Postharvest handling of dates

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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. Date palms grow in several countries, but the industry is still most important in the Middle East and North Africa. Over 4 million tons of dates are produced annually, but only about 10% of the total production enters the world trade. Fruits of some cultivars are not very perishable, and can thus easily be shipped to distant markets and stored for prolonged periods, but the shelf life of some syrupy date cultivars is limited to a few days unless special care is taken. Adequate harvest and postharvest techniques need to be implemented to maintain the highest and safest fruit quality possible. Despite extensive reports and books on date production, little research has been carried out on the postharvest physiology, biochemistry and handling of dates, and few reviews have been written (Rygg, 1975; Vandercook et al., 1980), particularly in recent years. Harvest and postharvest handling techniques for dates are reviewed in this article and research findings are reported.

Introduction

Phoenix dactylifera L., the date palm, has been a stable food for the population of the Middle East and North Africa for thousands of years. World production exceeds 4 million tons annually, with the Middle East and North Africa being the major producing regions. Approximately one tenth of total world production enters the world trade, mostly from Iraq, Saudi Arabia, Tunisia, Algeria, Morocco and Iran. Other major producers include Egypt, Libya, USA, Kuwait, Qatar, United Arab Emirates, Oman, Pakistan, India, Mexico and Brazil. Date palms start to bear fruits at the age of 4 or 5 years and reach full maturity at the age of 10 to 12 years depending on local conditions 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 3 to 10 and each bunch is formed from 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 in Egypt having average yields per tree of 70 to 180 kg (Munier, 1973). Depending on cultivar and area, the flowering to harvesting interval ranges between 6 and 9 months. The flowering period lasts from late January to March and ripening starts in July and continues until October-November for late cultivars.

Fruit morphology and composition

The date fruit is a drupe with a single seed or pit. The fruit is oblong in shape, 2.5 to 7.5 cm long, with thick or thin flesh. It is astringent when premature and becomes sweet when ripe. The proportion of seed to flesh, which is sometimes considered an important parameter for fruit quality and classification, varies from 9 to over 30%. The date is a high-energy food for both human and animal consumption. The fruit is rich in carbohydrates and other nutrients. Several reports indicate that dates contain a significant amount of macroelements, particularly potassium, phosphorous, calcium, chlorine and magnesium, and appreciable quantities of microelements such as iron, manganese, copper and zinc (Rygg, 1975; Vandercook et al., 1980). The flesh also contains small amounts of protein, vitamins A, B1 and B2, riboflavin and nicotinic acid. 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 (Hasse et al., 1976). Fruits of soft, semi-dry and dry cultivars have a pectin content of 1.04, 1.75 and 1.51% dry weight, respectively. This content decreases from the immature to the ripening stage (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 50% oleic, 25% palmitic, 10% stearic and 10% linoleic acid, with some capric and caprylic acid content. Dry and semi-dry dates are rich in sucrose, while most soft dates contain reducing sugars (glucose and fructose) with very low or no sucrose content. Fruits of cv. vhars in Algeria, and cultivars Bougouass and Mejoul (Mejdjool) in Morocco, contain no sucrose at harvest (Munier, 1965). The quantities of sucrose and reducing sugars, which are related to
quality and texture, depend on the cultivar and fruit maturity. The glucose:fructose ratio in Deglet Noor fruits grown in California has been reported as 1.28 (Coggins et al., 1968). Yusuf et al. (1982) found that fruits 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. Date flesh acidity reaches the highest level during the period of most rapid growth and decreases during maturation and ripening (Ryyg, 1975). Rouhani and Bassiri (1976) reported that titratable acidity decreased from 7.7 at the immature stage to 1.4 meq/100 g dry weight at the mature stage, and pH increased from 5.13 to 7.0 between these stages. Palmitic acid is the most dominant acid followed by capric and caprylic acids.

Cultivars

Date cultivars are commonly divided into 3 major groups according to flesh consistency and moisture content at harvest. However, other classifications can be found within the same group based on fruit characteristics, size and sugar content. The 3 groups are soft, semidry and dry. The flesh of soft dates contains more than 30% moisture, semi-dry or semi-soft dates contain 20 to 30% moisture and dry dates contain less than 20% moisture (Hussein et al., 1976). However, fruits of any cultivar when left on the palm or exposed to excessive curing conditions will lose moisture and develop a hard flesh texture. Poponeu (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; Vitoz, 1979). A large number of these are propagated by seed. Very few cultivars are grown extensively in major producing countries, Zahdi or Zahdi, Khadrawy, Hillawy, Khustawy, Maktoom, Shalabi, Sukari and Sayer are commonly grown in Iraq; Hayani, Samani, Sady and Dwaiki are commercially grown in Egypt; Sady and Bikra in Libya; Boufgouss, Bousthami, Jihel, Boukri and Mejhoud and Mijidjou in Morocco; Deglet Noor, Haras and Deglet Beida in Algeria; Deglet Nour and Fimi in Tunisia; Halawi, Chichapa, Shanker, Barhee, Shahaani and Bureim in India; Anbar, Khlas, Khabs, Ruziis, Kheniiza, Sukkary, Dwaiki and Khudairi in Saudi Arabia; Kakkab, Sayer and Shahaani in Iran; and Jowan Sor, Karba, Kalud and Abdandan in Pakistan. In the USA, cultivars Deglet Noor, Zahdi, Khadrawy and Hallawi dominate commercial production (Salunkhe and Desai, 1984). In Oman, the main cultivars are Fardh, Naghal, Kamri, Mobsouli and Oum Sila (Vitoz, 1979).

Characteristics of selected cultivars

Deglet Noor (date of the light), a well-known cultivar at the commercial level, 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 fruits 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 fruits can be harvested soft or medium-hard to hard. They keep well during storage at very low temperatures. Hallawi (meaning sweet) 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. Khadrawy (meaning green) produces soft, high quality fruits which mature early, tending to reach a dark colour at full maturity, and have a short storage period. Sayer, although the most commercially grown cultivar in the world, is not of high quality, and has no distinctive flavour. The fruits are very mealy and the syrup is drained out or extracted commercially for sugar production. Mejdool produces very large fruits with a medium-soft texture and amber colour at maturity. The fruits have a thick flesh, are rich in flavour with a delicious taste, and keep well during storage and transport. Barhee produces soft sweet fruits with excellent quality, appropriate flesh thickness and a cylindrical shape, maturing to a dark brown colour. Khastawi 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 Zebra produces fruits with long fruit stalks, superior fruit quality and a distinctive rich flavour. Tadalafil produces semi-dry, large fruits which are attractive, brown-to-amber in colour, mature early and have moderate tolerance of moisture in storage.

Fruit development and maturation

The date palm is a dioecious tree and thus requires cross pollination, which occurs naturally or artificially. After pollination and fertilization, fruit growth follows a sigmoidal curve, and is usually divided into 5 stages of development known by their Arabic terms: "hababouk", "kimi", "khalaal", "rutab" and "tamar". The "hababouk" stage starts after fertilization and is characterized by the loss of 2 unfertilized carpels. This stage is sometimes included in the next stage. The colour of the fruit at this stage is creamy to faint green. "Kimi" 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. "Khalaal" 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 starch content. The colour of the fruit changes from green to yellow, pink or red, or yellow spotted with red, depending on 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 "khalaal and "rutab" stages, the fruit progressively loses water and starch is converted to sugars. The "tamar" (the Arabic name for dates) is the ripening stage of development. The fruit is mature and ready to be harvested and loses more moisture and gains more sugars, thus attaining a high sugars:water ratio (depending on cultivar). Most dates are harvested at the "tamar" stage, when the fruit has about 60 to 80% sugar content, depending on location and cultivar. At this stage, fruits 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 5 stages described above and will not reach full development.

Fruit compositional changes

Total sugars (reducing sugars and sucrose) increase during fruit development and especially with ripening. Deglet Noor fruits have total sugar and sucrose contents, respectively, of 13 and 8% at the "kimi" stage, 60 and 40% at the "khalaal" stage, and 77 and 53% at the "rutab" stage (Djerbi, 1996). In some soft and semi-dry cultivars, sucrose is hydrolysed to reducing sugars and thus no sucrose is found in fully mature dates (e.g. Mejdool and Boufgouss), whereas in some other cultivars (e.g. Deglet Noor) sucrose remains the dominant sugar at harvest (Djerbi, 1996). 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, and moisture content decreased during ripening and reached its lowest level at harvest. Most of the sucrose in soft or invert sugar cultivars is converted to glucose and fructose. Starch content, found mainly during the "kimi" and "khalaal" stages, is converted to sugars and no starch is found at the ripening stage (Djerbi, 1996). The flavour and quality of dates are affected by 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. In Deglet Noor dates, pH changes from 5.5 at the “kimri” 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 5.13 to 7.0 with fruit ripening and acidity decreased from 7.7 to 1.4 mg/100 g. In some cultivars, fruit acidity remains relatively high and ranged from 2.53 to 4.43 mg/100 g for 6 date cultivars in Iran (Ejali et al., 1975). Fruits of some date cultivars are astringent at the immature stage due to the presence of tannins. In some cultivars, the astringency disappears with the change in colour and the reduction in flesh moisture content during fruit ripening. The intensity of colour in fruit depends on the pigments produced by different browning reactions (Maier and Schiller, 1961). Vandercook et al. (1980) 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. 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 Smolenksy, 1971; Hasegawa et al., 1932; Hasegawa et al., 1969). Invertase was also found to play an important role as it converts sucrose into invert sugars with the release of water molecules. The onset of cellulase, polygalacturonase and invertase activity was found to be correlated with fruit ripening in Deglet Noor (Hasegawa and Smolenksy, 1970). The authors also reported that invertase activity is higher in soft dates than in dry dates. This increase in invertase activity, stimulated by the loss of membrane integrity leading to direct contact of the substrate with the enzyme, is correlated with the increase in reducing sugars content during date softening (Coggins and Knapp, 1969; Hasegawa and Smolenksy, 1970). Al-Jasim and Al-Delaimy (1972) found that the highest increase in enzyme activity occurs between the “khalal” and “rutab” stages with the maximum observed at the latter stage in 4 Iraqi cultivars. Skin surface is generally smooth from fruit set up to the “khalal” stage, and shows shrewelling or wrinkles as the fruit reaches maturity, as a direct consequence of moisture loss. The water content of the flesh decreases during fruit development and ripening. In Deglet Noor fruits, moisture content decreases from about 85% at the early “khalal” stage to 45% at the beginning of the “rutab” stage and only 20% at the “tamr” stage.

**Harvesting**

The harvesting season extends from July to late November depending on cultivar. Early harvest is commonly practised 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, microorganism attack, etc. 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 practised for good quality at prime maturity. When this approach is adopted, a number of pickings are made before harvesting all fruits. The commonest method is to harvest by bunch when the majority of dates are ripe. Time of harvest is based on sugar content, moisture content, date appearance and texture. Most of these characteristics depend on growers’ experience and date use and destination. Dates for immediate sale are often harvested when moisture content is still high whereas dates which will be stored are left on the palm for natural curing to lose excess moisture. Although some cultivars with low tannins but rich in sugar can be harvested at the “khalal” stage (i.e. “balali” in North African countries and “bis” in Oman), 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. 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. Makroot and Boufousss fruits can be harvested when 10-25% of the surface is translucent, and then ripened to an acceptable quality.

Pickers use different types of containers and harvesting aids to lower the dates from the palm to ground level. The picker empties the container (baskets, bags or buckets) and climbs the palm again until all fruits at the same stage are harvested. This procedure requires several pickings over several days or weeks. More usually the whole bunch is harvested when the majority of dates are ripe. 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. Mechanical aids for harvesting have been used extensively in the USA, Saudi Arabia and Iraq. Only dry types are suited for mechanical harvesting as the softer types of date can be damaged by improper harvesting. 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.

**Ripening**

Dates may need to be ripened after harvest when picked early to avoid damage by rain, insects or other factors. Ripening rooms should be equipped with means to control temperature, humidity and adequate air circulation. The exact temperature and time of ripening depends on the type of date, maturation stage and condition at harvest. A temperature of 40-43°C is recommended for ripening Khadrawy, Kustawy, Hayani, Sayer, Khalasa and Sphinks dates (Hyde, 1948). 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. 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, Makroot and Saidy. 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). 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 under 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. Another disadvantage of this technique is that ripening conditions are not controlled and remain the same for different cultivars.

**Dehydration**

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). Sometimes dehydration is carried out simultaneously with ripening until a safer level of moisture content is reached. This process is commonly accomplished by recirculating air until high humidity builds up and
then introducing fresh preheated air at very low humidity. Dehydration is also achieved by exposing dates to hot air (<70°C) inside a solar or industrial oven. The temperature should be kept below 70°C to avoid browning of sugars. Dehydration is an operation which 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. The temperature and duration required to reduce water content depend on the type of date, use and flesh consistency. In countries with low air humidity, dates are dehydrated in the sun for several days. Dates are either kept in or separated from the bunch.

Hydration

This process is used to soften the texture of fruits of hard-type cultivars. In addition, this treatment is effective in controlling some microorganisms and improving the keeping quality of the fruits. It is achieved by dipping dates in hot or cold water for a certain period of time. A treatment commonly used in California for Deglet Noor dates consists of introducing live 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 sulphate during hydration improves the quality of hydrated dates that are characterized by moderately high acidity (Rygg, 1975).

Quality characteristics and criteria

Quality characteristics depend on the 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 pit; 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 cultivar. The texture may be soft and syrupy, or firm or dry, depending on cultivar.

Standard grades for quality

The CA 1983 Standards for quality of dates and the US Standards for grades of dates are based on uniformity of colour and size and absence of defects or damages by discoloration of the flesh, rupture of the skin, deformity of the fruit, puffiness of the skin, scars, sunburn, insect damage, decay, black scald, fermentation, improper ripening, mechanical damage, dirt or any other foreign material. In general, the total sugars for different grades are usually the same when expressed as a percentage of dry weight, but the higher grades usually contain higher amounts of sugar per date.

Major postharvest operations

The first postharvest handling operation consists of separating ripe dates from immature ones or from those that have been damaged during harvesting, by insects, birds, rodents, transport, etc.

Cleaning: In general, and despite the necessary precautions taken during harvesting and transport, dates arriving from the farm may present 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 towel-lings 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 based on 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 cultivar. Medjool dates in the USA are classified into 3 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 package. 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. They include transparent film bags and trays overwrapped with film. Round fibreboard cans with metal tops and bottoms 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. For storage, dates can be packed according to destination. A wide range of package sizes and materials can be found in the major producing areas.

Optimum storage conditions: 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 fruit. 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 4 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. Temperature has an immediate effect on the keeping quality of dates. Storage at ambient or higher temperatures tends to reduce the shelf life of the fruits. Cold storage tends to reduce the rate of deterioration, slows down biochemical metabolism and colour changes, and maintains high pH (Benjamin et al., 1976). Dates remain in good condition for up to 12 months during storage at 0°C, but some cultivars may develop sugar spots or crystals. Fully mature soft and firm Deglet Noor dates can be kept for over a year when stored at -17.5°C but cannot be stored for more than one month.
at 27°C, 3 months at 15°C and 8 months at 5°C (Rygg, 1956). Partially dried dates can be held for one year at 0°C or lower, or for a few weeks at ambient temperature. Dry dates can be held at room temperature for years without significant quality losses. 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. 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 "kimri" and "khalaal".

Ethylene production and sensitivity

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). At 20°C, dates produce < 0.1 ml ethylene kg⁻¹ h⁻¹ at the "khalaal" stage, and none at the "rutab" and "tamr" stages. Ripe dates are not sensitive to ethylene exposure.

Respiration

Respiration rate in dates is very low, < 5 mg CO₂ kg⁻¹ h⁻¹ at 20°C at the "khalaal" stage, and < 1 mg kg⁻¹ h⁻¹ at the "rutab" and "tamr" stages. It increases as the moisture content of the fruit increases. Cured Deglet Noor dates with 20-22% moisture produced 0.4 mg CO₂ kg⁻¹ h⁻¹ at 24°C, and 2 mg CO₂ kg⁻¹ h⁻¹ when the moisture content increased to 27% (Rygg, 1975). The rate of CO₂ production is high initially, 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). Seed respiration accounts for about 20% of gas exchange in whole dates (Rygg, 1975).

Physiological disorders

Several physiological disorders can appear on dates, including darkening and development of sugar spots. 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. This disorder becomes severe when the skin separates from the flesh in a balloon-like fashion, becomes hard and brittle. Sugar spotting is characterized by lightly coloured spots under the skin and is restricted to the invert sugar dates. Almost all dry cultivars and several of the semi-dry cultivars contain large amounts of sucrose and are less sensitive to sugar spotting. In Deglet Noor, sugar crystals may form within the flesh when the dates become old. Sugar spotting decreases as the temperature decreases and when the moisture content falls below 22%. Sugar spots affect the appearance and texture of the fruits; they can be removed by washing, but can reappear if unfavourable conditions prevail (Rygg, 1975).

Postharvest pathology

The most common pathological deterioration of dates includes fermentation by yeasts (most important) and fungal infection. 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. Yeasts which are found on dates are those capable of growing on relatively concentrated sugar solutions such as Zygosaccharomyces and Hansenula. The formation of gas pockets under the skin, white aggregates of yeast cells, discoloured flesh and alcoholic odour characterize the infected dates. Fungi that commonly attack dates include Aspergillus sp., Alternaria sp., Stemphylium botryosum, Cladosporium sp., Macrosporium sp., Citromyces ramosus, Phomopsis dasypyr 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 "khalaal" or "rutab" stages (Djari, 1996). However, most fungi infecting dates, except Catenaria fujikleysa Saito, are unable to grow on dried fruits. The proliferation of toxigenic strains of Aspergillus parasiticus and the production of aflatoxins (in excess of 300 mg/kg) at the "khalaal" stage during growth at 28°C for 10 days has been observed in 8 date cultivars (Ahmed et al., 1997). Marked differences in susceptibility to infection and/or aflatoxin production were observed between the different cultivars and/or stage of maturation. It was 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. Dates with ≤ 23% moisture content are considered safe from microbiological spoilage, but they become increasingly susceptible as their moisture content increases.

Insects

Several insects can cause serious damage to fruits at different developmental stages. Oligonychus australis Banks and O. pratiensis Banks are mites known as "Bou Faroua" disease, which affect the fruits at the "hababouk" stage. The larvae develop around the fruit with white filament netting, which in turn causes fruit to drop prematurely. Infestation with the date stone beetle (Coccus pultiperda) has the same consequences, leading to fruit drop at the immature green stage. Parlatoria blanchardi attacks the fruits while still green and forms white filaments around the fruits, which reduce respiration and photosynthesis and the fruits do not reach maturity. The date or carob moth (Ectomyelois ceratoniae Zeller) is another Lepidoptera widely present in different producing areas of dates 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 Bactrocera amphyraea Meyr, Carphophila hemiptera, C. matiliana, Urophorus hermidis and Haptonus luteus, can cause serious damage to dates on the bunch or after harvest. Other pests, including Vespa orientalis, Cadra figulilella, Aepicus sabello and the mushroom mite (Tyrophagus linteri Osborn) can infest stored dates.

Quarantine issues

Fumigation by methyl bromide or phosphine, ionizing radiation, the use of low and/or high temperatures, and modified atmosphere treatments are registered for use as treatments for insect control in dates (Paul and Armstrong, 1994).

(a) High and low temperatures

Exposure dates to temperatures of 65-80°C for 30 min to 4 h at high humidity controls insects. This approach is not always very efficient for controlling insects in dates with high moisture content. High temperatures for prolonged periods may cause darkening and dull colour in fruits and loss of flavour. Fruits are first hydrated in a solution of sucrose for 15 to 20 min and then exposed to high temperatures of 60 to 70°C for 2 h (Barreved, 1993). At the end of treatment, dates are dipped in 10% glucose solution. Insect control can be achieved by dipping dates in boiled water for 20 to 30 min. Hussein et al. (1989) reported that boiled water is more efficient in controlling insect infestation of dates than exposure to a temperature of 70°C. Very hot water increases sugar loss which can reach up to 20%. Low temperatures can significantly reduce insect infestation. 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 (Barreved, 1993).

(b) Ionizing radiation and fumigation

Insects can be controlled by irradiation without altering date quality. Gamma irradiation treat-
ent is used at a rate of 30 to 500 krad (Auda, 1980; El-Sayed et al. 1983). Fumigation is carried out after harvest at 16°C or higher, either in the field under mats or in fumigation rooms. Methyl bromide is commonly used, while carbon disulphide, hydrocyanic acid and ethylene oxide have also been used. Current regulations in each country 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 Zadhi dates and reported that both techniques are efficient for disinfection during the first period of storage (25 days), but reinfestation of dates occurred during storage leading to detection of live insects. Meanwhile, Al-Taweel et al. (1993) reported that gamma irradiation had no significant effect on mating, sperm transfer and percentage of egg hatch in Ephesia cautella (Lepidoptera: Pyralidae).

(c) Modified atmospheres Storage in N2 or 100% CO2 can control insects within 1-2 days at ambient temperature. Low O2 atmosphere can also inhibit enzymatic browning.

Other postharvest treatments

To remove astringency, dates can be dipped in a solution of 3 - 4% acetic acid or in vinegar, or fumigated with acetic acid vapour in a heated container. Immature dates can also be immersed in hot water for a few minutes or incubated at 32-38°C for a few days, where the fruit softens, become translucent, and the flavour improves.

Processing

Various products can be obtained from dates. Dates can be pitted and stuffed, be macerated, 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 before 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). Barreved (1993) has described date processing and date products extensively.

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 techniques used in several countries, difficulties of access to many producing areas due to lack of adequate infrastructure (roads, electricity, etc.), and lack of information for small farmers which are the dominant producers. Research and reviews written on the postharvest physiology and handling of dates, particularly in recent years, are scarce. Topics which need investigating include selection of adequate cultivars for better quality fruits and smaller tree size, improvements in harvesting methods, improvements in 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, adequate packaging and storage conditions, and further biochemical studies on sugar interactions, tissue softening and browning.

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