>
<td>Sudan</td>
<td>336 000</td>
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<tr>
<td>Tunisia</td>
<td>127 000</td>
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<td>United Arab Emirates</td>
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Source: FAO (2008)
in Spain. In the new world, important date palm plantations are in the Coachella valley of Southern California, in Arizona and in northwestern Mexico, and a few plantings in South America (Ait-Oubahou and Yahia, 1999; Pavez-Wellman, 2007; Wright, 2007). There are also some plantings of date palms in the Australian deserts in Queensland. Outside the regions mentioned above, and when the winters are not too cold for it, the date palm will grow, but will not fruit properly.

Date palms start to bear fruit at the age of 4 to 5 years and reach full maturity at the age of 10 to 12 years depending on local conditions affecting rate of growth and development. Flowers are borne in strands on bunches at the top of the tree. The number of bunches per tree varies from three to ten and each bunch includes hundreds of strands and thousands of individual dates. Average bunch weight varies from 5 to 20 kg. One palm can produce up to 100 kg annually, with some cultivars having average yields per tree of 180 kg (Munier, 1973). Depending on cultivar and area, the flowering to harvesting interval ranges between 6 and 9 months. The flowering period in the Northern Hemisphere lasts from late January to March and ripening starts in July and continues until October–November for late cultivars. The date fruit is a berry with a single seed or pit, oblong in shape, 2.5 to 7.5 cm long, with thick or thin flesh. It is astringent when immature and becomes sweet when ripe. The proportion of seed to flesh, which is an important parameter for fruit quality and classification, varies from 9 to 30%.

There are more than 2000 date palm cultivars in the world (Hussain, 1974; Ait-Oubahou and Yahia, 1999). Popenoe (1973) reported over 1500 cultivars of dates in the world. Over 455 cultivars have been reported in Iraq, and more than 350 in Oman (Laville, 1966; Vittoz, 1979). A large number of these cultivars are propagated by seed. Very few cultivars are grown extensively in major producing countries. Zahdi or Zahidi, Khadrawy, Hillawy, Khustawy, Maktoom, Shalabi, Sukari and Sayer are commonly grown in Iraq; Hayani, Samani, Zaghlol, Saidy and Duwaki are commercially grown in Egypt; Saidy and Bikraari in Libya; Boufgous, Bousthami, Jihel, Bouskri and Mejhoul or Medjool in Morocco; Deglet Noor (Figure 4.2), Rhars and Deglet Beida in Algeria; Deglet Noor and Ftimi in Tunisia; Halawi, Chichap, Shanker, Barhee (see Plate VI in the colour section between pages 274 and 275), Shahaani and Bureim in India; Anbara, Khalas, Khasab, Ruzeis, Kheneizy, Sukkary, Duwaiki and Khudairi in Saudi Arabia; Kabkab, Sayer and Shahani in Iran; and Jowan Sor, Karba, Kalud and Abdandan in Pakistan. In the US, Medjool (Paulsen, 2005), Deglet Noor, Zahdi, Khadrawi and Hallawi dominate commercial production (Ait-Oubahou and Yahia, 1999; Hodel and Johnson, 2007). In Oman, the main cultivars are Fardh, Naghal, Kamri, Mobsouli and Oum Sila (Vittoz, 1979).

Depending on the flesh consistency and moisture content at harvest when fully ripe, date palm cultivars are divided into three groups, namely soft, semi-dry and dry (Hussein et al., 1976; Yahia, 2004). However, fruit of any cultivar when left on the palm or exposed to excessive curing conditions will lose moisture and develop a hard texture. Other classifications can be found within the same group based on fruit characteristics, size and sugar content. In soft cultivars (like Hillawi, Abada, Amhat, Barhee, Bentaisha, Halawi, Hayany, Honey, Khadrawy and
Medjool or Mejhool), almost all cane sugar (sucrose) is converted into invert or reducing sugars (glucose and fructose) during ripening, with a moisture content > 30%. Dry date cultivars (<20% moisture) include cultivars such as Badrayah, Bartamoda, Deglet Beida, Horra, Sakoty and Thoory. Semi-dry date cultivars (20–30% moisture) include cultivars such as Amry, Dayri, Deglet Noor, Khalasa, Sewy and Zahidi. Both dry and semi-dry dates retain a good amount of sucrose on full ripening, in addition to the reducing sugars.

Deglet Noor (meaning date of the light in Arabic) produces medium- to large-sized fruits with small seeds; the fruits are light in colour, have a delicate flavour and are of the semi-dry type with excellent keeping quality during storage and transport. The fruit are sensitive to rain, which causes them to sour. Zahdi produces very sweet medium-sized fruits which are cylindrical in shape and light golden brown in colour. The fruit can be harvested soft or medium-hard to hard. They keep well during storage at very low temperatures. Hallawi (meaning sweet in Arabic) produces light-coloured, soft, large fruits, which are extremely sweet and honey-like. The skin of the fruit shrivels easily and the fruits are tolerant of high humidity. Khadrawi (meaning greenish in Arabic) produces soft, high quality fruits which mature early, tending to reach a dark colour at full maturity, and have a short storage period. Sayer, one of the most widely grown cultivars for commercial use, is not of high quality and has no distinctive flavour. The fruit are very mealy and the syrup is drained out or extracted commercially for sugar production. Medjool produces very large fruits (with proper fruit thinning) with a medium-soft texture and amber colour at maturity. The fruit have a thick flesh, are rich in flavour with a delicious taste, and keep well during storage and transport at low temperatures. Barhee (Plate VII) produces soft sweet fruits with excellent quality, appropriate
flesh thickness and a cylindrical shape, maturing to a dark brown colour. Khustawi fruits have good eating quality, are soft and very juicy, thus requiring good curing, and keep well in storage. Maktoom produces large fruits which are soft with a thick flesh and mature to a brown colour. Fruits of Amir Hajj mature mid-season and are of high quality, soft with a delicate skin but thick flesh and can withstand high moisture. Deglet Beida produces light-coloured fruits, with a smooth skin and hard texture, which mature earlier than Deglet Noor fruits. Kush Zebda produces fruits with long fruit stalks, superior fruit quality and a distinctive rich flavour. Tadala produces semi-dry, large fruits which are attractive, brown-to-amber in colour, mature early and have moderate tolerance to moisture in storage.

Dates are consumed fresh, dried, or in various processed forms. They are often consumed fresh after picking especially at the ripe stage (‘rutab’ stage). In some cultivars, fruits are consumed at the physiological maturity stage (‘khalal’ stage). Most dates, however, are consumed at the fully ripe (‘tamr’ or tamar) stage. The fruits at this stage are characterized by very low moisture content and therefore are ideal for long-term storage to be consumed out of season. Losses during harvesting and postharvest handling and marketing are high in most producing countries due to the incidence of physical, physiological and pathological disorders and to insect infestation.

4.2 Fruit growth and development

Flowers have three carpels but on pollination only one develops and two abort. The shape of the fruit is usually more or less oblong or ellipsoidal. The seed, or pit, is bony and cigar-shaped, slightly pointed at the ends, from grey to brown in colour, and with a small embryo. The seed of the date palm fruit is unusual in that it stores the food materials for the developing embryo not as starch, but as hemicellulose.

4.2.1 Pollination

Pollination is one of the most important pre-harvest factors affecting fruit quality in the date palm (Al-Delami and Ali, 1969). The date palm trees are dioecious, with male and female flowers on separate trees. In commercial plantation, the female trees are artificially pollinated (hand or mechanical pollination) with pollen from male trees. Selection of a good pollinizer is of prime importance in the date palm, as the type of the pollen parent affects fruit size and time of fruit ripening, as well as the chemical composition of the fruit. Such effects of the pollen parent on various aspects of date fruit development are referred to as mataxenia (Abbas, 1997a).

4.2.2 Fruit set

Fruit set in the date palm is closely related to the pollen viability as well as temperatures prevailing during the pollination period. Good fruit is usually
obtained when daily temperature is in the range of 23.9–26.2°C (Nixon and Carpenter, 1978). Poor fruit set resulting from low temperature can be improved by covering flower clusters with paper bags at the time of pollination (Rygg, 1975). A fruit set of 50–80% is considered sufficient to obtain a full crop.

4.2.3 Fruit thinning
Fruit thinning affects postharvest quality (Ait-Oubahou and Yahia, 1999). It is essential to ensure adequate flowering in the following year, to reduce or prevent the phenomenon of alternate bearing, to improve fruit quality and to promote fruit ripening and to reduce compactness of fruit bunches. Thinning can be done manually or by the use of growth regulators. Manual thinning is more common and involves removal of some bunches and/or some strands from each bunch and/or shortening the length of the strands. However, removal of some fruits from each strand is the best method of fruit thinning, but it is very expensive. The easiest method of fruit thinning is to remove a number of spathes or inflorescences and balance the number of bunches with the number of green leaves on the tree (Rygg, 1975). Various growth regulators have been used as thinning agents in the date palm, such as auxins (NAA, 2,4-D) and the ethylene releasing compound, ethephon, but with variable results, and therefore manual fruit thinning is still the widely used practice (Nixon and Carpenter, 1978; Rygg, 1975).

4.2.4 Factors affecting fruit development and ripening

Temperature
For proper date fruit ripening on the date palm, it is essential that the growing season is hot and free of rainfall during the ripening period. The average optimal daily temperature from blossoming until fruit ripening is around 21°C for early ripening cultivars, 24°C for mid season cultivars, and 27°C for late ripening cultivars. The number of heat units (degree days) needed to ripen the fruit varies with cultivar and ranges between 2100 and 4700 for early and late ripening cultivars, respectively. Temperature also has a significant effect on fruit quality. Deglet Noor fruit produced during seasons when the maximum daily temperature during April and May exceeded 37°C were of dry texture and had high acid content and a high percentage of sucrose, and lacked the bright colour characteristic of high quality fruit. In general, fruit produced with 101 heat units in April–May were of excellent quality, but when the heat units were in the range of 147–234, dry textured, low quality fruit were produced (Rygg, 1975).

Relative humidity and rainfall
High rainfall and humidity during blossoming or later stages of fruit development may limit the production of date palms to the same degree as insufficient heat units (Ait-Oubahou and Yahia, 1999). High humidity and rainfall during later stages of fruit development may cause certain physiological disorders.
Furthermore, low relative humidity (RH) during the ripening period may cause some physiological disorders. High humidity and rainfall have a pronounced effect on the process of pollination. Early rainfall during flowering in the spring may cause the infection of the closed spathes with inflorescence rot. Date cultivars vary in their susceptibility to this disease, with cultivars such as Hillawi and Zahdi being very resistant, and Khadrawi and Sayer very susceptible.

**Mineral nutrition**

The date palm tree requires high nitrogen for good growth and productivity, and it is less sensitive to other mineral nutrients such as iron and boron, as compared with other fruit trees such as citrus (Mater, 1991).

### 4.2.5 Fruit growth pattern

As already mentioned, the date palm is a dioecious tree and thus requires cross pollination, which occurs naturally or may be done artificially. The normal date palm fruit is a berry which results from the ovary (Mater, 1991). After pollination and fertilization, fruit growth follows a sigmoidal curve, and is usually divided into five stages of development known by their Arabic terms: ‘hababouk’, ‘kimri’ (kimri, jimri), ‘khalal’ (balah, bisr), ‘rutab’ and ‘tamr’ (tamar) (Figure 4.2) (Abbas and Ibrahim, 1996; Ait-Oubahou and Yahia, 1999; Yahia, 2004). The ‘hababouk’ stage starts after fertilization and is characterized by the loss of two unfertilized carpels. This stage is sometimes included in the next stage. The colour of the fruit at this stage is creamy to faint green. ‘Kimri’ is the immature green stage, characterized by high water content and a rapid gain in fruit weight and size. This stage lasts about 9 weeks depending on cultivar and location. ‘Khalal’ (Plate VII) is the mature full-coloured stage, which lasts about 4 to 5 weeks, and results in a slight decrease in fruit weight and size, as well as in starch content. The colour of the fruit changes from green to yellow, pink or red, or yellow spotted with red, depending on the cultivar. During the ‘rutab’ (soft or moist) stage, the fruit softens, changes colour to light brown, and starts to lose weight and accumulates more sugars (mainly reducing sugars). During the ‘khalal’ and ‘rutab’ stages, the fruit progressively loses water, and starch is converted to sugars. The ‘tamr’ (the Arabic word for dates) is the fully ripe stage of development, when the fruit loses more moisture and gains more sugars, thus attaining a high sugar:water ratio (depending on the cultivar). Most dates are harvested at the ‘tamr’ stage (Fig. 4.2), when the fruit has about 60 to 80% sugar content, depending on location and cultivar. At this stage, fruit can be harvested soft, semi-dry or dry depending on destination and use. Dates can also develop parthenocarpically if not pollinated. However, these fruits will not undergo the five stages described above and will not reach full development.

### 4.2.6 Effect of growth regulators on fruit and development

The early period of date fruit development is associated with a rapid rate of cell division activity particularly in the embryo and endosperm (Rygg, 1975).
However, the major increase in fruit size is achieved by the vacuolation (enlargement) of the cells formed during the early phase of mitotic activity. Auxins and gibberellins, sprayed onto fruit bunches, have been found to increase fruit size and delay fruit ripening, with inconsistent effects on fruit chemical composition (Rygg, 1975; Nixon and Carpenter, 1978; Abou-Aziz et al., 1982; Mater, 1991). Indole acetic acid (IAA) was found to be very high in non-pollinated flowers of Hallawi dates, declines at fruit set, increases again as the fruit enters the rapid phase of growth, then declines as the fruit advances towards the ripening phase (Abbas et al., 2000). The tendency of the date palm flower to set parthenocarpic fruits if not pollinated may be related to levels of endogenous hormones in the ovary of unpollinated flowers. Parthenocarpic date palm fruits may also be obtained by treating unpollinated flowers with auxins, gibberellins or cytokinins. Such fruits are of low quality as compared to fruits produced by hand pollination and they will not ripen fully (Abou-Aziz et al., 1982). Fruit ripening is usually delayed in trees carrying a heavy crop, which can be remedied by fruit or bunch thinning at an early stage of growth, with the objectives of balancing the number of green leaves and the number of fruiting bunches. Pre-harvest treatment of date fruit of several cultivars with ethephon at 100–500 ppm advanced fruit ripening by 7 to 9 days, and also provided an opportunity for mechanical harvesting of the fruit by facilitating fruit drop.

4.2.7 Biochemical changes during fruit growth and maturation

During the khimri stage the fruit is still green, contains maximum moisture content, a small percentage of sugars and high percentages of tannins and fibers, and therefore the fruit is not edible. As the fruit enters the khalal stage, the green colour is lost and the fruit starts acquiring the distinctive colour which may be yellow, pink, red, or orange, depending on the cultivar. The loss of chlorophyll and the appearance of the distinctive colour is associated with a rapid translocation of sucrose to the fruit, and during this stage the fruit fresh weight reaches its maximum value. Also during this stage, dry matter content and fruit firmness are increased, whereas tannins are reduced.

At the end of the khalal stage, the intensity of the distinctive colour is increased and the fruit starts to soften, as it enters the rutab or ripening stage (rutab literally means softening stage). Date fruit undergoes various physical and biochemical changes during ripening (Rygg, 1975). Softening of the fruit at this stage usually starts at the apical end and ripening progresses inwards and towards the basal end and until the whole fruit is ripe. At the rutab stage, the fruit loses the colour of the khalal stage and starts acquiring a light brown (amber) or dark brown or black colour, depending on the cultivar. The fruit also loses moisture and the size is reduced. The water content of the flesh decreases during fruit development and ripening. In Deglet Noor fruit, for example, the moisture content decreases from about 85% at the early khalal stage to 45% at the beginning of the rutab stage and is only 20% at the tamr stage. The skin surface is generally smooth from fruit set up to the khalal stage, and shows shrivelling or wrinkles as the fruit reaches

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maturity, as a direct consequence of moisture loss. In some cultivars, softening occurs slowly and gradually, while in others it occurs rapidly. Fruit picked at the rutab stage are usually highly perishable and require refrigeration.

If fruit are left on the tree and are not picked at this stage, then they enter the last, tamr stage. At this stage, both fruit fresh weight and size are reduced due to the continuing loss of moisture and the halt in the translocation of sugars. During the tamr stage, the intensity of dark colour increases, with no further changes in fruit weight, size, moisture content and sugars. The texture of date fruit at the tamr stage depends on the percentage of dominant sugars. It is dry if the fruit contains a high percentage of sucrose and the cultivars are called dry dates. However, if most of the sugars are inverted into reducing sugars (glucose and fructose), then the texture is soft and the cultivars are known as soft dates. If the fruit contains some sucrose as well as reducing sugars, then they are called semi-dry dates. Such classification of dates was found to depend on the activity of the enzyme invertase (Cook and Furr, 1952; 1953).

Several studies (Hasegawa and Smolensky, 1970; Hasegawa and Mair, 1972) have shown that the activity of invertase starts to increase as the fruit changes colour from green to the distinctive colour at the end of the khalal stage, and then increases sharply. As the fruit enters the rutab stage and the process of softening is completed, the activity of invertase decreases rapidly and reaches a minimum at the tamr stage. Postharvest induced softening of Deglet Noor dates was achieved by treating the fruit with invertase, causing 50% increase in reducing sugars as compared to control. Polygalacturonase activity was very low at the khimri stage, but increased rapidly as the fruit entered the khalal stage, reaching maximum value as the fruit entered the rutab stage, but thereafter, the activity declined rapidly (Hasegawa et al., 1969). The use of this enzyme for the artificial ripening of some date cultivars was reported by Hasegawa and Mair (1972). Cellulase activity was found to be low in fruit at the khimri stage, and increased as the fruit advanced in maturity, reaching a maximum value at the end of the khalal stage (Hasegawa and Smolensky, 1971). Studies carried out by Al-Jasim and Al-Delaimy (1972) on several Iraqi date cultivars showed that pectinesterase activity increased as the fruit changed from khalal to rutab stage, followed by a rapid decline as the fruit became fully ripe (tamr). Commercial preparations of synthetic enzymes have been used for artificial ripening as well as to reduce the damage caused by some physiological disorders, such as hard nose, mixed green and sugar walls. For example, a commercial preparation, pectinase, known as Pectino-42, has been found to be effective in reducing the damage caused by the physiological disorder ‘mixed green’ (Smolensky et al., 1973). Vacuum infiltration with cellulase at 0.1% for 2 hours was very effective in softening Deglet Noor dates and improving quality (Smolensky et al., 1975).

Date flesh texture is an important factor determining quality. Texture changes during fruit ripening from crisp to soft, except for dry cultivars which develop a hard texture after the loss of water content from the flesh. Fruit softening is related to the activities of polygalacturonase, pectinesterase and cellulase (Al-Jasim and Al-Delaimy, 1972; Coggins et al. 1968; Hasegawa and Smolensky, 1971;
Hasegawa et al., 1932; Hasegawa et al., 1969). Invertase was also found to play an important role in fruit softening as it converts sucrose into reducing sugars with the release of water molecules (Coggins and Knapp, 1969; Hasegawa and Smolensky, 1970). Hasegawa and Smolensky (1970) reported that the onset of cellulase, polygalacturonase and invertase activity was found to be correlated with fruit ripening in Deglet Noor and that invertase activity is higher in soft dates than in dry dates. This increase in invertase activity is stimulated by the loss of membrane integrity, which leads to direct contact of the substrate with the enzyme.

Fruit of all date cultivars are astringent at the immature green (khimri) stage due to the presence of tannins. In a few cultivars, such as Barhi, Samani and Zaghlol, the astringency disappears with the change in colour to yellow, orange, or red at the khalal stage. Dates contain significant levels of procyanidins or condensed tannins (the cause of astringency) at the khalal stage. These tannins, which are mainly in the skin, are polymerized as the fruit ripens to the rutaband tamr stages. The intensity of colour in fruit depends on the pigments produced by different browning reactions (Maier and Schiller, 1961). Vandercook et al. (1980) and Maier and Metzler (1965) discussed different systems of formation of brown colour pigments in dates and concluded that browning is due to oxidation of polyphenols and tannins. Temperature, moisture content and maturity affect the rate of colour change.

Dates are the only fruit in which flavonoid sulphates have been reported. Hong et al. (2006) identified 13 flavonoid glycosides of luteolin, quercetin and apigenin and a combination of some flavonol glycosides with sulphate residues in khalal stage Deglet Noor dates.

4.3 Nutritional components and health benefits

The fruit of the date palm has been a staple food in the Middle East and North Africa since the first recorded history. Date palm fruits were found to contain carbohydrates (44–88%), sugars (60–80%), fats (0.2–0.4%), proteins (2.3–5.6%), fibres (6.4–11.5%) (Hasnaoui et al., 2010; Chaira et al., 2007; Al-Shahib and Marchall, 2003). Dates are considered an excellent source of readily available energy supplying 160–320 kcal 100 g$^{-1}$ depending on moisture content (Ait-Oubahou and Yahia, 1999). The fruit are also rich in Fe, K, Ca, with small amounts of protein (2%), lipids (less than 2%), Zn, Cu, Cl, S and vitamins A, B1, B2 (Nixon and Carpenter, 1978; Rygg, 1975; Vandercook et al., 1980). The crude fibre, which contains pectin, lignin, hemicellulose and cellulose, represents about 2–4% of fruit dry weight. Pectin plays an important role in date texture (Hussein et al., 1976). Fruits of soft, semi-dry and dry cultivars have about 1.0, 1.8 and 1.5% pectins (dry weight basis), respectively, which decrease as the fruit ripen (Rouhani and Bassiri, 1976). The protein content of dates, which is reported to be of high nutritive value, ranges between 1.5 and 2.0%, and the crude fat content ranges between 2.5 and 7.4%. The seed oil is composed of 45% oleic, 25% palmitic, 10% stearic and 10% linoleic acid, with some capric and caprylic acid
content. The quantities of sucrose and reducing sugars, which are related to quality and texture, depend on the cultivar and fruit maturity and ripeness stage.

Dry and semi-dry dates are rich in sucrose, while most, or in some cases all, of the sucrose in soft dates is converted to reducing sugars (glucose and fructose), so they have a very low sucrose content or contain no sucrose at all. In a study of 12 date cultivars produced in the United Arab Emirates (Ahmed et al., 1995), glucose and fructose levels increased rapidly throughout the developmental stages. The sucrose in Rhars dates in Algeria and Boufgouss and Mejhoul (Medjool) dates in Morocco is entirely hydrolysed to reducing sugars and thus they contain no sucrose at harvest (Munier, 1965), whereas in Deglet Noor, sucrose remains the dominant sugar at harvest (Djerbi, 1996).

The glucose:fructose ratio in Deglet Noor fruits grown in California has been reported to be 1.28 (Coggins et al., 1968). Yusif et al. (1982) found that fruit of the cultivars Hallawi, Sayer, Khadrawy and Zahdi in Iraq had glucose:fructose ratios of 1.17, 1.17, 1.16 and 0.83, respectively. Total sugars (reducing sugars and sucrose) increase during fruit development. Deglet Noor fruits have total sugars and sucrose contents, respectively, of 13 and 8% at the khimri stage, 60 and 40% at the khalal stage, and 77 and 53% at the rutab stage (Djerbi, 1996). Starch content, found mainly during the khimri and khalal stages, is converted to sugars and no starch is found at the ripe (rutab and tamr) stages (Djerbi, 1996).

The flavour and quality of dates are affected by their organic acid content. The acidity of the fruit tends to increase with fruit growth and then decreases at the beginning of the ripening stage, while pH increases at maturity. A high pH value is an indication of high quality in dates. Date acidity reaches the highest level during the period of most rapid growth and decreases during maturation and ripening (Rygg, 1975). Rouhani and Bassiri (1976) reported that titratable acidity decreased from 7.7 at the immature stage to 1.4 meq 100 g$^{-1}$ dry weight at the mature stage, and pH increased from 5.1 to 7.0 between these stages. Palmitic acid is the most dominant acid followed by capric and caprylic acids. In Deglet Noor dates, pH changes from 5.5 at the khimri stage to 6.2 at the rutab stage (Djerbi, 1996). Rouhani and Bassiri (1976) reported the same observations for cv. Shahani grown in Iran. The authors found that pH increased from 5.1 to 7.0 with fruit ripening, and acidity decreased from 7.7 to 1.4 meq 100 g$^{-1}$. In six date cultivars in Iran, fruit acidity remained relatively high and ranged from 2.5 to 4.4 meq 100 g$^{-1}$ (Ejlali et al., 1975).

Date fruits at the fully mature stage are rich in functional components, including phenolic compounds (Al-Farsi et al., 2005; Al-Farsi and Lee, 2008; Hussein, 1970; Sawaya and Mashadi, 1983; Al-Ogaidi and Mutlak, 1986; Regnault et al., 1987; Ramos et al., 1997; Modafar et al., 2000; Al-Abid, 2003; Ishurd et al., 2003; Allaith et al., 2008; Biglari et al., 2008; Saafi et al., 2009). Tannins, which are the most dominant phenolic compounds in date fruits and are closely associated with the fruit ripening process, decrease from a high level in the khalal stage to reach minimum concentration in the ripe (rutab and tamr) stages (Rouhani and Bassiri, 1976; Sawaya and Mashadi, 1983). Antioxidant activity varies among date cultivars from moderate to high relative to other fruits. Several studies have
indicated that the aqueous extracts of some dates have potent antioxidant and antimutagenic activity (Alhumaid et al., 2010; Mansouri et al., 2005; Mohamed and Al-Okabi, 2004). Dates were reported to have the second highest antioxidant activity among 28 fruits commonly consumed in China (Guo et al., 2003).

4.4 Postharvest physiology

4.4.1 Respiration

The respiration rate of dates is very low, < 5 mg CO$_2$ kg$^{-1}$ h$^{-1}$ at 20°C at the khalal stage, and < 1 mg kg$^{-1}$ h$^{-1}$ at the rutab and tamr stages, and increases with higher moisture content (Yahia, 2004). Cured Deglet Noor dates with 20–22% moisture produced 0.4 mg CO$_2$ kg$^{-1}$ h$^{-1}$ at 24°C, and 2 mg CO$_2$ kg$^{-1}$ h$^{-1}$ when the moisture content increased to 27% (Rygg, 1975). The rate of CO$_2$ production is high initially, but declines steadily as the fruit advances in maturity, reaching its lowest level as the fruit enters the stage of physiological maturity, and then increases to reach a peak as the fruit ripens (Abbas and Ibrahim, 1996). Rouhani and Bassiri (1976) found that the respiration rate of Shahani dates was high during the early stages of fruit development and decreased sharply as the fruit entered the ripening phase. Seed respiration accounts for about 20% of gas exchange in whole dates (Rygg, 1975). Most reports indicate that dates are non-climacteric (Biale and Young, 1981; Yahia, 2004; Ait-Oubahou and Yahia, 1999), although Abdul-Latif (1988), working with three date cultivars (Zahdi, Derey and Sultani), and Taain (1997) on Braim dates, claimed that the fruit is climacteric. Parthenocarpic fruit of Hillawi date did not experience the climacteric rise in respiration during development (Abbas, 1997a). Treatment of date fruits of several cultivars with ethephon was reported to increase the respiration rate and advance ripening (Rouhani and Bassiri, 1997).

4.4.2 Ethylene production and responses

Dates produce very low concentrations of ethylene; less than <0.5 μL kg$^{-1}$ hr$^{-1}$ for khalal stage dates and less than 0.1 μL kg$^{-1}$ hr$^{-1}$ for rutab and tamr stage dates kept at 20°C (Yahia, 2004). Ethylene production in Hallawi dates was not detected until 91 days after pollination, increased to reach a peak within 15 days and then declined rapidly (Abbas and Ibrahim, 1996). There is no effect of exposing khalal stage, yellow Barhee dates to 100 ppm ethylene for up to 48 hours at 20°C and 85–90% RH (Ait-Oubahou and Yahia, 1999). However, khalal stage dates may respond to ethylene action at higher temperatures (30–35°C), which are optimal for their ripening (Kader and Hussein, 2009). Rutab and tamr stage dates are not influenced by exposure to ethylene (Yahia, 2004; Ait-Oubahou and Yahia, 1999). Application of ABG-3161 (an ethylene blocker) at 3.33 g L$^{-1}$ significantly inhibited ripening of Helali dates, suggesting that ethylene has a role in fruit ripening (Awad, 2007).
4.4.3 Responses to modified (MA) and controlled atmospheres (CA)

MA and CA have been investigated for maintaining date fruit quality and for insect pest disinfestation (Al-Redhaiman, 2005; Baloch et al., 2006; Navarro et al., 2001). An elevated carbon dioxide concentration is fungistatic (inhibits growth of fungi), but once the dates are transferred to air, the fungal growth will resume, especially under higher temperatures (Yahia, 2009). Thus, it is important to market khalal dates stored in MA/CA soon after removal from storage. Packaging tamr dates in low-oxygen atmospheres (using vacuum packaging or nitrogen) can be useful in quality maintenance and insect control (Yahia, 2009). Navarro et al. (2001) reported that use of CA during ambient temperature storage is feasible to control insect pests and maintain the quality of dates for 4.5 months. Hallawi, Hadrari, Zahidi, Derei and Ameri dates were stored in a CA containing 60–80 kPa CO$_2$ for 4.5 months with no significant changes in peel sloughing and sugar formation on fruit surface, and quality of CA-stored dates was as good as those stored in normal air at −18°C (Navarro et al., 2001). Fruit quality of mature Barhi dates stored at 0°C under CA containing 5 or 10 kPa CO$_2$ (balance air) was maintained for 17 weeks against 7 weeks in air, while increase in CO$_2$ to 20 kPa was more effective for maintaining fruit colour, firmness, soluble solids and total tannins for 26 weeks (Al-Redhaiman, 2005). The degradation of caffeoylshikmic acid (CSA), one of the major phenolics undergoing losses during ripening, was also retarded greatly by CA containing 20 kPa CO$_2$ which suggested that CA was very effective in retarding the ripening process in dates. Fruit having lower levels of water activity (0.52 a$_w$) were stable for 4 months when stored under nitrogen atmosphere at 40°C (Baloch et al., 2006). The storage of fruit in air or oxygen atmosphere resulted in an increase in skin darkening and titratable acidity during storage; the same effects were also observed with an increase in the water activity of fruit (Baloch et al., 2006). The tolerance of dates to high CO$_2$ has been exploited to develop biologically safe alternatives to fumigation treatments to control storage pests (Navarro et al., 2001). Rygg (1975) suggested inert gas or vacuum packing for storage of high-moisture dates. Vacuum packaging was found to be useful for reducing darkening of dates during long-term storage (Mohsen et al., 2003). Browning was inhibited at low oxygen atmospheres (Mutlak and Mann, 1984). Further research is needed to investigate the effects of different atmosphere regimes on the quality of dates harvested at different maturities and with different moisture levels.

4.5 Maturity and quality indices

4.5.1 Maturity and harvesting indices

The stage of maturity at which the fruit are harvested depends on the cultivar and the purpose and intended day of fruit consumption. Time of harvest is based on sugar content, moisture content, date appearance and texture. Dates for immediate sale are often harvested when moisture content is still high, whereas dates to be stored are left on the palm for natural curing to lose excess moisture. As mentioned
above, maturity stages of dates include hababouk (earliest stage of development), khimri, khalal (Plate VI), rutab and tamr (Fig. 4.2). A few date cultivars rich in sugars and low in tannins, such as ‘balah’ in North African countries, ‘bisr’ in Oman, Barhee (Barhi, Berhi), Hayany, Samany and Zaghlol, are harvested at the khalal stage (partially ripe) when they are yellow or red (depending on cultivar), but many consumers find them astringent (due to high tannin content). Dates of other cultivars harvested before full maturity must be ripened artificially. Very immature dates cannot be properly ripened artificially and consequently will be of poor quality. Most dates are harvested at the fully ripe rutab (light-brown and soft) and tamr (dark-brown and soft, semidry, or dry) stages, when they have high levels of sugars, lower amounts of moisture and tannins (disappearance of astringency), and are softer than the khalal stage dates. Deglet Noor fruits should not be harvested before the turning stage in which the texture is yielding-to-pliable and the colour is amber-to-cinnamon. Fruits harvested with a reddish ring at the perianth end have better storage potential than fruits left on the palm until the ring has faded with more advanced maturity (Rygg, 1975). Hallawi fruits should not be harvested before the soft ripe stage, but can also be picked in the tamr stage. Maktoom and Bouf gouss fruits can be harvested when 10–25% of the surface is translucent, and then ripened to an acceptable quality.

A number of physical and chemical changes have been assessed as indices of maturity and harvesting (Ait-Oubahou and Yahia, 1999), including the increase in total sugars, total soluble solids, colour changes from green to yellow or red or orange or purple according to the cultivar, the rapid fall in fruit firmness, the sharp decrease in moisture content, the increase in reducing sugars and the decrease in sucrose, as well as the decrease in acidity and loss of tannins. The possibility of using the rise in ethylene production as a physiological indicator of maturity in Hillawi dates was also assessed, and the results showed that the rise in ethylene production began in 7–10 days (depending on the type of the pollen parent used in pollinating the female flowers) before fruit ripening (Ibrahim, 1996).

### 4.5.2 Quality indices

**Quality characteristics and criteria**

The date is a berry with a single seed that varies in size from 9 to 30% of the fruit weight; a smaller seed or pit and thicker flesh are preferred. Dates may be round, oval, oblong or cylindrical in shape, depending on the cultivar (Ait-Oubahou and Yahia, 1999; Yahia, 2004).

Quality characteristics depend on cultivar, type of date (soft, semi-dry or dry) and condition (whole, pitted, pieces or macerated dates). For fresh dates, high quality is attributed to dates with adequate size and colour, small pits, thick flesh, freedom from dirt, sand or leaf particles, no evidence of bird, insect or rodent damage, no fungal or mould infection, no sugar crystals formation and freedom from any other apparent alterations. The skin of dates should be smooth, with little or no shrivelling, and golden-brown, amber, green or black in colour.
depending on the cultivar. The texture may be soft and syrupy, or firm or dry, depending on the cultivar. In general, texture and flavour are considered the most important indices of quality in dates. Colour is a good quality attribute in light coloured cultivars. Sucrose is the main sugar in some cultivars (most of the semi-dry and dry cultivars), while reducing sugars (fructose and glucose) are predominant in others (most of the soft cultivars). Total sugars represent about 50% (fresh weight basis) or 75% (dry weight basis). The fact that consumers vary in their preferences for degree of sweetness should be considered when targeting each cultivar to a specific market and in developing products that combine dates with other foods to reduce their sweetness or balance it with acidity when desired (Kader and Hussein, 2009).

The quality of dates is influenced by various factors before harvest, and from the time of picking until the product reaches the consumer. Some of the pre-harvest practices that influence date quality at harvest include covering fruit bunches with paper bags to shelter them from dust, pests and rain (Fig. 4.3), and fruit thinning to reduce compactness of the bunches and increase fruit size and quality (Yahia, 2004). Quality of dry dates can be improved either by curing or hydration. On the other hand, quality of soft dates can be improved to a large extent by dehydration.

*Standard grades of quality*

CODEX Standard (http://www.codexalimentarius.net)

Quality factors in the CODEX Standard for dates include the following: (1) dates should possess the characteristic colour and flavour for the variety, be at the proper
stage of ripeness and be free of live insects and insect eggs and mites; (2) moisture content of 26 to 30%, depending on the variety; (3) minimum fruit size of 4.75 g (unpitted) or 4.0 g (pitted); (4) absence of defects, including blemishes, mechanical damage, unripe, unpollinated, embedded dirt or sand, damaged by insects and/or mites, souring, mould, and decay. Dates and their products should be free from objectionable matter and microorganisms that represent a hazard to human health. The CODEX Standard for dates includes three sizes based on the number of dates per 500 g: small (>110 dates without seeds or >90 dates with seeds), medium (90–110 dates without seeds or 80–90 dates with seeds), and large (<90 date without seeds or <80 dates with seeds).

US standards
In the US standards for grades of dates, the quality score includes 20 points for colour, 10 points for uniformity of size, 30 points for absence of defects, and 40 for character (well developed, well fleshed, and soft). US Grade A or US Fancy are given to whole or pitted dates of one cultivar that achieve a score of 90 or higher. Lesser grades include US Grade B or US Choice, and US Grade C or US Standard. Defects that reduce the quality score include discolouration, broken skin, deformity, decay, puffiness, scars, sunburn, insect injury, improper hydrating, mechanical injury, lack of pollination, blacknose, side spot, black scald, improper ripening, souring, mould, dirt, and insect infestation (USDA, 1955).

In the US, Medjool date growers use a grading standard that differentiates four grades based on fruit size and freedom from defects as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Dates per kilogram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumbo</td>
<td>35–42</td>
<td>No blemishes, skin separation, or dryness</td>
</tr>
<tr>
<td>Large</td>
<td>44–51</td>
<td>No blemishes, skin separation, or dryness</td>
</tr>
<tr>
<td>Extra Fancy</td>
<td>44–53</td>
<td>Minor blemishes, packed all sizes together</td>
</tr>
<tr>
<td>Fancy</td>
<td>44–57</td>
<td>Some dryness and skin separation, packed all sizes together</td>
</tr>
</tbody>
</table>

4.6 Preharvest factors affecting postharvest fruit quality

Date cultivars vary greatly in quality at harvest and during postharvest handling. A large number of date palm trees in many countries are grown from seeds and most of these trees produce low quality dates that end up as animal feed or waste. Improvement of date quality and value (marketability) can be achieved by selecting a few (no more than ten) cultivars of good quality that meet consumer preferences and by limiting future plantings to these cultivars, while gradually replacing the poor quality cultivars with the selected good quality cultivars in each date-producing country (Kader and Hussein, 2009).
Cultural practices (including irrigation and fertilization, pest management, fruit thinning, and harvest maturity) and climatic conditions (temperature, RH, rainfall, wind) influence the rate of development and quality at harvest of dates. For example, suboptimal water supply to the palm tree reduces yield and quality of the dates. Managing the crop load by reducing the number of bunches on the date palm tree and fruit thinning improves fruit quality (Ait-Oubahou and Yahia, 1999).

Only about 30–40% of the fruit normally ripen on the tree. Bunch bagging of dates on the tree with black or blue polyethylene, white agrisafe (polyethylene fleece) or paper bags significantly increases the rate of fruit ripening and increases rutab yield per bunch (Awad, 2007). Black and blue polyethylene bags were the most effective followed by agrisafe and paper bags.

4.7 Postharvest handling factors affecting quality

Postharvest losses in quality and quantity of dates are high and are related to incidence of physical, physiological and pathological disorders and to insect infestation (Ait-Oubahou and Yahia, 1999; Yahia, 2004). These losses are affected by moisture content of the dates, storage temperature and relative humidity, sanitation procedures, and efficacy of insect control treatments. Cooling dates soon after harvest to 10°C or lower and maintaining the cold chain throughout the postharvest handling steps are critical to reducing losses in quality and quantity (Yahia, 2004). An appropriate RH range for dates is 65–75%; at higher RH, dates will absorb moisture from the room air unless they are packaged in moisture-proof containers. Water activity of 0.65 to 0.85 corresponds with moisture content of 15 to 35% in dates. The lower the water activity, the greater the resistance to molds, yeast and bacteria that attack date fruits (Ait-Oubahou and Yahia, 1999; Yahia, 2004).

4.8 Physiological disorders

Several physiological disorders can affect dates, significantly influencing their quality in the market.

4.8.1 Darkening
Both enzymatic and non-enzymatic browning occurs in dates and increases with higher moisture content and higher temperatures (Yahia, 2004). Enzymatic browning can be inhibited at low oxygen concentrations and low temperatures.

4.8.2 Skin separation (puffiness)
Skin separation occurs when the skin becomes dry, hard and brittle, and separates from the flesh (Ait-Oubahou and Yahia, 1999). It is said to be severe when the
skin separates from the flesh in a balloon-like fashion. This disorder develops during ripening of soft date cultivars, which vary in susceptibility. High temperature and high humidity at a stage before the beginning of ripening may predispose the dates to skin separation. Puffiness or sunken separation, caused by high temperature and/or high humidity before the beginning of ripening, may increase during curing and affects only soft cultivars.

4.8.3 Sugar spotting (sugaring)
Sugar spotting is characterized by the appearance of light-coloured spots under the skin and in the flesh and occurs mainly in soft date cultivars (also known as invert sugar dates) in which glucose and fructose are the main sugars (Ait-Oubahou and Yahia, 1999; Yahia, 2004). Almost all dry cultivars and several of the semi-dry cultivars contain large amounts of sucrose and are less sensitive to sugar spotting. Although it does not influence taste it alters fruit texture and appearance. Incidence and severity of sugar spotting increases with storage temperature and time. Sugar spotting decreases as the temperature decreases and when the moisture content falls below 22%, so storage at recommended temperatures minimizes this disorder. Sugaring may be reduced by gentle heating of the affected dates, but can reappear if unfavourable conditions prevail (Rygg, 1975). In Deglet Noor, sugar crystals may form within the flesh when the dates become old.

4.8.4 Internal breakdown
Due to their high moisture content, soft date cultivars are susceptible to a physiological disorder known as internal breakdown which causes black discolouration of fruits, if they are not stored at the correct temperature (Ait-Oubahou and Yahia, 1999).

4.8.5 Black nose
Black nose (fruit checking at the tip region of the fruit that turns a dark colour) is caused by high humidity as the fruit advances from the khalal to rutab stage of maturity (Ait-Oubahou and Yahia, 1999). This physiological disorder occurs particularly in Deglet Noor dates.

4.8.6 White nose
White nose is believed to be due to low RH as the fruit is advanced from the rutab to the tamr stage, especially in the case of Hillawi and Zahdi dates (Ait-Oubahou and Yahia, 1999). It is characterized by the presence of a discoloured ring near the calyx area, which sometimes covers 50% of the fruit. It has been suggested that dry winds for many days during the rutab stage of ripening can cause the basal region of the fruit to ripen more than the rest, causing the ring appearance. However, some
studies have shown that this physiological disorder may be due to calcium within the fruit with the basal end containing less calcium than the apical end (Ibrahim, 1995). The disorder is alleviated or reduced in Hillawi dates by soaking in hot water (75°C) for five minutes (Ait-Oubahou and Yahia, 1999).

4.8.7 Mixed green
Mixed green is characterized by green spots on the ripe fruit, and can be alleviated by the application of some enzyme preparations (such as Pectino-42) (Ait-Oubahou and Yahia, 1999).

4.8.8 Splitting
Splitting can be a problem especially at the khalal stage. It can be caused by different climatic conditions (Yahia, 2004). Over-hydration, caused by a sudden increase in humidity, such as unseasonal rain, can give rise to a change in turgor pressure inside the fruit, resulting in splitting. Some date cultivars such as Deglet Noor are particularly susceptible to this disorder, whereas others such as Hillawi and Zahdi are less susceptible.

4.9 Pathological disorders
The most common pathological disorders causing quality deterioration of dates are fermentation by yeasts (the most significant problem) and fungal infection.

4.9.1 Souring
Yeasts which are found on dates are those capable of growing in relatively concentrated sugar solutions such as *Zygosaccharomyces* and *Hansenula* (Ait-Oubahou and Yahia, 1999). The formation of gas pockets under the skin, white aggregates of yeast cells, discoloured flesh and an alcoholic odour characterize the infected dates. Acetobacter bacteria may also convert the alcohol into acetic acid (vinegar). Souring of dates is due to the accumulation of ethanol and/or acetic acid. Dates are subject to fermentation and subsequent souring at the rutab and tamr stages, especially in soft cultivars, if not stored at the correct low temperatures. Souring can occur in dates with moisture contents above 25% when kept at temperatures above 20°C. Its severity increases with duration and temperature of storage. Storage at low temperatures reduces the incidence and severity of souring (Yahia, 2004).

4.9.2 Fungi
Fungi that commonly attack dates include *Aspergillus* sp., *Alternaria* sp., *Stemphylium botryosum*, *Cladosporium* sp., *Macrosorium* sp., *Citromyces ramosus*, *Phomopsis diospyri* and *Penicillium*. These fungi may cause significant losses before or just after
harvest during rainy or high humidity periods and can attack fruits at the khalal or rutab stages (Djerbi, 1996). Fruit rot (*Rhizopus nigricans* Ehr) is a minor disease of dates, causing more damage at the rutab, rather than at the tamr stages. Calyx-end fruit rot (*Aspergillus niger* Van Tiegh) is a disease that causes losses at the khalal, rutab and tamr stages in conditions of high humidity. Black rot (*Botryodiplodia theobromae* Pat) postharvest disease has been reported on stored dates (Ait-Oubahou and Yahia, 1999). Dates with ≤ 23% moisture content are considered mostly safe from microbiological spoilage, but they become increasingly susceptible as their moisture content increases. *Catenularia fuliginea* Saito is able to grow on dried dates.

The proliferation of toxigenic strains of *Aspergillus parasiticus* and the production of aflatoxins (in excess of 300 mg g\(^{-1}\) at the khalal stage) during fungal growth at 28°C for 10 days has been observed in eight date cultivars (Ahmed *et al.*, 1997). Marked differences in susceptibility to infection and/or aflatoxin production have been observed between the different cultivars and/or stage of maturation. It has been concluded that toxigenic *A. parasiticus* could proliferate on any date fruit that had suffered mechanical damage, and therefore such fruits should be considered unsafe for human or animal consumption.

### 4.9.3 Disease control strategies

The high sugar content of date fruit, especially at the tamr stage, is helpful in reducing or avoiding the growth of some microorganisms, but microbial spoilage can still be a problem if soft cultivars of dates are not stored at the correct temperature and RH (Rygg, 1975; Khatri, 1997). Although a number of treatments have been used to control microbial decay, such as the use of ethylene oxide and pasteurization, such measures are not a substitute for cold storage. Steam-hydrated dates are more resistant to attack by microorganisms than natural or non-hydrated dates because of the partial sterilization of steam-dehydrated fruits.

Some of the strategies proposed by Kader and Hussein (2009) to reduce disease problems are:

- Drying the dates to 20% moisture or lower to greatly reduce incidence of molds and yeasts.
- Maintaining recommended temperature and RH ranges throughout the handling system.
- Avoiding fluctuations in temperature to prevent moisture condensation on the dates, which may encourage growth of decay-causing microorganisms.
- Using adequate sanitation procedures in the packinghouse and storage rooms to reduce potential sources of microbial contamination.

### 4.10 Insect pests and their control

#### 4.10.1 Insect pests

Several insects can cause serious damage to dates at different developmental stages (Carpenter and Elmer, 1978; Dowson, 1982; Ait-Oubahou and Yahia, 1999).
Oligonychus afrasiaticus McGregor and *O. pratensis* Banks are mites that cause a disorder known as ‘Bou Faroua’ disorder, which affects fruit at the hababouk stage. The larvae develop around the fruit producing a white filament netting, which in turn causes fruits to drop prematurely. Infestation with the date stone beetle (*Coccotrypes dactyliperda*) has the same consequences, with the fruit dropping at the immature green stage. *Parlatoria blanchardii* attacks the fruit while still green and forms white filaments around the fruit, which reduce respiration and photosynthesis and the fruit do not reach maturity. The date or carob moth (*Ectomyelois ceratoniae* Zeller) is another Lepidoptera, which is a widely distributed pest in different date producing areas and is the cause of significant postharvest losses in stored dates. The moth is common on dates, pomegranates and carobs. Several other insects, such as *Batrachedra amydraula* Meyr, *Carpophilus hemipterus*, *C. mutilatus*, *Urophorus humeralis* and *Haptoncus luteolus*, can cause serious damage to dates on the bunch or after harvest. Other pests, including *Vespa orientalis*, *Cadra figulilella*, *Arenipses sabella* and the mushroom mite (*Tyrophagus lintneri* Osborn) can infest stored dates. The fig-moth (*Ephestia cautella* Walk.) is an important postharvest pest in some growing regions that can attack dates in the orchard, packinghouses or store (Ahmed, 1988). Dates at khimri, khalal and rutab stages are not attacked by this insect, only fruits at the tamr stage. The saw-toothed grain beetle (*Oryzaephilus surinamensis* L.) is a serious insect pest of stored dates in some regions.

4.10.2 Control methods

Fumigation by methyl bromide or phosphine, ionizing radiation, low and/or high temperatures and modified atmospheres can be used to control insects in dates (Paull and Armstrong, 1994; Yahia, 1998; 2004; 2009).

**High temperatures**

Heat treatment of dates at 60–70°C for two hours killed 100% of both the fig-moth and the saw-toothed beetle, but resulted in a shiny appearance or glazing of the fruit (Hussain, 1974). Exposing dates to temperatures of 65–80°C for 30 min to 4 h at high humidity controls insects (Yahia, 2004), but this approach is not always very efficient for controlling insects in dates with high moisture content, as such high temperatures for prolonged periods may cause darkening and the appearance of a dull colour and loss of flavour. Heated air at 50 to 55°C for 2 to 4 hours (from the time the fruit temperature reaches 50°C or higher) is effective for insect disinfestation (Navarro, 2006), but once again use of higher temperatures is not recommended because it makes the colour of the dates darker. Hussein *et al.* (1989) reported that boiled water is more efficient at controlling insect infestation of dates than exposure to air at 70°C. Very hot water increases sugar loss which can reach up to 20%.

**Low temperatures**

Low temperatures can significantly reduce insect infestation (Yahia, 2004). Temperatures below 13°C will prevent feeding damage and reproduction, and
temperatures of 5°C or lower are effective in controlling different forms of insect (Barreveld, 1993). Fig-moth larvae may live for 85 days at 2–6°C, but storage at 0°C can result in total mortality of the larva of the fig-moth and the adult grain beetle after 15 and 27 days, respectively (Hussain, 1974). Packed fumigated dates may be kept free of infestation at 4°C for as long as one year (Hussain, 1974). Freezing at −18°C or lower for at least 48 hours (from the time when the fruit temperature reaches −18°C or lower) is enough to kill all life stages of insects in stored products. This treatment is used by handlers who market organic dates.

**Ionizing radiation**

Ionizing radiation at doses below 1 kGy (the currently approved limit for use in fruits and vegetables) has potential for effective insect disinfestations without negative effects on the quality of dates (Ahmed, 1981; Al-Taweel et al., 1993). Ahmed et al. (1982) found that an irradiation dose of 0.86 kGy was adequate for the disinfestation of polyethylene wrapped small date packages, causing complete inhibition of adult emergence in both *Ephestia* and *Oryzaephilus*. Al-Taweel et al. (1990) reported that an irradiation dose of 0.44 kGy for 30 minutes was sufficient to disinfest dates and no live insects could be detected after a storage period of 185 days. Azelmat et al. (2005) found that 0.3 kGy was the minimum needed to prevent damage from feeding and prevent adult emergence and 0.45 kGy was required to kill the fourth instar of *Plodia interpunctella* (Huber) (Lepidoptera: Pyralidae).

**Fumigation**

Methyl bromide at 30 g cubic metre$^{-1}$ (30 ppm) for 12 to 24 hours at temperatures above 16°C is very effective for insect disinfestation (Ait-Oubahou and Yahia, 1999). Although methyl bromide for many applications may be phased out, its use for postharvest insect disinfestation is likely to be continued as long as it is trapped and reused. However, it is a good idea to research alternatives in case the use of methyl bromide is not permitted in the future. A potential substitute for methyl bromide is sulphuryl fluoride at 34 g cubic metre$^{-1}$ for 24 hours at 20–25°C, which has recently been registered by the United States Environmental Protection Agency (USEPA); however, environmental groups are also campaigning against this compound due to its potential negative effects on the environment. Phosphine is an effective fumigant, but treatment with phosphine takes 3 to 5 days at 20°C and 60% RH. However, using phosphine as a gas can shorten the required treatment time to a few hours. Current regulations in individual countries should be consulted before these fumigants are used. Fumigation was found to be more efficient when applied under low pressure. Ahmed et al. (1982) compared methyl bromide fumigation and irradiation of Zahdi dates and reported that both techniques are efficient for disinfestation during the first period of storage (25 days), but reinfestation of dates occurred during storage leading to detection of live insects. Thus, disinfested dates must be protected from reinfestation by storage at low temperatures and in insect-proof packages.
Modified atmospheres (MA) and controlled atmospheres (CA)

Storage in N$_2$ or 100% CO$_2$ can control insects for 1–2 days at ambient temperature, and low O$_2$ atmosphere can also inhibit enzymatic browning (Navarro et al., 1998; Yahia, 2009). Packing infested dates in polyethylene bags with 80–90% vacuum resulted in 100% mortality after two days (Hussain, 1974).

Biological control

Some biological methods for the control of the insect pests of stored dates, such as sterile insect technique, cytoplasmic incompatibility and the use of parasites, have been tried (Ahmed, 1988; Ahmed et al., 1982; 1994), but none of these methods are used commercially. Organic dates may be treated with 100% carbon dioxide for 2 days since chemical fumigants such as methyl bromide cannot be used. Heat treatments or freezing can also be used for insect disinfestation of organic dates.

4.11 Postharvest handling practices

4.11.1 Harvesting

As mentioned above, the stage of maturity at which dates are harvested depends on the cultivar and the purpose and intended day of fruit consumption. Time of harvest can be based on the date fruit’s appearance and texture (related to moisture and sugar content) (Yahia, 2004). Proper timing of harvest reduces incidence and severity of cracking or splitting of dates, excessive dehydration, insect infestation, and attack by microorganisms. Dates are harvested in July to August at the khalal stage or in September to December at the rutab and tamr stages in northern hemisphere production regions. The time taken for fruit to ripen depends on the cultivar, the heat units received during the growing season and the stage at which the fruit are picked. For early ripening cultivars the fruit within the bunch may take as long as 3–4 weeks to complete ripening, while for late ripening cultivars, fruit within the bunch ripens in about 8–12 weeks. Early harvest is commonly practiced to take advantage of higher prices in the market and to avoid adverse weather conditions, cracking or splitting of fruits, excessive dehydration in early maturing fruits, insect infestation, and microorganism attack.

As ripening of dates is progressive on the bunch some fruits can be overripe while others are still at the khalal or rutab stages. Selective picking of individual dates or strands is often practiced for good quality at prime maturity. When this approach is adopted, a number of pickings are made before harvesting all fruits. Frequency of picking depends on several factors such as type of date (soft, dry or semi-dry), climatic conditions, market demands, handling methods, cost of handling and availability and cost of pickers. On average, however, when ripe fruit are picked from bunches, three pickings are required over several days. The common method, though, is to harvest by bunch when the majority of dates are ripe. Yellow khalal Barhee (Plate VI) dates are sometimes marketed on branches (strands) or bunches (Fig. 4.4). The whole bunches are harvested when the dates
are fully yellow and lowered to ground level, then hung on a carrier for transportation to the packinghouse or to the market. Green to greenish-yellow and ripe (rutab) fruits are removed from the branches before packing for shipment to markets. Rutab and tamr dates are commonly harvested as whole bunches (Fig. 4.5) when the majority of dates are ripe, which are lowered to ground level and shaken into a bin to remove the ripe dates. Defective dates can also be removed from bunches (Plate VII in the colour section between pages 274 and 275) and strands (Fig. 4.6). The fruit are then packed in bulk bins and sent to the packinghouse. Date bunches on the tree are usually covered with net covers to collect the fallen ripe fruits. Fallen dates on the ground, which are more subject to mechanical damage, should never be collected and sold for human consumption because of the increased chance of microbial contamination and embedding of soil into the flesh when the dates touch the ground (Kader and Hussein, 2009).

As the palm tree grows taller, harvesting the dates by hand becomes more difficult and more costly as the trees have to be climbed. A wide belt woven out of coir is often used to support the climber’s back; the climber then cuts off the whole bunch. Hand-harvesting of dates in the USA involves the use of aluminum
ladders for short palms and picking platforms for taller palms. Pickers use different types of container and harvesting aids to lower the dates from the palm to ground level. If picking individual fruit, the picker empties the container (baskets, bags or buckets) and climbs the palm again until all fruits at the same stage are harvested. Bunches may be lowered either by ropes or by passing the bunch hand-to-hand.
Fruits are also harvested by shaking the bunch and all mature fruits which detach easily drop onto mats spread on the ground around the palm. Very soft fruits can be damaged in this process.

The cost of hand harvesting (Fig. 4.5) can reach as much as 45% of the operational costs, and therefore efforts have been made to develop mechanical harvesting methods for dates (Ibrahim et al., 2007). Some trials have been carried out on Deglet Noor dates in the Coachella valley, California, using platforms built on an extensible tower, enabling the picker to move from one palm to the other (Brown, 1982). More recently, the concept of mechanical harvesting of mature fruit bunches has been developed, in which whole bunches are cut off on two harvest dates as the majority of the fruit per bunch reach the tamr stage. A later development has been the use of mechanical shakers, in which the fruit bunch axis is shaken and fruit collected under the tree. Mechanical harvesting has been found to reduce the cost of harvesting operations and consequently, the mechanical harvesting method that involves cutting off the whole fruit bunches and then using mechanical shakers to remove the fruit has become the standard procedure in the Coachella valley. A still more recent development has been the use of a hydraulic crane with a basket built onto a truck, which is used by the picker to reach the top of the tree. The picker cuts off the whole bunch and places it in the basket, which is lowered by the crane to a shaker-trailer for shaking. Shaking makes the fruit fall into the bulk bins placed beneath the shaker-trailer. The bulk bins are then lifted by a shuffle and placed in trucks to be transported to the packinghouse. Almost 80% of dates produced in USA are now harvested by this method, which has cut harvesting costs by 50% (Rygg, 1975; Brown, 1982; Hodel and Johnson, 2007). Outside the USA, mechanical aids for harvesting have been used extensively in Saudi Arabia (Alhamdan, 2006) and the United Arab Emirates. Dry types are more suited for mechanical harvesting as the softer types of date can be damaged by inappropriate harvesting.

### 4.11.2 Ripening

Dates may need to be ripened after harvest when picked early to avoid damage by rain, insects or other factors (Yahia, 2004). Ripening rooms should be equipped with the means to control temperature and humidity and should have adequate air circulation. The exact temperature and time required for ripening depends on the type of date, stage of maturation and condition at harvest. A temperature of 40–43°C is recommended for ripening Khadrawy, Kustawy, Hayani, Sayer, Khalasa and Sphinx dates (Hyde, 1948). Temperatures of 45–46°C and 70% RH for a period of 2–4 days or longer are required to ripen cultivars with thick flesh such as Iteema, Maktoom and Saidy. Deglet Noor dates should not be ripened at temperatures above 35°C, in order to avoid fruit darkening and loss of flavour. Soft cultivars such as Hallawi, Dayri and Zahdi can be ripened at slightly higher temperatures (35–38°C). Ripening of these cultivars is complete in about 2 to 4 days when they have lost their translucency and little or no hard tissue remains.

Other techniques and chemicals have been tested for ripening dates. Dipping fruits of cv. Khasab, widely grown in Saudi Arabia, in 1% NaCl plus 2% acetic acid
resulted in good quality fruits after ripening (Asif and Al-Taher, 1983). Ripening enhancement of khalal stage dates can be achieved by treatment with acetic acid, ethanol, or acetaldehyde. In North African countries, where the weather is hot and the air is sufficiently dry, harvested immature fruits are ripened outdoors in the sun or in shade. Fruits are separated individually and spread on the ground or kept on the bunch where they ripen progressively. Although this technique is simple and cheap, the exposed fruits are subjected to adverse conditions such as rain, dust from winds, bird attack, rodents, etc., and ripening conditions cannot be controlled. Freezing for at least 24 hours can be used to accelerate ripening of khalal dates to rutab stage. Freezing at $-35^\circ\text{C}$ to $-50^\circ\text{C}$, which causes less damage to the tissues, is better than freezing at $-15^\circ\text{C}$ to $-18^\circ\text{C}$, which causes some damage to cell membranes and walls (Kader and Hussein, 2009).

### 4.11.3 Dehydration

Dehydration aims to achieve an appropriate sugar:water ratio which should be close to 2 for soft dates, greater than 2 for dry dates and lower than 2 for very soft dates. This ratio is a good indicator of date quality behaviour in storage. Fruits of soft and semi-dry cultivars need to be dehydrated to eliminate excess humidity if they are not to be consumed immediately or are to be stored at very low temperatures (Rygg, 1975). The temperature and duration required to reduce water content depend on the type of date, use and flesh consistency. Dates are either kept in bunches or separated from the bunch for dehydration. In countries with low air humidity, dates are spread out on trays and then exposed to the sun or under plastic tunnels until the moisture content has reduced to the desired level. Sometimes dehydration is carried out simultaneously with ripening until a safer level of moisture content is reached. This process is commonly accomplished by recirculating ambient air until high humidity builds up and then introducing fresh preheated air at very low humidity. For this process, the dates can be spread on stacked trays within a pallet that is covered by a shrink film with ventilation openings at the top and bottom of the pallet, or it can be carried out within plastic greenhouses with good air circulation. Drying in plastic houses, which can be constructed at a reasonable cost, protects the dates from dust, birds, rodents and other damaging factors. If solar or ambient-air drying is not possible, heated air can be used to dry the dates to their desired moisture content. The temperature of heated air used for drying depends on the cultivar, as indicated in the ripening section. Over-drying to less than 20% moisture should be avoided to keep the dates soft. The desired moisture content is 23 to 25%.

### 4.11.4 Hydration

If picked ripe and not over-dried, dates do not require hydration. However, sometimes hydration is used to soften the texture of some hard-type date cultivars. It is achieved by dipping dates in hot or cold water for a certain period of time. Dates are dipped in hot water or exposed to steam at 60 to 65°C and 100% RH for
4 to 8 hours (Ait-Oubahou and Yahia, 1999). Steaming for 10 minutes is enough for some cultivars such as ‘Fardh’. Hydration changes the dried dates into plump and glossy dates. Forced air circulation is used to improve uniformity of temperature and RH throughout the hydration room. In addition, this treatment is effective in controlling some microorganisms and improving the keeping quality of the fruit. A treatment commonly used in California for Deglet Noor dates consists of introducing steam at 5 psi until the temperature reaches 60°C for 4–8 h. In Algeria, the treatment consists of a temperature of 65–70°C and 55% RH for 24 h (Rygg, 1971). High acidity dates are difficult to soften by hydration, and acidity during the process changes very little unless neutralizing agents are added. The addition of alkaline ammonium sulphite during hydration improves the quality of hydrated dates that are characterized by moderately high acidity (Rygg, 1975).

4.11.5 Pasteurization
Dates may be pasteurized by exposure to 72°C and 100% RH air until their flesh temperature reaches 66°C, where it is kept for one hour. However, such conditions may induce colour darkening of the dates.

4.11.6 Preparation for market

Cleaning
In general, and despite the necessary precautions taken during harvesting and transport, dates arriving from the farm may be contaminated with particles of dirt and dust, sand particles, plant debris and chemical products. Dates should be cleaned to remove these particles which stick to the date skin. Cleaning can be achieved by (i) blowing air on the fruits and brushing the dates softly to avoid damage to the fruit skin or by (ii) washing the fruits with running water. Dates can also be cleaned by passing them over damp towelling or with the use of washers. Spray jets can be used for soft dates instead of washers. Germicides are used to reduce microbial activity, and moist dates are air-dried after washing to remove excess water before packaging.

Sorting
Dates are sorted to remove culls and to separate them into uniform sizes. Sorting can be carried out manually or mechanically in crates or on moving belts. Dates can be sorted according to maturity, flesh consistency, colour, shape and size. Within different groups, dates are separated according to quality. Discarded fruits consist of dates with defects and abnormalities such as parthenocarpic fruits, immature or overripe fruits, fruits mechanically damaged during harvesting or on the palm, fruits damaged by birds or insects, and fruits with physiological disorders or diseases.

Sizing
This operation is done manually or mechanically to separate dates based on their size and weight. Uniformity of size in a package is one of the quality criteria for
dates. Date size varies depending on the cultivar. Medjool dates in the USA are classified into three size categories: Jumbo for less than 10 dates per pound, Mixed for 10 to 15 dates per pound and Conventional grade for more than 15 individual dates per pound.

Surface coating
The objective of this process is to reduce stickiness and improve appearance. Several materials have been recommended for this purpose including a 5% or 6% solution of soluble starch as a dip, 3% methyl cellulose or a combination of 2% butylated hydroxyanisole, 2% butylated hydroxytoluene, 6% vegetable oil, 90% water and a wetting agent.

Packaging
Dates are packed in several types and sizes of packages (Plate VI and Fig. 4.7 and 4.8). Some dates are marketed in 15-pound flats of fibreboard or wood, others in 5- or 10-pound cartons. Large reinforced cartons are used for packing dry dates, especially for export. Consumer packages in a number of sizes and shapes are widely used for dates (Fig. 4.7 and 4.8). They include transparent film bags and trays overwrapped with film. Round fibreboard cans with metal tops and bases containing 500–1000 g are also used. Rigid transparent plastic containers with a capacity of 200–300 g are commonly used. Small consumer packages are also used such as bags containing about 50–60 g.

Cooling
Cooling to below 10°C (preferably to 0°C) before transportation or storage under the same temperatures (0°C to 10°C) and 65–75% relative humidity is important

Fig. 4.7 Packaged dates.
to maintain quality. Hydrocooling can be used to cool khalal dates to near 0°C in 10 to 20 minutes, depending on initial temperature (Elansari, 2008), but requires effective disinfection of the water and removal of excess surface moisture from the cooled dates before packing in the shipping containers. Use of a perforated plastic liner within the box can reduce water loss during transportation and marketing.

4.11.7 Storage conditions

Low temperature storage is the most effective method of maintaining high quality in dates (Rygg, 1975; Benjamin et al., 1976; Ait-Oubahou and Yahia, 1999; Yahia, 2004). It minimizes loss of colour, flavour and textural quality, delays development of sugar spotting, incidence of moulds and yeasts, and insect infestation, and prevents development of syrupiness (due to conversion of sucrose into reducing sugars) and souring of excessively moist dates. Studies on the cold storage of dates were carried out in the United States as early as 1916. Those early studies indicated that freshly picked dates could be successfully stored for 5 months at 1–2°C (Rygg, 1975; Nixon and Carpenter, 1978). However, it was later demonstrated that date fruits must be dehydrated to remove excess moisture if successful storage is required both at room temperature and under refrigeration. In general, soft date cultivars require a lower relative humidity in the store compared to semi-dry cultivars (Rygg, 1975). The effect of different temperatures on the storage behaviour of Deglet Noor dates was investigated by Rygg (1948; 1956). Fruit of this cultivar could be stored for one year with little loss in quality at 0°C, for 8 months 4.4°C, for 3 months at 8°C, and for one month at 12°C. Deglet Noor dates with moisture content of 28 and 24% could be stored at 4.4°C for 3 and 12 months, respectively (Rygg, 1948).
Dates picked at the khalal stage should be stored at 0°C and 85 to 95% RH to reduce water loss, delay ripening to the rutab stage and maintain their textural quality and flavour. Packaging in plastic bags or use of a plastic liner in the box helps in reducing water loss. Date fruits at the rutab stage are highly perishable and require immediate refrigeration (Abdul-Latif, 1988). Optimal temperature for tamr dates is 0°C for 6–12 months, depending on the cultivar (semi-soft dates, such as Deglet Noor and Halawi have longer storage life than soft dates, such as Medjool and Barhee). For longer storage durations, use temperatures below the highest freezing temperature of −15.7°C. Dates with 20% moisture or lower can be kept at −18°C for more than one year, or at 0°C for one year, or at 4°C for 8 months, or at 20°C for one month; relative humidity should be kept between 65 and 75% in all cases (Yahia, 2004). Ripe dates at the rutab or tamr stages, commonly harvested and handled in the world market, are not sensitive to chilling and freezing temperatures. However, freezing temperatures can injure dates at the early stages of khimri and khalal.

Relative humidity also has a profound effect on the date’s quality. Pathological and physiological deterioration increases with increasing moisture content and storage temperature (Rygg et al., 1953). Very soft and syrupy dates are subject to mould invasion and fermentation more than other types of dates. Relatively small differences in moisture content may have an important effect on the keeping quality of Deglet Noor fruits (Dull et al., 1991). At 24°C, the rate of skin darkening is four times faster in Deglet Noor dates stored at 24% moisture content than at 20% moisture content (Rygg, 1975). Relative humidity during storage should be controlled according to fruit initial moisture content to avoid excess drying or gaining of moisture. Generally, 75% RH or lower is recommended for fresh dates in storage. At high RH, dates will absorb moisture from the air unless they are packaged in moisture-proof containers.

Dates can readily absorb odours and thus should not be mixed in storage or during long distance transport with garlic, apples, onions or potatoes or other foods with strong odours (Yahia, 2004; Ait-Oubahou and Yahia, 1999).

4.11.8 Handling organic dates
The main concern when handling and storing organic dates is to keep them separate from conventionally produced dates and other produce items and to prevent any possibility of cross-contamination of the organic produce by chemical residues that may be present on the conventionally produced fruit. Thus, it is best to use a separate storage room for the organic produce. If this is not feasible, then a physical and spatial separation of at least one metre should be maintained between the organic and conventional produce when stored in the same room. If the produce is well protected from cross-contamination by packaging, the potential for cross-contamination is much reduced (Kader and Hussein, 2009).

The storage room must be thoroughly cleaned to remove any possible residues from previously stored, conventionally produced foods. It is important to keep accurate, specific records of cleaning and sanitizing materials identified by brand.
name and source. A list of permitted cleaners, disinfectants, sanitizers, and other chemicals is available on the website of the Organic Materials Review Institute (http://www.omri.org). The area for food storage must be physically separate from non-foods, especially materials which can contaminate foods by odours or spillage. Packaged organic products must be received into, and despatched from, storage facilities unopened, free from damage and correctly labelled. The optimal storage conditions (temperature and relative humidity) are the same for organic and conventional dates. The potential storage life for organic dates may be shorter than for conventional dates if the latter are treated with approved chemicals to control decay and/or insects.

4.12 Processing

Various products can be obtained from dates (Al-Abid et al., 2007a, b; Barreveld, 1993). Dates are marketed whole, pitted, cut into small pieces or macerated (ground or chopped). Whole unpitted or pitted dates may be marketed loose or pressed (compressed into layers using mechanical force). Dates can be pitted and stuffed and used in pastries. Date flour can be obtained from dry or dried dates. Syrup can be produced from very soft dates (drained out) or from low quality dates after hydration and maceration. The syrup obtained is concentrated to 30/35° Brix then filtered to reach a light brown colour. Sugar is extracted from dates, and vinegar, alcohol and yeast can also be produced from dates (Munier, 1965; Al-Abid, 2006; Sidhu, 2006). Kimri stage (green) dates may be used to make pickles and chutney. Khalal stage dates may be used for jam or dates-in-syrup. Rutab stage dates may be used for jam, butter, date bars and date paste. Tamar stage dates may be processed into date bars, date paste, date syrup or concentrated Tamr juice (Dibis). Date processing by-products and low quality dates may be used for sugar extraction or production of sugar alcohols, citric acid, ethanol, vinegar or baker’s yeast.

4.13 Food safety considerations

Safety factors in dates include contaminants such as mycotoxins, bacterial toxins, heavy metals (cadmium, lead, mercury), environmental pollutants, residues of pesticides and microbial pathogens (Al-Turki and Magid, 2004; Yahia, 2004). While health authorities and scientists regard microbial contamination as the number one safety concern, many consumers rank pesticide residues as the most important safety issue. Unless fertilized with animal and/or human waste or irrigated with water containing such waste, dates normally should be free of most human and animal enteric pathogens, unless they have been contaminated if allowed to fall to the ground. Organic fertilizers, such as chicken manure, should be sterilized before use in date orchards to avoid the risk of contaminating dates that come into contact with the soil with Salmonella, Listeria and other pathogens.
Dates should not be picked from the ground and used for human consumption because of the greater risk of contamination with human pathogens. Strict adherence to ‘Good Agricultural Practices’ during production, ‘Good Hygienic Practices’ during post-harvest handling, and ‘Good Manufacturing Practices’ during processing are strongly recommended to minimize microbial contamination (Kader and Hussein, 2009).

Sanitation standard operating procedures (SSOPs) are specific procedures that allow the date processing plant to achieve sanitary process control in its daily operations. These procedures include:

- safety and purity of the water used in all operations
- cleanliness of utensils and equipment
- prevention of cross-contamination
- hand washing and toilet facilities
- protection of food from contaminants
- labelling and storage of toxic compounds
- monitoring employee health and not allowing sick employees to touch the food
- pest control.

Proper washing of dates significantly reduces the microbial load on their surfaces. Clean, disinfected water is required in order to minimize the potential transmission of pathogens from water to dates, from infected to healthy dates within a single lot, and from one lot to another over time. Waterborne microorganisms, including postharvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on date surfaces. Natural date fruit surface contours, natural openings, harvest wounds and scuffing can be points of entry as well as providing a safe harbour for microbes. In these protected sites, microbes are largely unaffected by common or permitted doses of postharvest water sanitizing treatments, such as chlorine compounds, ozone, peroxyacetic acid and hydrogen peroxide. It is essential, therefore, that an adequate concentration of sanitizer is maintained in water in order to kill microbes before they attach or become internalized in the dates. In some countries, standards of microbial quality have been established with a maximum microbial load allowed in any of the samples tested of 1000 CFU g\(^{-1}\) yeasts, 10,000 CFU g\(^{-1}\) moulds, and/or 10 CFU g\(^{-1}\) \textit{E.coli}. Such microbial load testing may be helpful in indicating the efficacy of the sanitation procedures used to prevent microbial contamination.

### 4.14 Conclusions

Despite being an important food crop, only a small proportion of the world production of dates is handled in world trade. The reasons for this are diverse and include inadequate handling techniques used in several countries, and lack of information for small farmers who are the dominant producers. Research and reviews written on the postharvest physiology and handling of dates, particularly those written in recent years, are scarce. Topics which need investigating include
selection of adequate cultivars for better quality fruits and smaller tree size, improvements of harvesting methods, ripening procedures, dehydration and hydration techniques, safe methods for insect and pathogen control, prevention of toxins and development of adequate detection methods, practical methods for moisture determination, optimal packaging and storage conditions, and further biochemical studies on sugar interactions, tissue softening and browning.

Some of the important means to produce good quality dates and to maintain quality after harvest include: selecting the right type of male clones for pollinating female cultivars, developing adequate date palm mechanization, especially for pollination and harvesting, proper use of the cold chain, adequate packaging and packages, adequate food safety measures, effective methods of insect control and prevention of reinfestation during postharvest handling. Storage and transport at low temperatures is the most important way of maintaining quality of dates because it minimizes loss of colour, flavour, and textural quality; delays development of sugar spotting, reduces incidence of molds and yeasts, and insect infestation; and prevents development of syrupiness (due to conversion of sucrose into reducing sugars) and souring of excessively moist dates.

4.15 References

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Plate V  (Chapter 3) Harvesting dabai fruit by placing a net on the ground and climbing up the tree, then using a long pole with a sharp sickle at its end to harvest branches with fruits.

Plate VI  (Chapter 4) Barhee (Barhi) dates.
Plate VII (Chapter 4) Removing defective dates from bunches.