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Review

Commercial techniques for preserving date palm (*Phoenix dactylifera*) fruit quality and safety: A review

Mohammad Sarraf^a, Monia Jemni^b, Ibrahim Kahramanoğlu^c, Francisco Artés^{d,e}, Shirin Shahkoomahally^f, Ahmad Namsi^b, Muhammad Ihtisham^g, Marian Brestic^h, Mostafa Mohammadiⁱ, Anshu Rastogi^{j,*}

^a Department of Horticulture Science, Shiraz Branch, Islamic Azad University, Shiraz 71987-74731, Iran

^b Regional Research Center in Oasis Agriculture of Degache, Tunisia

^c European University of Lefke, Faculty of Agricultural Sciences and Technologies, Gemikonagi, via Mersin 10, 99780 Northern Cyprus, Turkey

^d Postharvest and Refrigeration Group, Department of Food Engineering, Universidad Politécnica de Cartagena (UPCT), Paseo Alfonso XIII, Cartagena, Murcia, Spain

^e Institute of Plant Biotechnology, UPCT, Campus Muralla del Mar, Cartagena, Murcia, Spain

^f Department of Horticultural Science, University of Florida, Gainesville, FL 32611, USA

^g College of Landscape Architecture, Sichuan Agricultural University, Chengdu, Sichuan 611130, China

^h Department of Plant Physiology, Slovak University of Agriculture, A. Hlinku 2, 949 76 Nitra, Slovakia

ⁱ Young Researchers and Elite Club, Bushehr Branch, Islamic Azad University, Bushehr, Iran

^j Laboratory of Bioclimatology, Department of Ecology and Environmental Protection, Poznan University of Life Sciences, Piątkowska 94, 60-649 Poznan, Poland

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ABSTRACT

The popularity of date palm (*Phoenix dactylifera*) fruit is increasing, therefore the demand for high-quality date palm fruit with less or no chemical treatment is the topic of interest for date producers and consumers. The quality of date palm fruit is much dependent on its postharvest handling and processing. For preventing the degradation and maintenance of the high quality of dates during the storage an appropriate harvest and post-harvest processes are required. The process should control the biotic and abiotic factors like insects, fungus, temperature, as well as handling and processing of dates. Therefore, in this work, we reviewed the literature related to the protection of date fruits during their post-harvest life. The commercially viable advance and updated techniques that can be used to avoid storage losses and problems while keeping fruit quality (nutritional, color, flavor, and texture) and microbial safety under optimal conditions are discussed.

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* Corresponding author.

E-mail addresses: sarraf.science@gmail.com (M. Sarraf), anshu.rastogi@up.poznan.pl (A. Rastogi).

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1. Introduction

Date palm (*Phoenix dactylifera*) is probably the oldest tree cultivated by humans. Historical evidence has shown that their fruits were cultivated and used for thousands of years (Popenoe, 1913; Tavakolian et al., 2013). It seems to have a 7,000-year history that coincides with the first human civilizations from northeastern Africa to the northwestern Tigris and Euphrates rivers (Ashraf and Hamidi-Esfahani, 2011; Dawson, 1982). For people in the Middle East and North Africa, dates are more than just a fruit. The date palm is a tree that was mentioned in Islam, Christianity, and Judaism and it used to be the food of most people (Ashraf and Hamidi-Esfahani, 2011; Munier, 1973). It is the most important way of nutrition and livelihood in most arid and semi-desert areas (Awad, 2007; Botes and Zaid, 1999). Countless sources have examined the history of date cultivation and domestication. In ancient Greece, this plant was called Phoenix because of its transmission and cultivation by the Phoenicians in the Mediterranean region at that time (Ashraf and Hamidi-Esfahani, 2011). Due to its high carbohydrate and other nutrients content date fruits have been used as a complete and nutritious food in military trips and other caravans throughout history. After eating the fruit, they inadvertently dispersed the plant’s seeds in various areas around the world (Ashraf and Hamidi-Esfahani, 2011; Barrevel, 1993).

Dates are known for their numerous food and industrial uses (Munier, 1973; Shaghaghian et al., 2014). Thousands of years ago, humans realized their importance, and the inclusion of dates in the diet is currently associated with several positive effects on human physiology (Hussain et al., 2020; Khalid et al., 2017). Its fruits are known to include an abundant amount of essential nutrients and are considered as a complete food with carbohydrates, fiber, and lipids present in significant amounts. In addition, dates are shown to have a high antioxidant capacity (Biglari et al., 2008; Hussain et al., 2020) and diabetes-reducing properties (Mard et al., 2010; Salehi et al., 2019). All of these shows that date fruits are very important for a healthy diet and they contribute to the improvement of human health.

Thousands of date cultivars exist around the world (Chao and Krueger, 2007). It can grow in hot and low humidity areas under any type of soil and is known to be tolerant to saline conditions as compared with many other cultivated plants (Lobo et al., 2014). The growth rate and development of date fruit follow a sigmoid growth curve (Chao and Krueger, 2007). The growth of date palm and its shelf life is known to be determined by different environmental factors (including precipitation, birds, wind, insects, microbial attacks, temperature, humidity, etc.).

It has been shown that the nuclear size of a date palm genome is about 670 Mb which is distributed among 18 chromosomes. A diploid date palm has $2n = 2x = 36$ of chromosome number per pair

(Al-Mssallem et al., 2013). Improved genomic technology and better research based on phenotype characteristics in population genomics provides an opportunity for the researchers to investigate the origin of the date palm tree (Al-Mssallem et al., 2013). There are huge differences between cultivated and wild date palms from morphological and genetic perspectives, and their natural distribution is unidentified (Gros-Balthazard et al., 2018).

The total production of dates fruit was recorded to be 3.43 million tons in 1990 which was harvested on about 625,000 ha area. Over the past three decades, the demand for global markets has increased reaching 8.52 million tons in 1,092,000 ha, Fig. 1. Egypt, Iran, and Saudi Arabia have always been the largest producers of date palm, and a large share of their exports to these countries is allocated (FAOSTAT, 2018).

Due to the importance and growing acceptance of date fruits, it is a need of time to discuss the advantages and disadvantages of past and current fruit processing techniques. Therefore, in this review article, we have discussed past and modern processes to process and store date fruits for their better and profitable consumption. Fig. 2 shows the important consideration factors for the handling and storage of date fruits which makes the trade of date profitable for its producer and consumers and described in the following section.

2. Handling, treatments, and storage conditions required for dates

The date fruit can be classified into four categories: Fresh (used as fresh, Barhee variety), Wet (maturation achieved by storing at low-temperature or refrigeration, Hayany variety), Semi-dry (Deglet Noor and Medjool varieties), and Dry (Ameri, Halawi, Khadrawy, Thoory, and Zahidi varieties). Further, the date fruits are consumed, stored, and distributed according to their moisture content such as sweet Khalaal (yellow or red with 50–85% moisture

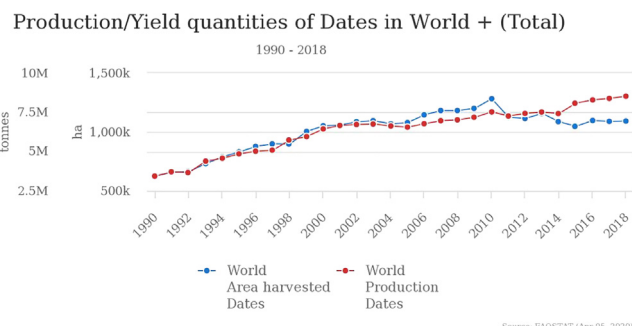


Fig. 1. World Production of Date Palm “between” 1990–2018 (FAOSTAT, 2018).

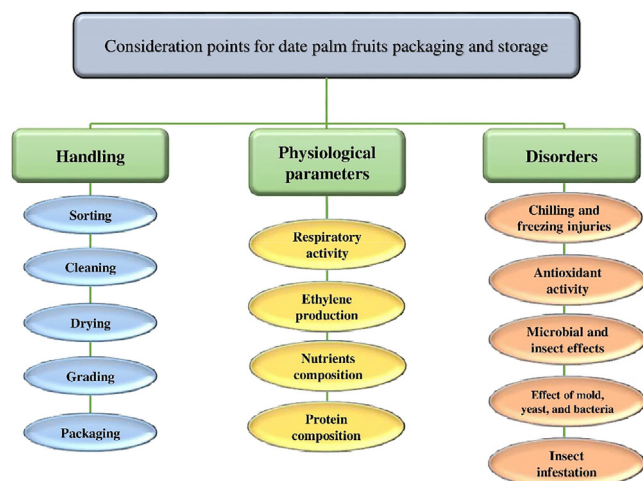


Fig. 2. A systematic representation of consideration points for date palm fruits packaging and storage.

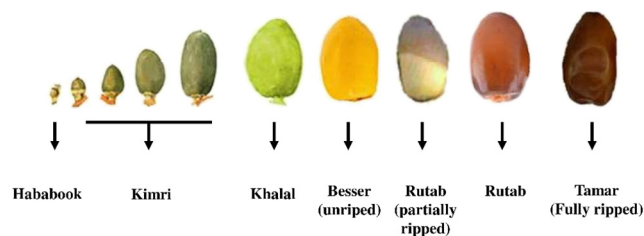


Fig. 3. Stages of maturation of date palm fruits.

content), the Rutab (light brown with 30–45% moisture content), and the Tamar (amber to dark brown with the moisture content of <25%) (Navarro, 2006). Fruits in the Tamar stage are resistant to microorganism infection. In Fig. 3, we showed the six stages of date palm ripening from Hababook to the Tamar stage. In table 1 we have also presented different methods to preserve the date food from different degrading agents as mentioned below, whereas table 2 presents some of the reported work where different biological, physical or chemical factors are mentioned to cause a negative impact on date fruits.

2.1. Sorting:

Date fruits do not get mature at the same time, therefore, the mature fruits are generally handpicked from their bunch. The main steps of date fruit handling involve classifying, disinfection, drying, selection, grading, and packaging. The first step is the classification of the dates which aimed to remove culls and distinguish them into uniform sizes. This process can be performed by hand or by using mechanical means (Yahia, 2011). Generally, date fruits are sorted and graded manually through visual inspection by professional or guided workers (Phulpoto et al., 2012). These steps are among the most time-consuming steps in postharvest operations, which can postpone packaging and marketing of date fruits (Al Ohali, 2011). Sorting is based on the uniform sizes, maturity, flesh consistency from soft to dry, color from yellow to black, and shape. The date fruit is commonly sorted by removing culls, immature or overripe fruits, and discarding fruits with physical and physiological disorders, and abnormalities such as parthenocarpic. Color is one of the important external characteristics used in sorting and grading, it is a vital feature between acceptable or immature date

fruits. Numerous studies are being conducted for the purpose to perform intelligent and precise operations with quick sorting of date fruits to improve the grading efficiency (Siddiq and Greiby, 2014). Fadel et al. (2001) envisaged a machine vision system according to sugar content and color values (RGB) to differentiate among various date cvs. Another machine vision was designed to evaluate the date quality by reflective near-infrared imaging through analyzing two-dimensional images, which improved grading accuracy (Lee et al., 2008). Pourdarbani et al. (2015) has also developed an automatic sorting system for date fruits which differentiate the Khalal, Rutab, and Tamar according to their color and maturity.

2.2. Washing and grading:

The date fruits arrived from farms may be contaminated with any physical particles, i.e. dust, biological materials, i.e. plant parts, and chemical products. So, this must be eliminated before processing. Brushing or pressurized air is among the most used techniques for cleaning but it should be kept in mind that the dates are sensitive to physical damages and the cleaning should be carried softly (Yahia et al., 2014). The grading of dates is based on their size and weight. Several factors influence quality grades in date fruits such as lack of visual defects, abnormality, skin puffiness, sunburn, insect damage, uniformity of color and size, decay, fermentation, and mechanical damage. These criteria are usually applied for Codex and US Grades A, B, C, standard and substandard, for all types of date fruits including whole, pitted, or dry. The size of a package is one of the important factors for the quality criteria and depends on the date fruits variety. In the U.S. for Medjool date fruits, there are three different gradings based on the weight i.e. for <10, 10–15, and more than 15 dates per pound categorized as Jumbo, Mixed, and Conventional respectively (Yahia and Kader, 2011). The classification may differ in different countries. For example in Pakistan, date fruits are mainly classified, from best to worst, as Extra Class, Category-A, Category-B, Good Quality, Fair Quality, and Industrial Grade (Phulpoto et al., 2012).

2.3. Dehydration and storage:

The optimum moisture content (23% – 25%) of the date fruits can be achieved by dehydration. This is one of the most important requirements of quality preservation during storage. The use of hot air or steam (60 to 65 °C) is a successful method for dehydration which may generally be performed in an industrial oven. The recommended duration for this process is between 4 and 8 h (Yahia et al., 2014). Studies recommended that using steam for dehydration improves resistance to microbial pathogens (Kader, 2003, 2007).

During handling and storage of date fruits, the packaging is applied to avoid water loss, physical and insect damages. There are various types and dimensions used for the packaging of date fruits. The fiberboard boxes are used for marketing 6.8 kg of date fruits. Whereas, the dry date fruits are usually exported in large reinforced cartons. A wide variety of sizes and types with different capacity are commonly used for consumer packages including transparent bags or overwrapped trays with poly film, and round fiberboard cans (0.5–1 kg), transparent plastic containers (0.2–0.3 kg), and small bags (50–60 g dates) (Yahia et al., 2014).

Before storage, the date should be cooled to < 10 °C, favorably to 0 °C. Hydro-cooling is one of the cooling methods of date fruits at the Khalal stage which requires 10–20 min at near 0 °C temperature (Elansari, 2008). Before shipping the containers of date fruits, excess moisture from the cooled date fruits should be removed from the surface. During shipping, some physiological processes like sugar crystallization can be reduced by optimum temperature

Table 1
Different preservation methods for date palm fruit.

Methods/Techniques employed	Advantages	Disadvantages	Reference
Refrigeration	Slow down enzymatic reactions, as well as the activity of microbial and insect's life	The efficacy of low temperatures depends on (i) the inherent initial quality attributes of the dates, (ii) the microbe and insects present at harvest, and (iii) the temperature applied. Cooling does not prevent insect infestation although it reduces it, however, insect infestation does not take place at temperature below 4 °C, but at these levels the insects will not necessarily be destroyed	(Lallouche et al., 2017)
Fumigation	Killing insect life in all its stages of development: egg, larva, pupa and adult	Treatment must not be applied to fresh fruits or when stored under deep refrigeration, and the average practical dose is 15 g/m ³ for 12–24 h at 15–16 °C Fumigant is slow acting Does not stop insects to emigrate from the dates (disinfestation) and insects in various countries have developed resistance to this gas The residue levels after treatment stay within the MRL (maximum residual levels)	(El-Mohandes, 2010; Navarro, 2006)
Heat Treatment	100% mortality of emigration and control of nitidulid beetles in dates	Cause discolouration and have a blistering effect that separates the skin from the flesh of the fruit	(Finkelman et al., 2006; Kader and Awad, 2009; Navarro, 2006; Rafaeli et al., 2006)
Modified Atmosphere Packaging (MAP)	The most effective to preserve the quality maintenance of dates with limited effects on the appearance of physiological disorder signs	Limited effects on the appearance of date fruits	(Al-Redhaiman, 2005; Dehghan-shoar et al., 2010; Kader and Awad, 2009)
Edible Coating	Improve the appearance of dates, protect the fruits, and reduce stickiness in case of soft dates Reduce water evaporation from the fruit and thereby reduce its weight loss by up to 50% and maintain the quality of the fruits	Some negative influence mainly on sensory attributes and flavor	(Aboryia and Omar, 2020)
Ozone(O ₃) Treatment	Reduce or eliminate all life stages (adults, larvae, and eggs) of Indian meal moth (<i>Plodia interpunctella</i>) and sawtooth grain beetle (<i>Oryzaephilus surinamensis</i>) The O ₃ is a generally recognized as safe sanitizer in the food industry It is a strong oxidizing agent, very effective on microorganisms Enhance total phenolics contents	Effectiveness depends on the application dose, temperature, duration, pH and soluble solids in water and even on the method of washing, as dips or drench. Bacteria are more sensitive to O ₃ than yeasts and fungi, Gram-positive bacteria are more sensitive to O ₃ than Gram-negative organisms and spores are more resistant than vegetative cells. O ₃ induced changes in surface color of some treated products, and their antimicrobial effect during storage was variable depending on the type of microorganism, characteristics of fresh produce and prevailing storage conditions.	(Jemni et al., 2014a; Jemni et al., 2014b; Niakousari et al., 2010)
Electron-Beams	100% for all electron-beam treatments, also hatches were less compared to microwave, steaming and fumigation	The high cost as known with irradiation and other electromagnetic rays, and technical feasibility	(Al-Farsi et al., 2010)
The UV-C light	The main advantages of UV-C light is that it does not leave any residue, is lethal to most types of microorganisms, is easy to use without extensive safety equipment, and does not have legal restrictions	Exposure of cells to visible light after UV-C treatment induces enzymatic photorepair and expression of excision-repair genes that may restore DNA integrity	(Jemni et al., 2014a)
Electrolyzed water	Electrolyzed water involves on-site production of the disinfectant, which means there are no chemicals to store or handling costs for dealing with them Electrolyzed water is not corrosive to skin, mucous membranes, or organic material, hile having a high oxidation reduction potential with strong effect against microorganism	The effects of Electrolyzed water on by-product formation should be more studied	(Jemni et al., 2014a)

and the speed of refrigeration inside the shipping containers. Also, tearing the skin of date fruits, due to the breaking of cell walls, can be facilitated in low temperatures and above 20% moisture (Glasner and Botes, 2002).

Date fruits are usually stored at low temperatures to prevent color changes, sugar spots, and syrupiness processes, disease incidence, and insect infestation. In addition, cold storage minimizes flavor, textural, and quality losses. Optimal storage temperature depends on cvs and ripening stage of date. To prevent water loss and over-ripening, date fruits at the Khalal stage should be stored at 0 °C and 85 to 95% relative humidity (RH). Tamar date fruits can be stored at 0 °C for 6–12 months. Some semi-soft cvs, like *Deglet nour* and *Halawi*, can be stored longer than soft cvs such as *Med-*

jhool and *Barhi*. For longer storage time, the date fruits should be kept below the highest freezing temperature (–15.7 °C). However, some dry date fruits with 20% or lower moisture can be stored at –18 °C, 0 °C, 4 °C, and 20 °C for more than 1 year, 1 year, 8 months, and 1 month, respectively (Siddiq and Greiby, 2014). In comparison to *Deglet nour* dates stored at 0 °C, for 10 months of storage freezing at –20 °C maintain their overall quality better after a subsequent thawing of 7 days at 5 °C. Consequently, extending the shelf-life during a long-term storage period –20 °C was preferable. Both chilling and freezing could be commercially used and simply realized at an industrial scale (Jemni et al., 2019b).

Another important factor during the storage of date fruits is RH, which minimizes weight loss, the development of fungal diseases,

Table 2
Biological, physical, and chemical factors reported to cause a deteriorating impact on date palm fruits.

Factors	Alterations cause	Effect on dates	References
Microbiological	Fungal species: <i>Aspergillus</i> spp., <i>Alternaria</i> spp., <i>Stemphylium botryosum</i> , <i>Cladosporium</i> spp., <i>Macrosporium</i> spp., <i>Citromyces ramosus</i> , <i>Phomopsis diospyri</i> , etc	Attack fruit in the khalal stage and the Rutab stage. Growth of <i>Aspergillus flavus</i> on dates can result in aflatoxin contamination that would make them unsafe for human consumption and unmarketable	(Warner et al., 1990) (Yahia et al., 2014)
	yeast genera: <i>Saccharomyces</i> , <i>Hanseniospora</i> and <i>Candida</i> spp, <i>Zygosaccharomyces</i>	Yeast-infected dates develop an alcoholic odor (become fermented). Fermentation by yeast also results in souring of dates due to accumulation of ethanol and/or acetic acid with moisture content above 25% when kept at temperatures above 20 °C and its severity increases with duration and temperature of storage. Storage at low temperatures reduces incidence and severity of souring	(Warner et al., 1990; Yahia et al., 2014)
	Bacteria: <i>Escherichia coli</i> , <i>Staphylococcus aureus</i> and <i>Bacillus cereus</i> , <i>Acetobacter</i>	Bacteria are responsible for the acidification of dates (transformation of sugar in lactic acid or citric acid) (Warner et al., 1990). Lactic acid bacteria are present only at the Rutab stage in some varieties	(Warner et al., 1990; Yahia et al., 2014)
Physical	The physical alterations, commonly of mechanical origin, occurs during different operations of date's manipulation (shocks, crushing and drying)	These operations cause lesions that accelerate the process of biological alterations	(Yahia et al., 2014)
Chemical	The richness of the date <i>Deglet Nour</i> in invertase	It causes sucrose inversion. This inversion can cause a decrease in the equilibrium of the relative humidity of dates and a change in its natural flavor	(Yahia et al., 2014)
	Sugar spotting (sugaring)	It results from crystallization of sugars in the flesh of soft date cultivars It alters fruit texture and appearance	
Biochemical	Skin separation (puffiness) Enzymatic browning	The skin is dry, hard and brittle, and is separated from the flesh The browning reaction requires the presence of O ₂ , phenolic compounds and polyphenol oxidases (PPO) enzymes and is usually initiated by the enzymatic oxidation of monophenols into o-diphenols and o-diphenols into quinones, which undergo further non-enzymatic polymerization leading to the formation of pigments	(He et al., 2008)
	Nonenzymatic browning	It causes browning reactions.	(Martins et al., 2000)
Insect infestation	<i>Oligonychus afrasiaticus</i> and <i>O. pratensis</i> are mites that cause a disorder known as "BouFaroua" disorder	Affects fruit at the Hababook stage. The larvae develop around the fruit producing white filament netting, which in turn causes fruits to drop prematurely	(Yahia et al., 2014)
	<i>Coccotrypes dactyliperda</i> (date stone beetle) <i>Parlatoria blanchardii</i> (date palm scale)	the fruit dropping at the immature green stage It attacks the fruit while still green and forms white filaments around the fruit, which reduce photosynthesis and the fruits do not reach maturity.	
	<i>Ectomyeloides ceratoniae</i> Zeller (date carob-moth)	It causes significant postharvest losses in stored dates. The moth is common on dates, pomegranates and carobs.	
	<i>Batrachedra amydraula</i> Meyr (lesser date moth), <i>Carpophilus hemipterus</i> (dried-fruit beetle), <i>C. mutilatus</i> (confused sap beetle), <i>Urophorus humeralis</i> (pineapple beetle), and <i>Haptoncus luteolus</i> (pineapple sap beetle), <i>Vespa orientalis</i> (Oriental hornet), <i>Cadra figulilella</i> (raisin moth), <i>Aphomia sabella</i> Hampson (greater date moth), and the <i>Tyrophagus lintneri</i> Osborn (mushroom mite) <i>Ephestia cautella</i> Walk (fig-moth)	They cause serious damage to dates on the bunch or after harvest. They infest stored dates.	
	<i>Oryzaephilus surinamensis</i> L. (saw-toothed grain beetle)	It is a postharvest pest that can attack dates in the orchard, packinghouses or stores. Dates at the Kimri, Khalal, and Rutab stages are not attacked by this insect, only fruits at the Tamar stage.	
		It attacks stored dates	

and some physiological disorders. Appropriate RH for storage of date fruits is 65–75%, the lower RH, the greater the resistance to microbial pathogens. During storage, dates should not be kept with strong odors emitters commodities such as apples, garlic, onion, and potato because they can absorb their odors. In addition, some chemicals like sulfur dioxide (SO₂) and NH₃ have a detrimental impact on date quality (Kader and Awad, 2009).

2.4. Automation and robotics in the handling of fruits:

Numerous scientific studies had been highlighting that the availability of natural resources, mostly soil, and water, had been decreasing, where the human population, thus the need for food is increasing throughout the world. Therefore, most of those studies recommend that optimum use of natural resources with the highest outputs is necessary for ensuring sustainability on the pla-

net. This then highlights the importance of innovation and agriculture, including advancements in technology such as sensors, robots, GPS technology, and the internet of things (IoT) (Rose and Chilvers, 2018). The increase in the need to supply products in a short time and with high quality had increased the need for the automated grading of horticultural crops. Besides that, it is well known that the damaged fruits with defects can not be stored for long time period. Thus, automatic and robotics can provide a more accurate and quicker selection of fruits than human labor. Besides that, visible-NIR (Near Infrared) spectroscopy is known to have a long history in the use for analyzing fruit color and so the quality of fresh products (De Jager and Roelofs, 1996). Besides scientific studies, the industry is at the same time working on automation in agriculture and there are several companies now available in the market which produce packing lines with multiple cameras and sensors, integrated with Vis-NIR spectrometric probes to pre-

dict different quality parameters of the fruits (Walsh et al., 2020). Moreover, automation technologies helped to introduce guarantee safety and security of food for the consumers. There are available technologies for measuring fruit size, color, shape, external defect, soluble solids content, fruit acidity, and several internal quality parameters (Njoroge et al., 2002). Automation also helps to easily record any information about the products to ensure traceability, including grower name, harvest time, agro-chemicals applied, and etc. This kind of information is nowadays being highly asked by the consumers. (Kondo, 2010) reported that automation is highly applicable in orange grading, eggplant grading, and leek preprocessing. Similar to other fruits, such kinds of techniques can be used in date processing. In a such study, Alavi (2012) reported that Mamdani fuzzy inference system can be used to provide decision-making for the classification of Mozafati date fruits. The study suggested that the evaluation based on MFIS model is more accurate (86.00%) than experts and provides better date fruits grading representation. In another study, Al Ohali (2011) suggested that a prototypical computer vision system, which works on the base of RGB images, could provide 80.00% accuracy in grading and sorting of date fruits.

2.5. Nanotechnology utilization in storage:

Nanotechnology is a field of research and innovation including design, characterization, production, and application of structures, devices, and systems, at the nanoscale (about 1 to 100 nm). The products of nanotechnology are reported to be used in more than hundreds of sectors including cosmetics, textile, sports, drugs, environment production, clean-up products, agriculture (including micronutrients, nano pesticides, nanomaterials-based delivery of CRISPR for crop improvement, nanosensors, nanofibers, nanocoatings, food packaging, fruit storage) and etc. (Lyddy, 2009; He et al., 2019)). Nanotechnology had been reported to be very effective as an antifungal agent in many fruits and vegetables. Coatings and films have several advantages in food preservation by reducing water loss, retardation of ripening, prevention of microbial decay, reduction of chilling and mechanical injury, and improving the visual appearance of food products including fruits and vegetables. Polysaccharides, proteins, and lipids can be used for the production of edible coatings. Chitosan-based nanoparticles are among the most widely studied and used materials for producing edible films and coatings. It is a natural antimicrobial compound known to reduce the postharvest decay of fruit and vegetables (Chaudhary et al., 2020; Kumar et al., 2020). In a most recent study, Saqib et al. (2020) recommended that the chitosan-coated iron oxide nanoparticles (CH-Fe₂O₃ NPs) provide successful results against *Rhizopus stolonifer* in peach fruits. Nanotechnology materials can also be used to produce innovative, active and smart packaging which can improve the storability of fruits and vegetables by controlling the respiration and transpiration of the fresh products (Acharya and Pal, 2020; Alfei et al., 2020). The use of these packaging is promising alternatives for any kind of fruit and vegetables, including date palms.

3. Microbial and insect effects on date palm

The microbes and insects causes severe damage to fruits particularly during heavy rains at the last stages of fruit ripening (Kader and Awad, 2009; Yahia et al., 2014). The estimated loss of the dates, caused by fungal spoilage is estimated to be more than 50% (Al-Sheikh, 2009; Atia, 2011). The most common fungi genera responsible of decay spoilage losses because of their pathogenicity are *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Rhizopus*, and *Penicillium* (Al-Bulushi et al., 2017; Al-Mutarrafi et al., 2019; Al-

Sheikh, 2009; Al Ghamdi et al., 2019; Bokhary, 2010; Colman et al., 2012; Gherbawy et al., 2012; Ibrahim and Rahma, 2009; Lobo et al., 2014; Nasser, 2017; Omamor and Hamza, 2006; Palou et al., 2016; Quaglia et al., 2020; Ragab et al., 2001).

3.1. Effects of mold, yeast, and bacteria on dates

There are different causes of microbial spoilage at the date fruits. The main reasons are mold, bacteria, and yeast (Al Hazzani et al., 2014; Atia, 2011; Hamad, 2008; Ibrahim and Rahma, 2009; Kader, 2007). The mold caused deterioration and fermentation leads to the development of undesirable alcoholic flavor. Due to the influence of temperature on microbial growth it can be assumed that temperature significantly influences the storability and shelf life of date fruits. Microbial growth was also reported to be facilitated by the high moisture content (Kader, 2007; Lobo et al., 2014).

Aspergillus, *Penicillium*, *Alternaria*, and *Fusarium* are among the most important mycotoxin-producing microbes which were previously isolated from date fruits (Hamad, 2008; Kader, 2007). *Aspergillus* spp. are the most common fungi species infecting dates under moderate temperature and high RH (Shenasi et al., 2002b).

The most important causal fungal agents of disease in Spanish date palm fruits were *P. expansum*, *A. alternata*, *C. cladosporioides*, and *A. nigerclade* (Palou et al., 2016). Other species belonging to the genera *Aspergillus*, *Penicillium*, and *Cladosporium* are *A. flavus*, *A. tubingensis*, *P. brevicompactum*, *P. crustosum*, *P. glabrum*, *P. venetum*, *C. cladosporioides*, *C. limoniforme* and *C. halotolerans* (Quaglia et al., 2020).

The spoilage of dates could be also caused by some yeast species and lactic acid development by the yeast. Previous studies recommended that the microbial counts are generally lower at the Kimri stage which significantly increases during Rutab stage and then decreases at Tamar stage (Shenasi et al., 2002a).

Storage at low temperatures reduces the incidence and severity of souring (Yahia et al., 2014). Microbial pathogens decrease when the fruits are stored at temperatures below 5 °C as compared with the 25 °C (Abdul Aly et al., 2018). The freezing at -19 °C provides better control of the microbial pathogens (Al Jasser, 2010). Overall, current knowledge suggests that refrigeration is the best way to control pathogens in stored date fruits (Abdul Aly et al., 2018). Avoiding fluctuations in temperature is among the most important methods for the prevention of microbial growth. Besides that, drying the fruits down to < 20% moisture together with sanitation are the other major methods for the control of yeast and mold. After the prohibition of methyl bromide (disinfestation agent), different alternatives had been studied in the scientific media and date palm industry. Chlorination of the washing water is one of the alternatives recommended by Beuchat et al. (2004). However further studies also recommended that chlorine can cause skin irritation and/or react with organic materials to produce carcinogens (Rico et al., 2008). Ozone application is the other well-known methods against microbial growth. Moreover, controlled atmosphere applications, physical control measures and electrochemical disinfection are also available (Dehghan-shoar et al., 2010). Bessi et al. (2014) recommended that anolyte water (with a pH 7–7.5 and oxidation–reduction potential 800–850 mV) is an ecologically safe alternative when used at 1–5% with 2 to 4 min for disinfecting dates where it was noted to provide 99.5% reduction of the total count of mesophilic bacteria, and 100% reduction of the yeast and molds. The use of edible films and/or edible coatings (gelatin, chitosan, guar gum, etc.) was noted to delay the ripening which improves the storability of the *Barhi* date fruits (Abu-Shama et al., 2020). Studies of Aloui et al. (2014) was also suggested that the combination of chitosan and locust bean gum inhibits the development of *A. flavus*. Dehydration to below 20% of moisture

was also known to greatly reduce the incidence of pathogens. Current knowledge also suggest that the handling method and cold-chain significantly affects the optimum shelf life of date fruits (Kader, 2003). To sum up this topic, Al-Ahmadi et al. (2016) suggested that the best condition for the soft date fruits is cold environment, whereas the dry conditions are better for dry date fruits.

3.2. Insect infestation

One of the main causes of losses in date fruits is insects. *Coccotrypes dactyliperda* (date stone beetle) infect date fruits at the green stage which results in early fruit dropping at immature stage. *Parlatoria blanchardi* (date palm scale) also attacks green fruits and forms white filaments around the fruit. The infection results in a reduction of photosynthesis and the fruits do not reach maturity. The date carob-moth (*Ectomyelois ceratoniae* Zeller) is a common insect in different dates producing areas and it causes significant postharvest losses during storage, whereas, the lesser date moth (*Batrachedra amydraula* Meyr), dried-fruit beetle (*Carpophilus hemipterus*), pineapple beetle (*Urophorus humeralis*), confused sap beetle (*Carpophilus mutilates*), and pineapple sap beetle (*Haptoncus luteolus*), are also known to cause serious damage to dates on the bunch or after harvest. Some of the other insects which are harmful to date after postharvest are *Cadra figulilella* (raisin moth), *Vespa orientalis* (Oriental hornet), *Aphomia sabella* Hampson (greater date moth), and *Tyrophagus lintneri* Osborn (mushroom mite) (Bachrouh et al., 2010; Jemni et al., 2014a; Jemni et al., 2014b; Marouf et al., 2013; Mediouni et al., 2004; Mohandass et al., 2007; Wakil et al., 2015; Warner et al., 1990).

4. Disinfestation

Infestations in date fruits are due to insects (mainly coleopterons, lepidopterons and hymenopterons) as well as by bacteria like (*Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*) and by several fungi genera (Warner et al., 1990). Regulations on the use of agrochemicals to control pathogens became more and more stringent. In fact, the reduction in the use of postharvest insecticides needs studies on technically and economically viable sustainable substitutes for the purpose to maintain fruit quality and safety. Among the chemicals/process being used to protect dates includes the use of phosphine (PH₃), SO₂, carbon sulfate (CS₂), carbon dioxide (CO₂), ethylene oxide (C₂H₄O), ozone (O₃), microwaving (MW), freezing, heat treatment, ultraviolet (UV-C) radiation, radio frequency (RF) or irradiation, alone or combined, have been stated (Jemni et al., 2015).

PH₃ is a powerful fumigant, but it requires 3 to 5 days at 20 °C and 60% RH. The UV-C light (200–280 nm) is non-ionizing radiation with probed effects as an efficient technique, mainly at 6.22 kJ m⁻² for keeping quality of *Deglet nour* cv (Jemni et al., 2014a). Micro waves have been used to heat products by converting electromagnetic energy to heat energy and are a potential quarantine treatment method to control some insects pests (Dorantes-Alvarez et al., 2000; Ooi et al., 2002; Zouba et al., 2009) RF energy quickly heat insect larvae, which can kill the insects with a negligible influence on fruit quality (Monzon et al., 2006). The insecticidal effect of O₃ is due to its ability to diffuse through biological cell membranes and high oxidation potential (Jemni et al., 2015). Electrolyzed water (EW) is a more effective bactericide and fungicide than NaClO while it enters more easily in the product surface (AL-Haq et al., 2005; Izumi, 1999; Martínez-Hernández et al., 2013; Tomás-Callejas et al., 2011). Neutral EW (pH 7.2, ORP 814 mV, and 300 mg L⁻¹ of free NaClO) was very effective against *Ectomyelois ceratoniae* spread on *Deglet nour* date, being considered as a hopeful tool for commercial disinfec-

tion and extending shelf-life (Jemni et al., 2014b). The combined use of UV-C light and EW or ozonated water lowered the microbial growth on *Deglet nour* dates which showed a better color and sensorial quality than control (Jemni et al., 2014a). The ionizing radiation is also an effective disinfestations method that has negligible effects on fruit quality (Çopur and Tamer, 2014; Yahia et al., 2014)

The modified atmosphere packaging (MAP) technique alters the gases surrounding perishable food products creating a modified/adequate atmospheric composition for the products. The MAP maintains a high RH around the produce and slow senescence. High CO₂ levels in MAP inhibits the growth of many fresh food spoilage microorganism (Al-Ati and Hotchkiss, 2002; Artés, 1995; Artés et al., 2006; Escalona et al., 2004; Farber et al., 2003; Homayouni et al., 2015; Jemni et al., 2016a; Sandhya, 2010; Toivonen et al., 2009). The combined use of CO₂ and PH₃ provides better performance with shortened duration of control of the pests (*Oryzaephilus surinamensis* and *Tribolium confusum*) in stored dates without causing undesirable quality changes (El-Mohandes, 2010). The O₂ promotes several deteriorative reactions in foods including fat and pigment oxidation, browning reactions, and is highly required for pathogens (Al-Ati and Hotchkiss, 2002; Farber et al., 2003; Sandhya, 2010).

5. The overview of physiological processes in date palm which affects its storage potential

5.1. Respiratory activity

Date fruits have a relatively low respiration rate (RR) and are classified as non-climacteric fruits. However, some of the previous studies with Zahdi, Derey, Sultan and Braim cvs claimed the date fruits as climacteric (Kader and Yahia, 2011; Lobo et al., 2014). Respiratory activity varies depending on several factors: temperature, ripening stage, moisture content, CO₂, O₂, and C₂H₄ levels within the package. Commonly, the RR is high initially but decreases progressively until reaching the lowest position. At that time the fruits called in physiologically mature and then the RR increases to a slight peak as the fruit ripens (Kader and Yahia, 2011). At 20 °C the RR is lower than 25 mL CO₂ kg⁻¹ h⁻¹ for Khalal stage dates, and then 5 mL CO₂ kg⁻¹ h⁻¹ for Rutab and Tamar stages (Lobo et al., 2014). Very few and incomplete works are available on the RR and C₂H₄ emission from date fruits. However, both are key factors in the design and operation of refrigerated storage facilities, since they affect chilling storage and transportation, air exchange and circulation needs, loading density, and handling, packaging, and stacking methods. Particularly, the RR values are needed for an optimum design of polymeric packages when MAP takes place (Artés et al., 2002; Jemni et al., 2016b).

Changes in RR of *Deglet nour* cv (moisture 20.13 ± 1.35%) at 0 °C and 20 °C throughout storage are shown in Fig. 4. At 0 °C, the RR was 0.10 ± 0.03 mL CO₂ kg⁻¹ h⁻¹, with a maximum value of 0.83 ± 0.02 mL CO₂ kg⁻¹ h⁻¹. At 20 °C, the RR increased from 0.55 ± 0.04 mL CO₂ kg⁻¹ h⁻¹ in the initial day up to 8.1 ± 0.58 mL CO₂ kg⁻¹ h⁻¹ in day 8. This increase was very probably due to fungal attacks which were first observed after 6 days of storage. The presence of mold, yeast, and bacteria on the dates increases the RR and the need for aeration during storage. Cured *Deglet nour* dates with 20 to 22% moisture kept at 24 °C produce about 0.22 mL CO₂ kg⁻¹ h⁻¹ and about 1.1 mL CO₂/kg⁻¹ h⁻¹ when moisture was 27% (Jemni et al., 2019b; Rygg, 1975).

5.2. Ethylene production

Ethylene (C₂H₄) is an important plant hormone that significantly influences the changes in fruit firmness, color, soluble solids

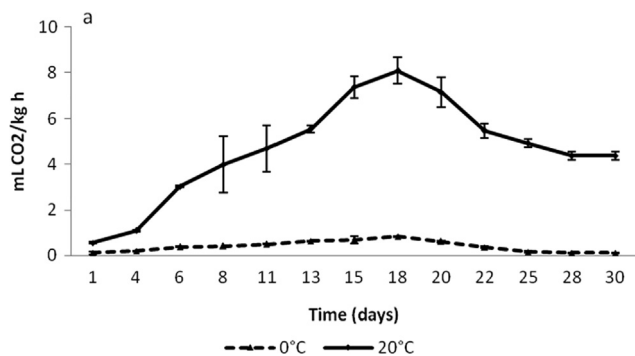


Fig. 4. Changes in respiration rate of *Deglet nour* cv at Tamar stage with $20.13 \pm 1.35\%$ moisture content at 0 and 20 °C (Jemni et al., 2019b).

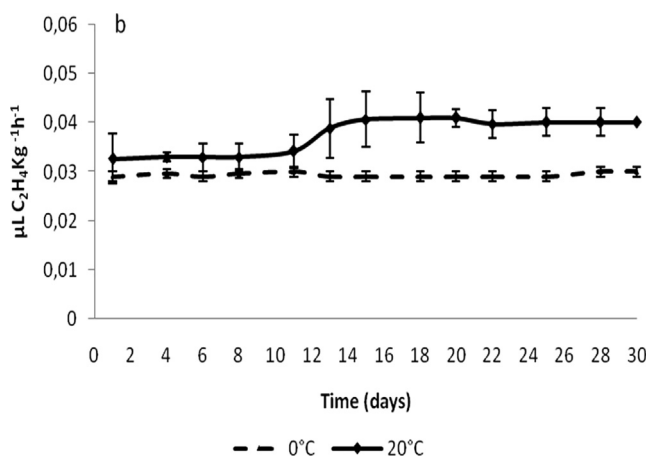


Fig. 5. Changes in ethylene emission of *Deglet nour* cv at Tamar stage with $20.13 \pm 1.35\%$ moisture content at 0 and 20 °C (Jemni et al., 2019b).

concentration, and titratable acidity in dates. The production rate of C_2H_4 at dates changes according to the stages. It is reported to be $< 0.5 \mu L kg^{-1} h^{-1}$ for Khalal stage (at 20 °C), and $< 0.1 \mu L kg^{-1} h^{-1}$ for Rutab and Tamar stages. Studies with Halawi variety suggested that the C_2H_4 production was zero for 91 days after pollination, which then starts to increase (reaching a peak in 15 days) and then having a declining trend. Rutab and Tamar stage of dates is reported to be not influenced by exposure to C_2H_4 (Kader and Yahia, 2011). The C_2H_4 emission of *Deglet nour* cv within packages stored at 0 °C was quite stable at $0.029 \pm 0.003 \mu L kg^{-1} h^{-1}$ (Fig. 5). Also, no relevant changes in C_2H_4 emission within packages at 20 °C were found which values ranging between 0.033 ± 0.005 and $0.041 \pm 0.006 \mu L kg^{-1} h^{-1}$. The slight or no significant rise in C_2H_4 started about at the same time as that in CO_2 production, the authors indicated that it was probably due to fungal development (Jemni et al., 2019b). The changes in RR and C_2H_4 emission were typical of a non-climacteric fruit and the reached RR levels might be considered as moderate (Kader and Kasmire, 1984).

6. Nutrients composition in date palm

Date fruit is very nutritious and has assimilative components (Biglari et al., 2009). Its 2762 kcal kg^{-1} average energy is higher than many other food sources, i.e. figs 2553, wheat bread 2464, catfish 2294, avocado 1786, milk (3.3% fat) 1345, cooked rice 1198, banana 924, mango 652, apple 587, apricot 486 or orange 473 kcal kg^{-1} (Gebhardt and Thomas, 2002). About 65–70% of the date fruit is composed of carbohydrates mostly formed by

inverted forms, glucose, and fructose (Ghnimi et al., 2017). The level of sucrose is highly variable and mainly depended upon the cvs. with very low (5.1%) for *Mabrom* (Ghnimi et al., 2017) or very high (56.6%) for *Deglet nour* cv (Kchaou et al., 2013). The carbohydrate levels of *Burni*, *Suqaey*, and *Khodari* cvs were 81.4%, 79.7%, and 79.4% respectively (Assirey, 2015). In the same way, the carbohydrate content of 9 different cvs was reported to be between 59.6% and 76.8% (Abdul-Hamid et al., 2020). These results highlight the varietal dependences on the carbohydrate level. The levels of sucrose, glucose, and fructose are reduced after a heat treatment prior to storage (Ben-Amor et al., 2016a).

The protein composition of different date palm cvs was reported by Assirey (2015) to vary between 1.72% (*Mabrom*) to 4.73% (*Shlaby*). Similar ranges of proteins in different date cvs were found by Al-Harrasi et al. (2014) and Abdul-Hamid et al. (2020) as 2.63–3.78% and 2.08–3.1%, respectively. The amino acid and protein composition of the dates vary among cvs and ripening stages. Assirey (2015) reported 18 amino acids where the highest levels were for glutamic acid (158–265 mg 100 g^{-1} dw), aspartic acid (127–225 mg 100 g^{-1} dw), proline (86–113 mg 100 g^{-1} dw), glycine (83–102 mg 100 g^{-1} dw) and alanine (78–105 mg 100 g^{-1} dw). The other amino acids were arginine, cysteine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, serine, threonine, tryptophan, tyrosine, and valine. Among these 18 amino acids, 17 were also reported by Hamad et al. (2015) except threonine; and 17 of them were also found by Ali et al. (2014) except tryptophan. The amino acid contents may exhibit different reactions against the postharvest treatments and storage. For example, the glutamic acid and methionine were unaffected by storage duration but reported to be affected by hot water treatment (Ben-Amor et al., 2016b).

Dietary fiber is a carbohydrate that cannot be completely broken down by human digestive enzymes and is typically comprised of polysaccharides such as cellulose, beta-glucan, resistant starch, pectin, and arabinoxylans (Hussain et al., 2020). Numerous studies have reported high contents of dietary fiber for date fruits (Camire and Dougherty, 2003; Englyst and Hudson, 1996; Prosky et al., 1988). Mrabet et al. (2017) found that the dietary fiber level of the Tunisian date palm cvs ranged from 4.7 to 7 g 100 g^{-1} , and the oil- and water-retention capacities were 4 and 17 mL g^{-1} fiber, respectively. This work showed that the dietary fiber composition of neutral Klason consists of 33.3–50.4% lignin, 17.0–24.8% cellulose, 10.7–16.7% uronic acid, and 15.6–25.7% monosaccharides. The composition and concentration of dietary fiber vary depending on the cvs and also on the ripening stage of the date fruits. For example (Mustafa et al., 1986) reported that the Rutab dates had higher pectin content than Tamar fruits, due to the minimal activity of pectin esterase during this period. Date fruits with a high amount of pectin and a low amount of lignin are accepted as high-quality, where the opposite pattern is noted as inedible. The *Deglet nour* and *Allig* cvs were reported to have higher dietary fiber levels than those of Tunisian cvs (14.4% and 18.4%, respectively) (Elleuch et al., 2008).

Phenolic compounds are secondary metabolites that are responsible for the red color of the date fruits and have strong antioxidant properties. The total phenolic compounds content (TPC) of date fruit vary depending on the cv, ripening state, and growing conditions (Daoud et al., 2019; El Hadrami et al., 2011; Saafi et al., 2009). Date fruits are known to have high antioxidant, anti-inflammatory, and anti-cancer properties and to stimulate the immune system by the valuable amounts of nutraceuticals contained (Hussain et al., 2020; Khalid et al., 2017). El Hadrami et al. (2011) reported that the polyphenols level decreased as the fruits ripen and can only be increased if the fruits are damaged. Abu-Reidah et al. (2017) tested 52 different phenolic compounds on pulp, skin, frond, cluster, and pollens of date palms showing that only 3 of them (L-7-(6Rh)Hx, I-3-(6Rh)Hx, and Chr-7-(6Rh)Hx)

are found on all plant parts and 17 of them are found on fruit pulp. The most abundant phenolic compounds in date palm fruit are caffeic, gallic, cinnamic, and ferulic acids (Bouhlali et al., 2018; Daoud et al., 2019; Eid et al., 2013; El Hadrami et al., 2011; Hamad et al., 2015; Mrabet et al., 2016; Saafi et al., 2009). Date fruits have some soluble tannins but their levels are found to decrease as the fruits ripen (Hammouda et al., 2013). The health benefits of soluble tannins are lower than those of the other phenolic compounds (Pompella et al., 2014). The TPC of different date cvs was between 2.49 and 8.36 mg GAE g⁻¹ (Abdul-Hamid et al., 2020; Mansouri et al., 2005). It was also found that the sugar content of dates has a positive correlation with the TPC of fruits (Abdul-Hamid et al., 2020; Al-Farsi et al., 2005). The phenolics composition of 10 Algerian date cvs was tested on a fresh weight basis (Benmeddour et al., 2013) showing that the TPC contents varied from 167 in *Deglet nour* to 709 mg GAE 100 g⁻¹ of fresh weight in Ghazi. Saafi et al. (2009) found a range from 209 to 448 mg GAE 100 g⁻¹.

Date fruit is a good source of K, Ca, Mg, β-carotene, and vitamin A, with a very low content of Na and fat (USDA, 2020). Phytochemical and nutritional composition of the date fruits vary depending on the cvs, environmental condition, and ripening stage (Hussain et al., 2020; Kahramanoğlu and Usanmaz, 2019; USDA, 2020). The moisture content losses during storage improve the storability of the date fruits but reduce their acceptability by the consumers (Assirey, 2015). It was reported to change from 15 to 30% in date (Gebhardt and Thomas, 2002).

The seed of the date palm have also high nutritive characteristics. The chemical composition of the date seeds includes about 1.77–9.55% total sugar, 3.7–6.14% protein, 1.07–1.30% ash, and 4.68–7.96% lipid (Bouhlali et al., 2017; Juhaimi et al., 2012). The difference in the chemical composition is due to differences among cvs, origin, ripening stage, and growing and climatic conditions (Golshan Tafti et al., 2017). The oil of date seeds is used in medicine, cosmetics and food products (Jemni et al., 2019a) and was reported to have 1.06–2.10 mg KOH g⁻¹ acid value and a range of 10.1 to 25 meq O₂ kg⁻¹ peroxide value. It has been found that among 16 different fatty acids from the date seeds oleic is one of the most abundant and known to have positive impacts on human health by reducing the LDL cholesterol and cardiovascular disease risks (Jemni et al., 2019a). The negligible amounts of linoleic acid content in date seeds make it relatively stable to oxidative deterioration and good for human skin (Nehdi et al., 2018).

The storage conditions influence the chemical composition of the date including the textural quality. In fact, high temperature, especially during the retail period, reduces fruit firmness. The optimal storage temperature is highly variable among cvs (Ben-Amor et al., 2016a). A general recommendation for Tamar dates is 0 °C which helps to keep quality about 6–12 months (Kader and Awad, 2009). The combined passive MAP (6 kPa O₂ + 12 kPa CO₂) and moderate temperature (20 °C) may help to protect commercial quality; but the better conditions for 1 month of storage is 0 °C with or without passive MAP (Jemni et al., 2016b). It seems to exist a positive correlation between date quality and CO₂ levels around the fruits, and the use of MAP and partial vacuum improves its postharvest storability (Jemni et al., 2016a). A hot air treatment (55 °C for 30 min or 60 °C for 15 min) was effective in both controlling postharvest infestation by *Ectomyeloid ceratoniae* and improve storability of *Deglet nour* cv at 2 °C (Ben-Amor et al., 2016a).

7. Disorders

The date fruit has some pre- and post-harvest physiological disorders which affect their quality. The most important are the white nose, black nose, and freezing damage (Chao and Krueger, 2007; Kader and Yahia, 2011). White-nose mainly appears after dry

weather during the early Rutab period and causes rapid maturation of the fruits. The postharvest effect of this disorder appears as a whitish drying at the calyx end of the fruit and an increase in sugar content. The black nose is the abnormally shriveling and darkening of the fruit tip, mainly caused by the humid weather at the Khalal stage. Fruit bagging with brown wrapping paper was reported to inhibit black nose disorder (Zaid et al., 1999). The freezing damage occurs by moisture freezing inside the cells with crystallization of water (Kader and Yahia, 2011). Another important disorder of date palm fruits is wilting disorder. It is mainly caused by the high temperature and low relative humidity, which is more prevalent in recent years because of climate change. A study of Alikhani-Koupaei et al. (2018) suggested that regulated deficit irrigation can be used to control wilting disorder and fruit dropping percent.

7.1. Chilling and freezing injuries

Chilling and freezing injuries affect many fruits and vegetables. Chilling injury (CI) is generally a problem for tropical and subtropical fruits which are very sensitive to CI. CI mainly occurs at temperatures below 12 °C but above freezing point (0 °C). With the low, but nonfreezing temperatures, the tissues weakened leading to cellular dysfunctions because they are unable to carry on normal metabolic processes. The symptoms of CI include surface pitting, loss of flavor, internal discoloration, water soaking of the tissue, and increased susceptibility to microbial decay (Wang, 1989). Symptoms of CI may occur in 1 week to 3 months, depending on the produce, but mainly appear after the fruits are transferred to non-chilling temperatures. The use of intermitted warming, edible films/coatings, packaging, and application of salicylic & jasmonic acids are among the most used techniques for the prevention of CI (Aghdam and Bodbodak, 2013). It has been reported that date fruits are resistant to chilling injuries and low sensitivity to freezing injuries (Al-Ani, 1985; Aleid, 2012). The other type of injury is freezing which may occur in the field or in the cold rooms at a temperature below 0 °C. Exposure to freezing temperatures may cause ice formation in the tissues which results in tissue damages. Regarding freezing damages, it occurs by moisture freezing inside the cells and it could harm the dates when stored below -18 °C (Zaid et al., 1999).

7.2. Antioxidant activity

Lipid peroxidation is the oxidative degradation of the lipids where free radicals steal electrons from the neighboring lipids in the cell membranes (Ahmad et al., 2010; Ahmad et al., 2008; Kohli et al., 2019). This oxidation process produces more free radicals, thereby leading to chain reactions that may damage the cells (Ahmad et al., 2010; Ahmad et al., 2008; Ahmad et al., 2019; Kohli et al., 2019). Antioxidants are bio-compounds able to inhibit oxidation and terminate these chain reactions scavenging free radicals (Ahmad et al., 2010; Ahmad et al., 2008; Kohli et al., 2019). Date fruits are rich in polyphenols, carotenoids, tannins, and vitamin A which have high antioxidant potential (Alhaider et al., 2017; Benmeddour et al., 2013; Julia et al., 2015; Khalid et al., 2017; Lobo et al., 2014; Martín-Sánchez et al., 2014; Moss and Ramji, 2016). The scavenging of free radicals prevents the occurrence and/or cure some chronic diseases, i.e.: cancer, cardiovascular disease, and Alzheimer's disease (Kim et al., 2015). The ripening stage influences the antioxidant activity of the date palm, where Khalal stage is known to have the highest antioxidant potential which reduces as fruits ripen (Mohamed Lemine et al., 2014).

8. Marketing

Unlike other subtropical or tropical fruits, the date fruits are not marketed as value-added products. Generally, dates are sold as a whole, ground, chopped, and pitted pieces in pastries (Al-Abid et al., 2006) or derived products like alcoholic beverages, vinegar (Huntrods, 2011), liquid sugar, jelly (Masmoudi et al., 2010) and Tamar juice (Aleid et al., 2013; Augstburger et al., 2002; Hui, 2008). Date syrup is usually obtained from very soft or low-quality dates after hydration and concentration to 30/35°Brix which can be a good replacement of sugar in food formulations as it is a nice source of fructose and glucose (Tavakolipour and Kalbasi-ashtari, 2007). The date fruits collected at the ripening stage can be handled differently. Kimri stage date with green color is marketed for pickles and chutney, Rutab stage can be used for butter, jam, and paste, Khalal stage is used for syrup and jam, and Tamar stage date is usually used into syrup, paste, and bars. By-products and other processed dates with low quality are widely used to produce ethanol, citric acid, alcohols, vinegar, and yeast in the bakery (Aleid, 2011). The dates at ripening stages are usually immersed in 3 to 4% of acetic acid or vinegar for astringency removal. Additionally, immature dates can be dipped in hot water or incubated at 32–38 °C for a few days to become soft, translucent, and better flavor (Yahia et al., 2014). Some by-products such as date seed and press cake can be obtained. Due to their high fiber contents and nutritional values, date seed can be used for feeding cattle, poultry, sheep, and camel (Amany et al., 2012). Moreover, the hearts and terminal buds of date palm trees are good additional recipe for a tasty salad.

9. Conclusion

Date fruits are subject to important commercial activity. However, its sensitivity to the alteration and the lack of mastery of conservation methods on production sites may cause serious problems to cultivators and operators. In this review, we have identified and discussed different methods to be used for the protection and storage of dates fruits.

The need for the preservation of date fruits is encouraged by a number of factors that make proper application of appropriate processing techniques, packaging, and storage. The suitable storage and packaging can help in: i) the preservation of dates for long term storage and uptime during periods of high consumption; ii) ensuring a higher added value and therefore increase the economic profitability for date farmers; iii) minimizing post-harvest losses of dates caused by different alterations incurred in farmers' incomes and living standards; iv) consumption of dates through good quality fruit and available throughout the year. Thus this review can be used by cultivators and operators to get updated information in the area.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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