

REVIEW ARTICLE

Socioeconomic and traditional importance of date palm

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Abstract

The date palm fruit is a drupe exhibiting a high diversity in texture, shape, color and chemical composition depending on the genotype, environment, season and cultural practices. The fruit typically characterize the variety. The socio-economic value of dates is particularly known from oases, where date palms grow and fruits were historically the medium of exchange between populations. The geographical distribution of date palm cultivars is not yet well studied and the international demand on some of them will have disastrous impacts on the sustainability of this crop in the long term. This impoverishes germplasm and narrows the diversity grown among oases. In addition, despite the presence of several reports on the chemical composition and the nutritional value of dates, many other potentialities of the fruits remain to be explored. Many claims report on the antibacterial, antifungal, antitumor, antiulcer and immuno-modulatory properties of dates. Recently, the antioxidant activity of some cultivars was investigated and attributed to phenolic compounds. Dates are very rich in phenolics, in quality and quantity, which opens many fields of investigation in terms of new potential uses. This study summarizes the recent progress in date research, providing an up-to-date overview of the worldwide production/commercialization and the traditional and medicinal uses. Other current and future applications of dates also are highlighted.

Key words: Date palm, *Phoenix dactylifera*, Dates, Chemical composition, Phenolics, Health benefits, Functional food, Nutraceuticals, Medicinal, Antioxidants

Introduction

Phoenix dactylifera L., date palm, is among the most important species in the Palm family (Arecaceae), which encompasses about 200 genera and more than 2,500 species (El Hadrami and El Hadrami, 2009; Jain and Johnson, 2011) and includes *P. canariensis* (Canary Islands date palm), *P. reclinata* (Senegal date palm) and *P. sylvestris* (Indian sugar palm). The species name was inspired by the finger like shape of the fruit and the genus from the legendary bird of Ancient Greece. It is a long-lived monocotyledonous species and one of the tallest domesticated trees. This perennial and dioecious species represents a cornerstone of the economy in many producing countries, especially in North Africa and the Middle East. Over 100 million trees are currently grown worldwide on an estimated area of 1 million ha. Date palm provides

fruit, fuel, fiber and shade for other essential cover crops. The annual world production of dates has reached 6-8 million mt, representing a market exchange value of over 1 billion USD. The top three producing countries are Egypt, Iran and Saudi Arabia; the largest importer of dates is India (El Hadrami and El Hadrami, 2009; El Hadrami et al., 2011a).

Botanical description of the date palm

All species belonging to the genus *Phoenix* grow vertically to form an unbranched trunk driven by the activity of a single terminal shoot apex. To support such elevated vertical growth, the root system is highly developed and reaches deep for water resources. Date palm leaves are very developed and can reach several square meters in area. The leaves are erect, arranged in a spiral pattern on the trunk. Sheathing becomes denser at the top of the tree forming a crown with hundreds of leaves forming a terminal rosette. The leaves are pinnate with needle-sharp tips to defend the plant from grazing animals and reduce water loss.

Vegetative, floral or intermediate auxiliary buds can be found at the base of each leaf. During the juvenile life of the tree, these buds can form the so-called offshoots or suckers, which can develop

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into an adult palm and bear fruits at maturity. Date palm flowers also emerge from auxiliary buds within the terminal rosette and form branched clusters. Given that the date palm is a dioecious species, male and female flowers are found on separate palms and only female palms can bear fruit upon natural or artificial fertilization.

Flowers are typically small for such a large tree, white in color, and arranged on an abundantly-branched spadix surrounded by a large single spathe. The calyxes are three-toothed and cup-shaped, the same as the petals. The latter are twice as long in the female flowers. Date palm flowers consist in general of three ovaries, but only one is able to develop into a drupe. The stamens are six in number bearing linear dorsifixed anthers. Palm pollination is often wind-borne and artificial pollination is also a common practice to achieve higher yield. A mature fully-productive palm can bear several hundred kilograms of fruit each year. Dates are single-seeded fruits of a cylindrical, rounded or ovoid shape, with a fleshy sweet mesocarp covered with a thin epicarp, somewhat yellowish to reddish brown in color. The fruits are usually arranged on spikelets bearing a few dozen individual dates each. Spikelets are attached to a central stalk to form a bunch. The number of bunches per tree varies from 5-30 depending on the cultivar and environmental conditions.

Three major methods are currently practiced to propagate date palm (El Hadrami et al., 2011c). Historically, the most common method relies on the transplanting of offshoots exchanged or traded between growers and groves. Transplanted offshoots develop slowly. A well-maintained palm can produce up to three offshoots per year with a maximum of 10-40 during its lifetime. Under normal conditions, transplanted offshoots begin to bear fruit within 5-8 years with full maturity at around 30 years. Production often shows a decline after 100 years of cultivation, depending on the soil, microclimate and cultural practices and so on. The second method of propagation is by seed. Although it is the easiest, palm seedlings may take up to 10 years before beginning to flower and produce fruit. During the last few decades, a tremendous effort has been given to the development of alternative methods that are fast and reliable in generating large numbers of plants. This relies on the use of micropropagation and various tissue culture methods and biotechnologies (Jain, 2006; El Hadrami and El Hadrami, 2009; El Hadrami et al., 2011b).

Characteristics of important commercial cultivars

Date palm germplasm is claimed to encompass over 5,000 cultivars, some of which have been more or less characterized in detail (El Hadrami and El Hadrami, 2009). A majority of the cultivars are often susceptible to diseases and pests or yield poorly in comparison to elite varieties, hence leading to their exclusion from the groves. This trend had led to impoverished monoculture with a narrow genetic diversity, which threatens the perennial aspect of the crop. This is the case of Deglet Noor cv. in Tunisia and Algeria, where it represents over 65% of the total population, and Boufeggous-O-Moussa and Jihel cvs. in Morocco.

A comprehensive study from the 1920s, providing descriptions of the fruits of 1,500 cultivars, was published in 1973 (Popenoe, 1973). It also reports on the history and significance of the most important date cultivars according to country of origin.

Date fruit by-products

Besides the use of fresh fruits for human consumption, a number of by-products derived from dates also have various uses. These include jam, jelly, juice, syrup and fermented beverage. Cull dates from grading and sorting, as well from storage and conditioning are often utilized as animal feed. Several reports show that a number of bioactive compounds can be extracted from these by-products, thereby adding industrial value which could compensate for the economic loss from under-grading and/or deterioration. Various metabolites also are reported to be produced from dates or their by-products, such as citric acid, oxytetracycline and ethanol. In recent years, interest has been increasing to extract essential oils, polyphenols and dietary fiber from date seeds.

Due to the high production potential of dates worldwide, it may not always be possible to consume all the freshly-harvested fruit locally or export them. This has opened, in recent years, new opportunities to turn the surplus production into value-added products such as syrup and fermented juice. Al-Hooti et al. (2002) reported on a new technology developed on a laboratory scale to produce syrup from dates of Kuwaiti commercial cvs., Birhi and Safri, both very rich in sugars (88%). The study showed that the procedure developed, using pectinase/cellulase enzymes, recovers 68% of total soluble solids, as compared to regular procedures not relying on enzymes which recover only 35%.

Other studies have concentrated on finding ways to add value to some second-grade dates with a hard texture. Besbes et al. (2009) found that these dates are equal to first-grade dates in terms of their sugar, fiber and total phenolic contents. To add value to this type, the authors explored using them to produce jam, and conducted a series of tests of the composition and physical characteristics, such as the content of reducing sugars, firmness, moisture retention capacity, as well as customer acceptability in comparison with the made jam from first-grade fruits and consumed locally. Overall, the study revealed that jam from hard texture second-grade dates represents a commercially viable venture.

Socio-economic and traditional importance of dates

Date palm is socio-economically and traditionally important for local populations where the culture thrives (Jain, Al-Khayri and Johnson, 2011). Establishment of date palm groves helped nomad populations in the past to settle and organize communities and begin farming. These populations became a hub for marketing/trading commodities, animal and other products. Dates were and still are among the most important and appreciated products for trading at these oases-based communities. They are appreciated for their food and feed uses. Dry and soft dates are often eaten out-of-hand. They may also be press-packed, sliced or prepared in many ways to generate other products consumed locally and elsewhere. These include their use in pudding, bread, cakes, cookies, ice cream, candy bars and cereals. An entirely new industry has also been developed in recent years around date palm and dates. For example, factories with more or less sophisticated means of pitting, piercing, crushing and sieving dates provide a significant number of local jobs. Surplus production not consumed fresh often is transformed locally into paste, spread, powder (used locally as a sugar), jam, jelly, juice, syrup, vinegar and alcohol. Unused dates do not go to waste. They are often dehydrated, crashed and mixed with grains and straw to become a valuable feed for domestic animals.

Besides the fruit, young leaves and terminal buds are sometimes prepared as vegetables. Seeds also are often roasted, crushed and used in some countries as an extender to coffee or flour. Tapping date palm trees to extract the sugary sap is also a common practice in many countries in North and West Africa. The sweet sap is converted into sugar, molasses and alcoholic beverages. Date seeds are often softened by soaking in water to feed camels,

sheep, goats and horses, or crushed dry and added to chicken feed.

Date seeds have other nutritional and value-added property potential (El Hadrami et al., 2011d). They contain over 60% carbohydrates, up to 10% fat and 5% protein and a substantial amount of dietary fiber (6-12%). They also represent a source of sterols, oestrone and some alkali-soluble polysaccharide. The seeds yield a yellow-green, moisturizing oil rich in essential fatty acids such as lauric (8%), myristic (4%), palmitic (25%), stearic (10%), oleic (45%), linoleic (10%) as well as traces of caprylic and capric acids, suitable for use in soap and cosmetic products. Date seeds can also be chemically processed to produce up to 65% oxalic acid or burned to produce charcoal for silversmiths. The seeds are also often strung into necklaces.

Date palm leaves are often used to make mats, screens, baskets, crates and fans or for religious purposes (e.g. Palm Sunday). Petioles are often appreciated as a source for cellulose pulp. Mature leaves are used in insulating board, packsaddles, ropes, coarse cloths and hats, given their richness in fiber. They also represent a source of fuel and raw material for making fishing implements and objects such as walking sticks and brooms.

A number of medicinal uses are directly or indirectly ascribed to the consumption of dates. The fruit is rich in tannins, making it a good astringent remedy for intestinal troubles. Formulations such as infusions, decoctions, syrups and pastes are often administered against colds, sore throat and bronchial cough. They are also taken to relieve fever, liver and abdominal aches, cystitis, gonorrhoea and edema. The roots are used to treat toothache and the pollen is appreciated for its estrogenic compound, estrone.

Historical importance of date production

Historically, date palm cultivation was practiced by ancient civilizations and is nowadays considered one of the oldest domesticated fruit-bearing trees. Remains of date palms were found in Jericho - the oldest site known to date to be the origin of agriculture. Date palm cultivation gained socioeconomic importance among tribes and countries due to its ecological plasticity and high adaptation to arid conditions where the annual precipitation rarely exceed 250 mm combined with hot summers up to 50°C and cold winters down to -10°C. Production of dates provides jobs for a manpower population estimated at 50 million people, 35% of which are located in the southern Mediterranean countries (El Hadrami and El Hadrami, 2009).

Another important fact for date palm cultivation relates to the microclimate the tree creates in the desert, fostering the growth of cover crops and vegetables to sustain local human populations and their animals. Dates are an excellent source for carbohydrates, proteins, fats, dietary fiber, essential minerals and vitamins (Al-Shahib and Marshall, 2003a,b). They are also used to produce syrup, jam, chutney, vinegar and fermented date juice. In addition, date palm trees provide shade to grow coffee, pomegranates, mango, citrus, cotton, maize, alfalfa, vegetables and cereals.

Other parts of the palms such as the leaves are often dried, dyed and plaited into mats, hats, trays or baskets. Combined with other material, this high-fiber foliage can also be used to produce ropes and twines. The woody midribs of the leaves are often used for roofing as well as to make dome-shaped traditional fishing cages. Sturdier trunks are used to make fishing crafts in some countries.

Current situation of date production

The date palm is currently grown for fruit production intended for local consumption, trade and export in 37 countries around the world. A few other countries grow the crop on small areas intended for local market consumption.

Geographical distribution of date palm

Phoenix dactylifera is a widely distributed species occurring in diverse geographic, soil and climatic areas (El Hadrami et al., 2011a). The vast majority of the trees are located in the Middle East and North Africa although the crop has been established in California, Arizona and Mexico in the Americas. The common requirement among all date palm growing areas is the high temperature (35° C) necessary for an optimal development of pollen and the low relative humidity for fruit setting and ripening. Such desert-adapted tree require large quantities of water drawn from deep in the soil through a well-established root system or from surface irrigation. Date palm grows in nearly rainless regions at 9-39° North latitude, which are represented by the Sahara and Southern fringe of the Near East (Arabia Peninsula, Southern Iraq and Jordan). Both wild and domesticated trees are morphologically and ecologically similar. Wild date fruits are small and inedible compared to those originating from domesticated trees. Cross-hybridization between the two types of trees occurs in some regions, making their distinction quite difficult to determine.

Worldwide date production

FAO estimates that the harvested area of date growing was 1.3 million ha in 2009 (FAO Statistics, 2010). This area had increased by 0.3 million ha over the previous decade. The largest area (833,351 ha) is located on the Asian continent, which includes the Middle Eastern producing countries, followed by Africa (416,695 ha), North Africa (392,200 ha). In the Americas and Europe the production covers only a few thousand hectares.

The worldwide production of dates was estimated in 2009 to 7.3 million mt, which represents an increase of over 1 million mt in a decade. The production mirrors the area of producing groves with production shared between Middle Eastern and North African countries (2.7 million mt).

According to FAO statistics, the world's largest producer over the last five years was Egypt with an average of 1.3 million mt followed by Iran (just over 1 million mt), Saudi Arabia (979,017 mt), United Arab Emirates (754,400 mt), Pakistan and Algeria (540,000 mt) each and Sudan (333,500 mt). Other significant producing countries are Oman, Libya, Tunisia, Morocco, Yemen, Mauritania, USA, Bahrain, Qatar, Spain and Kuwait.

In terms of annual yields, the USA leads with an estimated average of 67.093 hg/ha. Next is Africa especially the Northern parts, producing 64.974 hg/ha on average. In the Middle Eastern countries, although a large area of producing groves, yields are below the world average (53.798 hg/ha).

Advances in date palm breeding

Date palm breeding relies on the use of conventional methods as well as biotechnologies. From the 1950s to the 1970s conventional breeding programs were given special attention. However, the slow growth of the trees to generate backcrosses and recurrent selection among the progenies quickly became a burden. In addition, difficulties were encountered in selecting female trees, due to the fact that they are indistinguishable from the male trees until they mature, which may take 5-8 years, depending on the cultivar and growth conditions (El Hadrami and El Hadrami, 2009; El Hadrami et al., 2011a). The development of tissue culture in the 1970s and its extensive application for date palm production to the present has made a tremendous contribution to the breeding of this important crop. Currently, a number of micropropagation techniques and biotechnology approaches have made it possible to clonally produce large quantities of material intended to

replace dead or senescent trees in the groves and to establish new areas. These techniques have also provided conventional breeding with new ways to accelerate the breeding process and more quickly obtain progeny. There is still a long way to go before these biotechnologies will be able to help introgress new traits such as yield, quality, and tolerance/resistance to abiotic and biotic stresses. Recently, the entire genome of the date palm cv. Khalas was sequenced and made publically available (Al-Dous et al., 2009, 2011), and in the years to come this will help decipher the genetic secrets of this important monocotyledonous species.

Physico-chemical composition of date fruits

In recent years, reports on the physico-chemical composition of dates and their derived by-products have been on the rise (El Hadrami et al., 2011d). Elleuch et al. (2008) analyzed the color, moisture and oil-holding capacities and the rheological behavior of the dietary fibers extracted from dates flesh of two Tunisian cvs. Deglet Noor and Allig. The findings showed that on a dry matter basis, Deglet Noor cv. constituted 53% sucrose, 14% glucose, 13% fructose, 14% total dietary fiber, 2% protein and 2.5% ash, in comparison with Allig (14, 30, 29, 18, 3, and 2.5%, respectively). In both cultivars, the content of total dietary fibers, which is water insoluble, represents 10% of the dry matter.

Al-Shahib and Marshall (2003b) analyzed the fat content and fatty acid profiles of 14 cultivars of date seeds using gas chromatography-mass spectrometry. Quantitatively, the fat content range was 5-9% (w/w). In terms of quality, the authors reported the presence of 11 fatty acids; among them oleic acid was primary, representing up to 50% of the profile. Different results among samples were ascribed to both cultivar and cultural differences.

Studies of the saturated fatty acids in the flesh and seeds of dates revealed the presence of saturated fatty acids, including capric, lauric, myristic, palmitic, stearic, margaric, arachidic, heneicosanoic, behenic and tricosanoic acids (Al-Shahib and Marshall, 2003b). Unsaturated fatty acids included palmitoleic, oleic, linoleic and linolenic acids. A number of reports list the content of these fatty acids in several commonly grown varieties (Fayadh and Al-Showiman, 1990; Al-Showiman, 1990). Other studies (Saafi et al., 2008) have reported the physicochemical composition of the pulp and the pit and showed total sugars of 63.4% (51.6% reducing sugars and 11.8% sucrose) on a dry-weight basis, 3.9% protein and 0.3% oil in

the pulp; versus 8.2% (6.6% and 1.5%), 5.3% and 8.3% for the pit. Chromatographic analysis revealed differential fatty acid profiles between pulp and pit. While linoleic acid was the major unsaturated fatty acid found in the pulp (32.8%), oleic acid was highly abundant in the pit (47.66%). The major saturated fatty acids were palmitic (20.6%) and lauric acid (17.4%) in the pulp and the pit, respectively. Other fatty acids encountered in these date by-products included myristic, stearic and linolenic acids.

Texture and firmness of the pericarp

As they ripen, edible dates go through four ripening stages termed *kimri*, *khalal*, *rutab* and *tamar* (Fayadh and Al-Showiman, 1990). These represent the immature astringent green, mature full colored, soft brown and hard raisin-like stages of development, respectively. In the first 4-5 weeks, the dates are fully green and become *kimri*; at this stage, average fruit size is 27.5 mm long x 17.8 mm in diameter and weighs 5.8 g on average, quickly increasing due to the accumulation of carbohydrates and moisture content. Acidity is quite high at this stage with an average protein level of 5.6%, fat 0.5%, and ash 3.7% (Al-Hooti et al., 1995).

In the *khalal* stage, the fruit color changes from green to a yellowish/reddish tone depending on the cultivar, over a period of 3 to 5 weeks. Sugar and moisture content decrease from the values recorded at the *kimri* stage along with a decrease in acidity. In this stage, the fruit averages 32.5 mm in length and 21 mm in diameter while the fruit weight increases to 8.7 g (Al-Hooti et al., 1995). The percentages of protein, fat and ash decrease to 2.7, 0.3 and 2.8%, respectively.

At the *rutab* stage, dates begin to soften (2-4 week period) due to an increased loss of moisture content and an increase of enzymatic activities of pectinases and polygalacturonases (Figure 1). The protein, fat and ash percentages in this stage decrease to 2.6, 0.3 and 2.6%, respectively. At the *tamar* stage, dates are drier and rather firm in texture while their color turns to a darker tone.

Freshly harvested dates are commonly consumed or stored for a short period of time before being eaten at the *khalal* and *rutab* stages. Keeping dates in storage past the *rutab* stage lowers their moisture content and they become *tamar* stage. This stage is the most appreciated by consumers and has a better storability and shelf life. A number of cultivars are not allowed to reach this stage and are commercially sold either as *khalal* or *rutab* fruit.

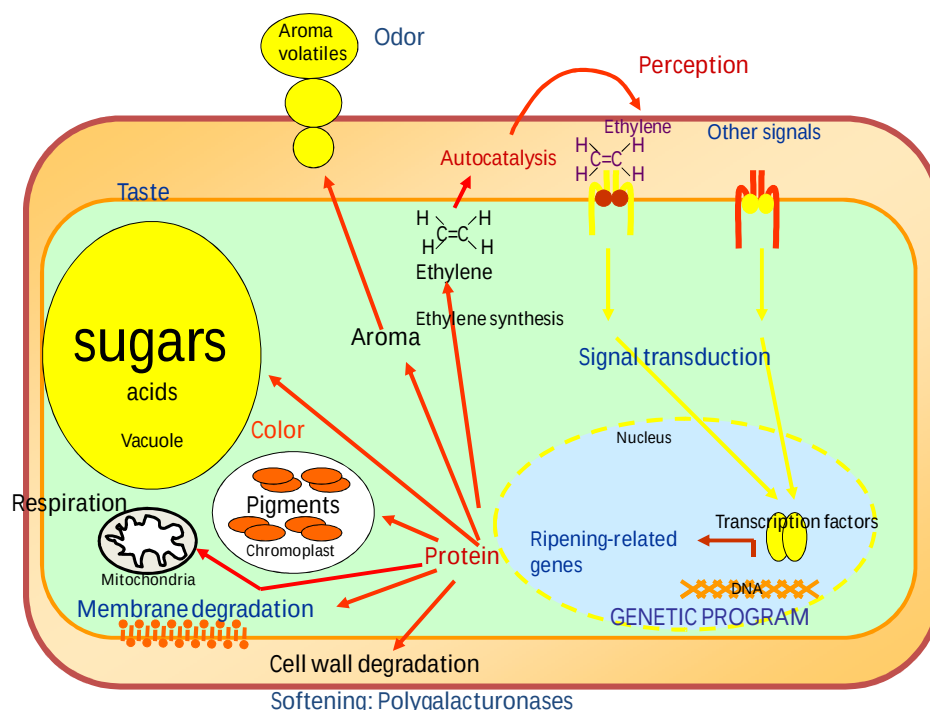


Figure 1. Illustration representing the series of metabolic changes that occur in dates during ripening process.

Firmness of the pericarp in dates mainly depends on the content of carbohydrates and fiber. There are relatively few reports on the content of dietary fiber in dates, especially during the various ripening stages. According to Spiller (1993), the dietary fiber content of widely retailed dried dates (rutab and tamar stages) was estimated at 4.4% with 3.2% insoluble and 1.2% soluble. Over the last few years a number of new methods have estimated these amounts to be higher.

Color and sweetness

As part of the various stages of ripening, dates undergo change in color from dark green to light green and yellow, light to red brown, and to dark brown. A number of experimental procedures were developed to guarantee the quality of traded date fruits in terms of ripeness and color. One in common use is the CIE Lab coordinates ($L^*a^*b^*$), where L^* measures the lightness ranging from black to white on a scale of 0 to 100; a^* the greenness to redness on a scale of -100 to +100; and b^* measuring the blueness (-100) to yellowness (+100). When the a^* and b^* values increase, the color becomes saturated and chromatic, while when they approach zero they indicate neutral colors e.g. white, grey or black. This method is also used to assess the quality of derived by-products such as syrup and juice.

Elleuch et al. (2008) used the CIE approach to compare Deglet Noor and Allig cvs. and showed

that Deglet Noor is characterized by higher L^* , a^* and b^* than Allig, suggesting that Deglet Noor is lighter, more yellow and red than Allig. Using the same technique, Al-Hooti et al. (1996) studied other cultivars from the United Arab Emirates, namely Bush bal, Gash, Gaffer, Gash Abash, Lulu and Shale and reported that the values of L^* range between 17.5 and 23.1, indicating that these cultivars bear darker dates than the Deglet Noor or Allig cvs. studied by Elleuch et al. (2008).

The sweetness of dates depends on the ripening stage. At the kimri stage, dates are still green-yellow in color and very astringent. Their levels of reduced sugars are very low. At the khalal, rutab and tamar stages, total sugar content becomes 6-9 times higher than at the kimri stage. Reduced sugars at these stages are also high, 4-7 times greater than those recorded at the kimri stage (Ahmed et al., 1995).

Other date palm by-products are also known to be appreciated by local populations for their sweetness. A literature search indicated that little attention has been given to sap from date palm, as well as other palm trees such as the coconut and African oil palm. Palm sap is traditionally collected and consumed as a fresh juice or alcoholic beverage, especially in Asian countries, or to make palm sugar, appreciated in cakes, desserts, food coating, and drinks.

Metabolic and physiological changes during ripening

Date fruit shape and size, although genetically controlled, are also influenced by environmental components, especially the number of leaves supplying carbohydrates to each fruit branch, the tree water supply and the degree days to maturity.

A series of metabolic physiological changes occur in date fruits during growth, development and ripening. These changes are under the control of the genotype, branch size, temperature and heat units, light and water potential, carbohydrate supply and hormonal changes, especially gibberellin, auxin and ethylene levels. Although no clear studies have been conducted on dates, auxins may be involved in the stimulation of fruit development through the promotion of ethylene synthesis. Gibberellins, on the other hand, are believed to increase fruit stalk length within the branches, hence alleviating compaction and allowing dates to grow larger. As for ethylene, it is synthesized from methionine and the intermediate S-adenosylmethionine via the activity of two main enzymes; the 1-aminocyclopropane-1-carboxylic acid (ACC) synthase and oxidase. The ACC oxidase depends of the level oxygen in storage and can be a rate-limiting factor for dates ripening. Dates continue to ripen after harvest, exhibiting a characteristic respiratory rise before ripening preceded by a spike in ethylene production, which accelerates the process.

The physiological changes that occur in dates during ripening begin with the recognition of external

signals including the ethylene spike that occurs before the respiratory rise (Figure 2). Following complex signaling pathways, a number of transcriptional factors are activated inducing the transcription of ripening-related genes. Newly synthesized proteins are involved in many processes, including ethylene synthesis, which increases ethylene levels and accelerates ripening and the rise in mitochondrial respiration. Some of these proteins are involved in aroma and the creation of other volatiles responsible for the date-ripening odor. Others are involved in the synthesis of sugars and organic acids that improve taste. Among the proteins, there are also enzymes responsible for pigment degradation and color change during the kimri-khalal-rutab-tamar stages. The most important category of accumulated proteins is involved in membrane and cell-wall degradation (i.e., polygalacturonases, pectinesterases) ensuring softening of the fruit. El-Zoghbi (1994) showed that the percentage of pectin in dates decreases from the kimri stage (1.6g per 100g of dates) to 0.54% in the tamar stage, the fully ripe dry date. The study also pointed out that hemicelluloses, cellulose, lignin and total fiber contents decreased with the fruit transition from kimri to tamar stages. Pectinesterase activity in dates was also shown to increase with ripening reaching a maximum of 60.8 IU per 100g of tissue, thereby explaining the loss of pectin (El-Zoghbi, 1994). Similarly, cellulases activity was estimated to be 2-4 times higher in fruit during ripening (El-Zoghbi, 1994).

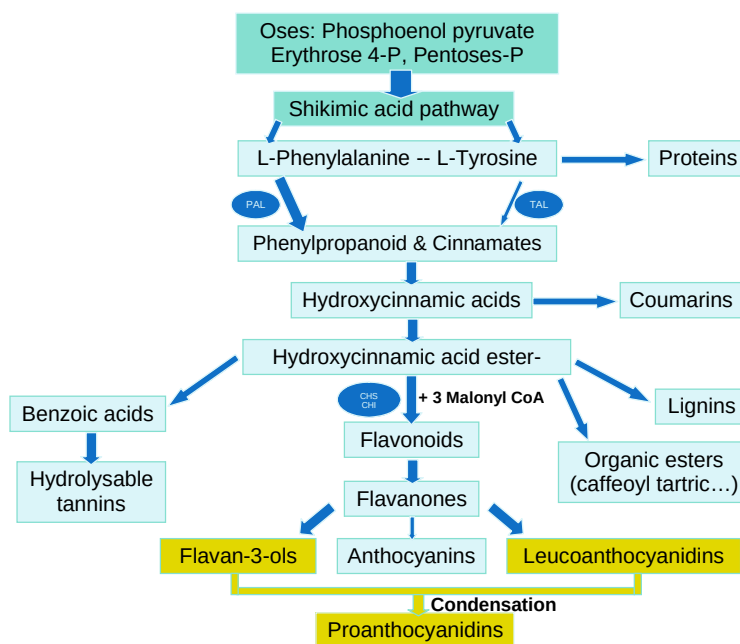


Figure 2. A simplified diagram representing the phenylpropanoid (shikimate) pathway in date palm.

Phenolic content and other secondary metabolites

In dates, three main families of phenolics (hydroxycinnamates; flavonols, flavan-3-ols, flavan-3,4-diols and proanthocyanidins) can be detected (El Hadrami et al., 1998; Daayf et al., 2003; El Hassni et al., 2004; J'Aiti et al., 2009). The major hydroxycinnamates found are derivatives of *p*-coumaric, chlorogenic, ferulic, and sinapic acids as well as their esters i.e. caffeoylshikimic acid derivatives (El Hadrami, 1995; El Hadrami et al., 1998; El Hassni et al., 2004; J'Aiti et al., 2009). Flavonoids such as luteolin, quercetin, and kaempferol, as well as more or less polymerized proanthocyanidins are also found in abundant quantities in fresh dates.

Saafi et al. (2009) examined the phenolic contents of dates derived from four commercial cultivars. The analysis revealed that the total phenolic ranged from 209.4 mg of gallic acid equivalents per 100 g fresh weight in cv. Kentichi to 447.7 mg equivalent in cv. Allig. Similar results were reported in other studies conducted using local cultivars grown in Oman and Bahrain (Al-Farsi et al., 2005, 2007; Allaith, 2008). Mansouri et al. (2005) and Biglari et al. (2008a) reported that total phenolic content ranged from 2.49 to 8.36 mg gallic acid equivalents per 100 g of fresh weight of Algerian and Iranian dates, respectively. Other studies conducted in the USA using Deglet Noor and Medjool cvs. showed a total phenolic content of 661 and 572 mg gallic acid equivalents per 100 g fresh weight.

A number of factors affect the phenolic content in dates and may justify the variation observed among studies. These include the cultivar, geographic origin, growing conditions, maturity of the tested dates, season, fertilizers, soil type, amount of sunlight received and conditions of storage, sampling and extraction.

Other chemical properties

Dates are rich in carotenoid and provitamin A. Boudries et al. (2007) analyzed the content of these two components in cvs. Deglet Noor, Hamraya and Tantebouchte, at khalal, rutab and tamar ripening stages. The major carotenoid pigments detected were lutein and β -carotene. Variation in total carotenoid content was detected among cultivars and ripening stages. Dates derived from the Deglet Noor cv. contained 61.7-167 μ g per 100 g of fresh weight, while Tantebouchte and Hamraya cvs. ranged from 32.6-672, and 37.3-773, respectively. The study also showed that in general carotenoids

disappear during ripening from the khalal to tamar stages.

Provitamin A value also varied with cultivar and ripening stage. In Deglet Noor cv. the values were 0.4-0.5 RE per 100 g of dates and remain unchanged during ripening. However, these values decrease during ripening from 11.7 to 1.6 RE and from 3.9 to 0.5 RE per 100 g of dates derived from cvs. Tantebouchte and Hamraya, respectively.

Dates possess a series of other characteristics due to their richness in dietary fibers. Rheological behavior, moisture- and oil-holding capacities are among the measurable parameters used to compare cultivars and ripening stages.

Nutritional value of dates

Dates represent an important nutritional element in the diet of local populations where the trees are grown. The fruit also becomes a part of the daily intake of residents in countries importing this fruit (El Hadrami and El Hadrami, 2009). Dates contain a high percentage of carbohydrate (total sugars, 44-88%), protein (2.3-5.6%), fat (0.2-9.3%), essential salts and minerals, vitamins and an elevated proportion of dietary fiber (6.4-11.5%) (El Hadrami and El Hadrami, 2009). They also contain oil in the flesh (0.2-0.5%) and the seed (7.7-9.7%). The seed represents 5.6-14.2% of the entire fruit weight.

A literature review over the last three decades showed an increasing number of reports on the chemical composition and nutritional value of dates (Yousif et al., 1976; Vandercook et al., 1977; Fayadh and Al-Showiman, 1990; Al-Hooti et al., 1995; Besbes et al., 2004) and date palm seeds (El-Shurafa et al., 1982; Al-Showiman, 1990; Devshony et al., 1992; Al-Hooti et al., 1998). These exhibit an increasing interest in utilization of the seed, often discarded or used as a feed for domestic animals, after technological or biological transformation of dates (Besbes et al., 2004).

Carbohydrates, proteins and fats

Dates are particularly rich in carbohydrates. Sugars, especially fructose, glucose, mannose, maltose, and other non-reducing sugars such as sucrose, represent over 80% of the dry matter. Glucose to fructose ratio varies between 1 and 2 depending on the cultivar and ripening stage. A small amount of the carbohydrates found in dates is represented by polysaccharides such as cellulose and starch (Shinwari, 1993). Elleuch et al. (2008) studied the sugar content of cvs. Deglet Noor and Allig and showed that sucrose was predominant in Deglet Noor, whereas in Allig, reduced sugars were more abundant with an equal proportion of fructose

and glucose. This difference was ascribed to the potential presence of high invertase activity in Allig cv. (Fayadh and Al-Showiman, 1990; Elleuch et al., 2008). Usually, the sugar content is lower in the kimri and khalal stages as compared to commercial dates at their full ripeness stage of tamar. Part of the sugar loss is also due to a well characterized non-enzymatic browning reaction, the Maillard reaction, which occurs during storage and involves sugars, free amino-acids and phenolics.

Analysis of the amino acid profile of dates and their seeds derived from the cvs. Deglet Noor and Allig showed the presence of 17 different amino acids, including glutamic acid that was foremost in the seeds, representing 17-18% of total amino acids. Other essential amino acids detected in the seeds included lysine, isoleucine, leucine, methionine, threonine, valine and phenylalanine. A number of proteins with molecular weights ranging from 22 kDa to 70 kDa were also abundant in the seed of both tested cultivars.

Fatty acids occur in both the flesh and seed of dates as a range of saturated and unsaturated acids. In seeds, at least 14 different fatty acids were detected, while in the flesh only eight occurred at very low concentration (Al-Shahib and Marshall, 2003b). Oleic acid represents one of the major unsaturated fatty acid in the seed with a content of 41.1-58.8%. Other detectable unsaturated fatty acids include palmitoleic, oleic, linoleic and linolenic acids. The seeds also contain 6-8% of a yellow-green, non-drying essential oil suitable for use in soap and cosmetic products. Seed oil is composed of 8% lauric; 4% myristic; 25% palmitic; 10% stearic; 45% oleic; 10% linoleic and traces of caprylic and capric acids (Morton, 1987).

Dietary fibers and vitamins

Fully mature dried dates have an average dietary fiber content of 4.4-6.5% (Spiller, 1993; Al-Shahib and Marshall, 2003a,b). Three quarters of this percentage represents insoluble fibers while the remaining proportion represents soluble ones. Depending on the method used for quantification, the content of these fibers can be more or less important (Yousif et al., 1982; Al-Showiman, 1998; Al-Shahib and Marshall, 2003a,b). Variation was also reported to be dependent upon the stage of ripeness (Al-Shahib and Marshall, 2003a,b). According to some studies, such as the one conducted by Al-Shahib and Marshall (2003a,b), six to seven dates (approximately 100g) consumed daily by an adult would provide 50-100% of the recommended daily intake. Dates were also reported to contain 0.5-3.9% pectin, thought to

possess health benefits (Al-Shahib and Marshall, 2003a,b).

Dates are very rich in vitamins, especially β -carotene (vitamin A), thiamine (B_1), riboflavin (B_2), niacin, ascorbic acid (C) and folic acid (folacin) (Yousif et al., 1982; Considine, 1982; El Hadrami and El Hadrami, 2009). Some of these vitamins provide 10-50% of the daily recommended intake of an adult. Ripe fruits were reported to contain a substantial amount of carotenoids including lutein and various forms of β -carotene and minor carotenoids. The contents vary with the cultivar and stage of ripeness, with the total content of carotenoids decreasing towards the final ripening stages and in storage.

Essential minerals

Dates are reported to contain at least 15 essential minerals, including phosphorus, potassium, sodium, zinc, manganese, magnesium, copper, iron, fluorine and selenium (Al-Shahib and Marshall, 2003a,b). Depending on the mineral, content varies from 0.1 to 1000 mg per 100 g dry matter of dates. Variation also depends on the cultivar and ripening stage as well as the cultural practices during the growing season, and especially soil and plant fertility. Al-Hooti et al. (1995) reported on the mineral content of five cultivars of dates at various ripening stages. They found that the iron content decreased in four tested cultivars from kimri to tamar ripening stage, whereas it increased in cv. Lulu. On the other hand, the authors showed that the percentages of phosphorus, potassium, calcium, sodium, magnesium and zinc decreased in all five tested cultivars of dates from the kimri to tamar stage.

Fluorine in dates is proven to protect against tooth decay. Selenium is thought to play several roles including the prevention of cancer and the stimulation of the immune systems (Al-Showiman, 1998). Dates are also considered as a good supplement for correcting iron deficiencies and anemia.

Other nutritional properties

Dates are known for numerous other nutritional properties due to their richness in non-starch polysaccharides and lignin (Elleuch et al., 2008). Total insoluble and soluble non-starch polysaccharides estimated by Englyst et al. (1992) showed the presence of neutral sugars such as uronic and galacturonic acids. Other nutritional properties include a number of antioxidant molecules such as polyamines, phenolics, and

glutathione, known for their health enhancement attributes.

Dates represent an important source of the nutritional daily intake, especially for local populations and to the other few millions who consume dates on a regular basis. In addition, dates contain a number of phenolics such as phenolic acids, hydroxycinnamates and flavonoids including tannins. These compounds are known for their beneficial effects on human health as well as against oxidation-linked chronic or degenerative illnesses such as cancer and cardiovascular diseases. The antioxidant metabolites contained in dates seem to be linked to the role of these phytochemicals in maintaining specific cellular homeostasis, and contributing in a preventive manner to beneficial effects across diverse biological systems and cell types. Phenolics are well known for their inhibiting pathogens and parasites.

Health benefits of dates

Natural dietary antioxidants from fruits such as dates are believed to activate the enzymatic and non-enzymatic antioxidant systems (El Hadrami et al., 2005). Epidemiological evidence suggests that a diet rich in fruits and vegetables promotes a lower incidence of chronic diseases such as cancer, cardiovascular disorders and diabetes (Block et al., 1992; Serdula et al., 1996; Tapiero et al., 2002; Duthie et al., 2003). Date consumption, therefore, can make a contribution to management of these degenerative oxidative diseases. Among all the dietary components of dates, phenolics account for most of the antioxidant properties, exhibiting a broad range of biological effects that can be classified into two main categories. One, the direct effect of phenolics as free radical quenchers, preventing nucleic acids, proteins and lipids oxidative damage (Götz et al., 1996; Rice-Evans et al., 1997; Offen et al., 1998; Morel and Barouki, 1999; Jakus, 2000; Droge, 2002). Two, the ability of phenolics to biochemically and physiologically or molecularly modulate cellular physiology.

In date palm growing areas, dates are used in the production of local beverages and alcohol and included in traditional medicines, tonics, aphrodisiacs and treatment of ulcers (Al-Qarawi et al., 2005). Date palm pollen grains have historically been used in Egypt to enhance/restore fertility, especially in women. Only a small number of pharmacological studies that have been conducted on dates. Al-Qarawi et al. (2003) showed that, depending on the type of extract used, fruit or pit extracts, a significant increase or decrease in

gastrointestinal transit in mice was observed. Vayalil (2002) reported that date extract has strong antioxidant and antimutagenic properties. Date palm kernels are also included in many concoctions used to reduce skin wrinkles due to its anti-aging properties (Bauza, 2002), and to prevent irritant contact dermatitis due to natural fats.

In most Muslim countries, dates are consumed in quantity during the fasting month of Ramadan. This is believed to help protect the gastric mucosa from the damaging effect of gastric acid and prevent the development of peptic ulcers.

Anti-microbial properties of dates

In the current era, there is great reliance on processed food to feed burgeoning human populations. Modern methods of food production and processing have opened the door to invasive pathogens and pests, which cause yield and quality losses. Often fresh and transformed products still contain traces of pathogen toxins and other metabolites that can harm consumers in many ways causing temporary chronic diseases.

Being very rich in phenolics, dates are known to exhibit anti-viral, -bacterial and -fungal properties, making them a remedy for certain diseases and prevention of chronic inflammations. The fruit and its by-products are rich in dietary fibers, selenium, carotenoids, ascorbate, and other essential antioxidant which may prevent the oxidative damages caused as a result of lymphocytes phagocytosis activity of invasive pathogens and pests.

Anti-tumoral and anti-ulcer properties of dates

Several studies have demonstrated the anti-carcinogenic properties of phenolics, several of which are abundantly present in dates (Mitscher et al. 1996; Yamada and Tomita, 1996; Uenobe et al. 1997). Phenolics are believed to interfere with the development of malignant tumors at various stages (Kuroda and Inoue, 1988). The anti-carcinogenic effect of phenolics has also been linked to their anti-mutagen activity (Mitscher et al., 1996; Yamada and Tomita, 1996; Uenobe et al., 1997) or their ability to inhibit the activity of enzymes involved in the formation of procarcinogens (i.e., cytochrome P450 class).

Phenolics were shown to be responsible for the decrease in carcinogenic potential resulting from mutagen exposure (Bravo, 1998). Phenolics such as caffeic and ferulic acids, highly present in dates, are known to react with nitrite and inhibit the *in vivo* formation of nitrosamine, hence inhibiting skin tumors (Kaul and Khanduja, 1998).

In addition to controlling oxidation-mediated disorders, phenolics have been ascribed the ability to reduce the impact of infectious diseases. Yoshida et al. (1990) examined the effects of quercetin, one of the flavonoid commonly found in dates, on cell growth of human malignant cells derived from the gastrointestinal tract and on cell cycle progression. Results showed that quercetin noticeably inhibited the growth of human gastric cancer cells with an IC_{50} value of 32-55 μ M. The flavonoid was also able to suppress DNA synthesis by 14% as compared to the control while blocking cell progression from the G_1 to the S phase.

Al-Qarawi et al. (2005) used ethanol-induced gastric ulceration in rats as a model, to test the medicinal claim that dates are effective against gastric ulcers in humans. The study showed that both the aqueous and ethanolic extracts of dates derived from the fruit were effective in improving the severity of gastric ulceration and in extenuating the ethanol-induced increase in histamine and gastrin concentrations, and the decrease in mucin gastric levels. The basis of the gastroprotective action of date extracts may be multi-factorial, and may include an anti-oxidant action given the fact that ethanolic un-dialyzed extract was more effective than the other extracts used.

Immuno-modulatory properties of dates

Dates being rich in both phenolics and dietary fibers can play an important role in the modulation of the immune system and prevention of cardiovascular diseases. Lower incidences of cardiovascular disorders are expected in populations relying on a regular intake of dates. This is believed to occur through the inhibition of the oxidation of low-density lipoprotein (Frankel et al., 1993) and through the prevention of platelet aggregation. Phenolics contained in dates may also be able to reduce blood pressure and have anti-thrombotic and anti-inflammatory effects as shown for other fruits (Gerritsen et al. 1995; Muldoon and Kritchvesky, 1996). In addition, phenolics are known to inhibit α -amylase and α -glucosidase activities behind the postprandial increase in blood glucose level, often manifesting in type-II diabetes (Andlauer and Furst, 2003; McCue and Shetty, 2004).

The immune modulatory activities of phenolics derived from dates include anti-allergic (Noguchi et al., 1999) properties able to suppress the hypersensitive immune response. It also includes anti-inflammatory responses triggered by the suppression of the tumor necrosis factor- α -

mediated pro-inflammatory pathways (Ma and Kinneer, 2002).

Functional and nutraceutical added-value of dates

In recent years there has been increasing interest in identifying food and by-products that can serve as functional foods and nutraceuticals to enhance the well-being of individuals and reduce the risk of various diseases and disorders. Dates consumed fresh or in by-products represent a good source for many nutritional elements, making them a potential source of both functional food and nutraceuticals.

Dates as functional food

A number of studies in the last five years have been dedicated to the composition and functional characteristics of dates and their derived by-products (Al-Farsi et al., 2007; Biglari et al., 2008b; Al-Farsi and Lee, 2008). An examination of over 80 references by Al-Farsi and Lee (2008) on the content and nutritional value of date by-products revealed the presence of substantial amounts of dietary fiber, vitamins and total phenolics. This suggests that they are a good source for natural antioxidants, especially seed by-products, and could serve either as a functional food or incorporated as an ingredient in functional food. Ten essential minerals are also reported in dates, with selenium, copper, potassium, and magnesium being primary.

Dates in the era of nutraceuticals

Metabolic processes in humans generate oxidant by-products that over time cause extensive damages to DNA, protein and lipid. These damages contribute to various degenerative diseases and disorders linked to aging, such as cancer, cardiovascular disease, immune-system decline, brain dysfunction and cataracts. There are several other exogenous factors that contribute to an increase in oxidative damage. These include smoking, a diet rich in iron and/or copper (i.e., excessive meat uptake) and a poor diet that does not include sufficient fruits and vegetables.

Defences against oxidative damage include ascorbate, tocopherol and carotenoids; dates represent a good source for these antioxidants. In recent years, an increasing demand on the exploration of potential nutraceuticals derived from dates has been noted. Biglari et al. (2009) analyzed the total phenolics, especially flavonoids, in different cultivars of dates stored for six months and suggested that certain storage conditions could diminish the antioxidant activity of the fruits. Other studies have focused on adding value to various by-

products derived from dates such as the pits, jams, syrup, jellies and others (Elleuch et al., 2008).

Conclusion

Dates have been a part of human diet for over 6,000 years and are proven to contain high levels of carbohydrate, proteins, vitamins, dietary fibers, and essential minerals and antioxidants, while containing low levels of fat. The nutritional value of this fruit consumed fresh or in the form of many other derived by-products is important worldwide. An increasing number of recent studies have highlighted its potential use as functional food and nutraceuticals. In the next few years, more will be known about the physicochemical properties and nutritional values of this important fruit, hence improving its incorporation into the daily intake of millions of people thereby improving their diet and helping to prevent a variety of diseases. The current biotechnological advances deciphering the secret of this majestic tree have been evolving rapidly, with the latest being the sequencing of the entire genome, which hopefully will help accelerate breeding and finding ways to improve the nutritional value of dates.

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