NFS Journal 6 (2017) 1–10

Contents lists available at ScienceDirect

NFS Journal

journal homepage: http://www.journals.elsevier.com/nfs-journal/

Review article

Date fruit (*Phoenix dactylifera* L.): An underutilized food seeking industrial valorization

Sami Ghnimi [a,*], Syed Umer [a], Azharul Karim [b], Afaf Kamal-Eldin [a]

[a] *Department of Food Science, United Arab Emirates University, P.O. Box 15551, Al-Ain, UAE*
[b] *Science & Engineering Faculty, Queensland University of Technology, Australia*

ARTICLE INFO

Article history:
Received 23 September 2016
Received in revised form 7 December 2016
Accepted 7 December 2016
Available online 12 December 2016

Keywords:
Phoenix dactylifera
Fruits
Seeds
Processing
Dietary fiber
Phenolic antioxidants

ABSTRACT

Background: The fruit of the date palm (*Phoenix dactylifera* L.) is one of the most abundant fruits in the world. Hundreds of varieties having different texture, color, and flavor are available for valorization and adoption in food processing operations. Such utilization should be based on the fruit valuable characteristics; mainly its richness in dietary fiber and phenolic antioxidants.

Scope and approach: This review article complements these existing reviews by primarily addressing the chemistry and processing of date fruits pulp and seeds with particular emphasis on dietary fiber and antioxidants as linked to important fruit processing and utilization features.

Key findings and conclusions: Date fruits contain 6.5–11.5% total dietary fibers (of which 84–94% insoluble and 6–16% soluble dietary fiber) and is very rich in phenolic antioxidants (1–2%) especially condensed tannin pigments based on (−)-epicatechin oligomers. Date seeds contain about 15% of fiber, characterized by a high level of water-insoluble mannan fibers. Date fruits are widely available in the global market, mainly at mature *Tamr* stage, but there is still room for improvement. It has been suggested that date fruits and seeds can be exploited in some food applications utilizing their high levels of fiber and antioxidants. The incorporation of date fruits and seeds as food ingredients is still growing with the aim to promote the presence of dates in the modern's consumer shopping basket.

Contents

1. Introduction

The tree of dates or the palm date (*Phoenix dactylifera* L., Family *Arecaceae*) has played an important role as a food security crop in the Middle East and North Africa region (MENA), providing valuable food for people for the last 5000 years. In appreciation of its fruits, the date tree is referred to as the sacred tree [74], the tree of life [69], and the bread of the desert [84]. The latin name of the tree is believed to have been derived from Greek *Phoenix daktulos*, which means purple or red finger.

Currently, about 100 million date trees are cultivated globally out of which ~90% are grown in the MENA. The annual global production of dates was recorded as 7.5 million tons in 2008. There is massive expansion in land areas being used for cultivation of dates not only in MENA region but also in other countries such as Australia. Date fruits are consumed at three different stages of maturation, the mature but unripe *Khalal* or *Bisr* (50% moisture), ripened *Rutab* (30–35% moisture), and

* Corresponding author.
E-mail address: sami_ghnimi@uaeu.ac.ae (S. Ghnimi).

http://dx.doi.org/10.1016/j.nfs.2016.12.001

mature *Tamr* (10–30% moisture) [18,34,88,89]. Due to the surplus production of dates, soft and semi-dry varieties are commonly stored after partial drying to a moisture level <25%, which has shown acceptable shelf life. Overproduction of dates with limited processing leads to huge losses especially for low grade fruits. Major losses, as high as 2 million tons per year, are globally observed during harvesting, storage, conditioning, and processing [21]. Low grade date fruits are dehydrated, grounded, and mixed with grain to form a very nutritious feed for camels and horses in the desert. Date seeds are added to animal feed for cattle, sheep, camels, and poultry.

Date fruits have enormous scope and potential for use as food because of their nutritional and economical value [50]. Date fruits contain 6.5–11.5% total dietary fibers (of which 84–94% insoluble and 6–16% soluble dietary fiber), about 1% fat, 2% proteins, and 2% ash and is a rich source of phenolic antioxidants (1–2%) [87]. Variations in the chemical composition of date fruits is expected to influence their nutritional value, sensory quality, and industrial utilization. Date seeds, representing 10–15% of the whole fruit [13,64], is a valuable byproduct of date fruit processing industries and is characterized by a high level of water-insoluble mannan fibers and may be used to enhance the fiber content of certain food products.

Date fruit is a key food security resource in the aridlands that requires intensive efforts for valorization. There is a large potential to especially develop healthy food products utilizing the high value fiber and phenolic antioxidants found in the fruit flesh and seeds. The ability to use dates to produce value-added products; such as date flour, fiber concentrate, juices, jam, date-based fruit bars, sugar, and functional ingredients in beverages, dairy and baking industry will help to make the palm date an economically viable commodity. However, steady and goal-oriented research and development is required to achieve this goal. The aim of this review is to summarize published research and patents on date fruit utilization, with special focus on the opportunity to develop knowledge on date fibers and phenolic antioxidants as ingredients in functional food products.

2. Description, ripening behavior and classification of date fruits

The date fruit is composed of a pericarp, mesocarp, endocarp and one seed (also called kernel, pit, or pyrene) (Fig. 1). The mesocarp, representing the most part of the fruit pulp, consists of enlarged parenchymatous cells and is divided into outer-mesocarp and inner-mesocarp intermediated by 3–10 layers of tanninferous cells [80]. The seed has a ventral side characterized by a furrow of varying depth and width running along its length. The dorsal side of the seed is convex with a small shallow hole called the micropyle under which lies the embryo. Seeds from different date varieties differ in the depth of the furrow and the position of the micropyle (central or peripheral).

Date fruits develop through five different stages *Hanabauk*, *Kimri*, *Khalal* (*or Bisr*),*Rutab*, and *Tamr* as shown in Fig. 1. The fruits become edible in the final three stages as a result of decreased bitterness, increased sweetness, and improved tenderness, and succulence [18,25]. Different varieties of date fruits may variably be harvested at the *Khalal*, *Rutab*, and/or *Tamr* stages with best time of harvesting being dependent on variety.

At *Tamr* stage, date fruits vary in size, shape, color, texture and flavor depending on the variety and agro-climatic conditions [26]. The number of date varieties grown globally exceeds 2000 but <10% of these are described regarding their characteristics, examples of which are shown in Table 1. *Tamr* fruits shape varies from oval to cylindrical with dimensions from 3 to 11 cm long and 2 to 3 cm diameter and color from

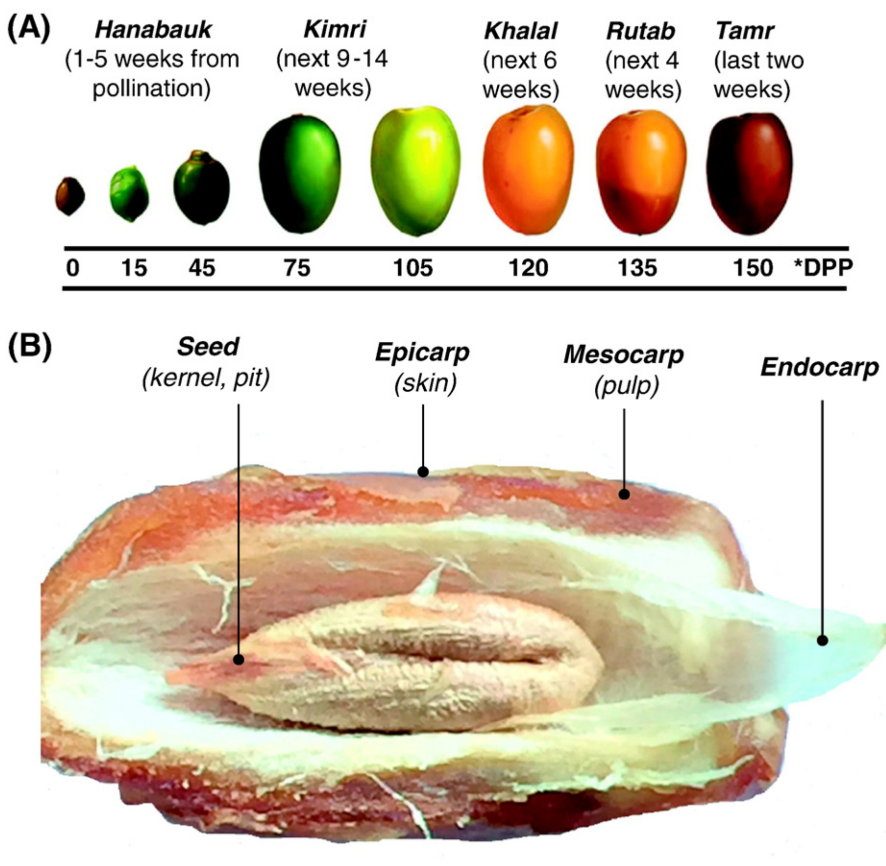

Fig. 1. (A) Different fruiting stages of date palm according to DPP* (days post-pollination) showing Khalal, Rutab and Tamr, the three edible stages of the fruit (*Reprinted from* Al-Mssallem et al. [11] *by permission from Macmillan Publishers Ltd.: [Nature Communications], copyright (2013)*); (B) The anatomy of the date fruit at Tamr stage showing the epicarp, mesocarp, endocarp and seed.

Table 1
Origin, ripening behavior, and quality characteristics of selected varieties of date fruit (*Phoenix dactylifera* L.).

Cultivar	Meaning of the name	Origin	Ripening	Color	Shape	Skin	Size	Flesh texture	Flavor	Calyx (cap)	Further comments
Barhi	Maturity affected by summer winds at Basra	Iraq	Medium-Late	Amber to reddish brown	Broadly ovate to rounded	Medium thick	30 × 21 mm	Soft, smooth and translucent	Rich and delicate	Small size, slightly protruding and inclined	Recognized for excellent flavor, eaten at *rutab* and *tamr* stages.
Deglet Noor	Date of the light	TunisiaAlgeria	Medium-Late	Slightly deep brown	Oblong-ovate	Medium thick	40–50 × 20–25 mm	Semi-dry, firm, soft, reddish white pulp, medium level of fiber	Delicate and distinctive	Large size, protruding	Well known internationally, eaten at *rutab* and *tamr* stages
Hallawy	Sweet dates	Iraq	Early	Golden brown	Oblong with rounded apex	Thin, shrinking with flesh in irregular wrinkles	38 × 21 mm	Soft, caramel-like, translucent, low fiber and pigments	Very rich, sweet, distinctive	Mid-size, protruding	Fruit has good keeping quality and moisture tolerance but wrinkles during ripening more than other dates
Fard	Defined, price	UAE	Late	Dark brown	Thick cylindrical	Separating from flesh, wrinkled	38–39 × 22–23 mm	Medium thick, white pulp with low fiber and pigments	Sweet, pungent	Mid-size, protruding	Semi-dry variety, eaten at *rutab* and *tamr* stages
Khadrawi	Green (when it starts to soften)	Iraq	Mid-early	Reddish brown	Oblong-elliptical to oblong-ovate	Medium thick, tender, sometimes blistered but shrinking more or less with flesh	32 × 23 mm	Soft, melting, caramel-like, free from fiber and pigments	Pleasant, delicious	Mid-size, slightly inclined and slightly protruding	Fruit with good keeping quality and do not wrinkle considerably, eaten at *rutab* and *tamr* stages
Khalas	Quintessence	Saudi Arabia, UAE, Oman	Mid-season	Deep amber to reddish brown	Oblong-oval	Thin, usually adhering to flesh	36 × 23 mm	Melting, tender, translucent, thick and white flesh with some yellowness, free from fiber and pigments	Rich, delicious	Mid-size, protruding, inclined	Recognized as excellent quality, eaten at *rutab* and *tamr* stages
Khasab	The abundant producer	Iraq	Very late	Deep red to dull reddish brown or even black	Rounded oval	Tough separating from flesh in blisters	38 × 25 mm	Thick, white flesh with some yellowness, mid-level of fiber and pigments	Delicate and pleasant	Large size, slightly protruding	Eaten at *rutab* and *tamr* stages. Preferred to be eaten at *Rutab* stage
Majdool	Unknown	Mid-season	Early	Amber to reddish brown	Oblong-oval to ovate	Medium thick adhering to flesh forming coarse irregular wrinkles	38–40 × 26–32 mm	Moderately soft, white flesh, low in fiber and pigments	Mildly rich, pleasing	Large size, located on a hollow hole	Large soft dates, Eaten at *rutab* and *tamar* stages
Zahidi	Small quantity and cheap	Iraq	Mid-season	Lower part dry & faded yellow, soft part reddish brown	Oblong-obovate	Rather thick & tough, tend to adhere to flesh	33 × 27 mm	Semi-dry, soft part thick, firm, of smooth consistency, drier part more or less fibrous and rather hard	Not outstanding, sweet but lacking delicacy	Large size, protruding, amber color	Can provide soft or dry dates depending on how long it allowed to remain on the tree. Eaten at *rutab* and *tamr* stages
Lulu	The pearl	Pakistan Oman	Mid-late	Dark amber	Oblong-oval	Separating from flesh	38 × 26 mm	Thick, less fibrous flesh	Sweet and soft	Small size, slightly protruding,	Eaten at *rutab* and *tamr* stages

yellow, brown, red, to black. The fruits are also different in the hardness of the edible part and are classified according to their moisture contents at fresh *Tamr* stage into soft (≥30% moisture), semi-dry (20–30% moisture) and dry varieties (≤20% moisture, <0.65 water activity) [40]. Generally, fruits of soft date cultivars are dominated by invert sugars (fructose & glucose) and contain little or no sucrose while dry varieties may contain a relatively high proportion of sucrose. According to sugar type, date varieties are classified into (i) invert sugar varieties containing mainly the invert sugars glucose, and fructose (e.g. Barhi and Saidy), (ii) mixed sugar varieties (e.g. Khadrawy, Halawy, Zahidi, and Sayer), and (iii) cane sugar varieties containing sucrose as the main sugar (e.g. Deglet Noor and Deglet Beidha). There is some agreement and disparity in the classification of date varieties according to moisture content or sugar type suggesting that the relationship is not strictly linear possible due to interference from fiber content and type.

The amount of sugars and relative proportion of sucrose-to-invert sugars (glucose and fructose) seem to determine the water sorption characteristics of the cultivar, the moisture content, and consequently the hardness of the fruit. Thus varieties are different in their hardness and sweetness with those high in sucrose being generally firm while those high in invert sugars being commonly soft [19,29,60,67,89].

3. Date fruits: rich sources of high value fibers and natural antioxidants

3.1. Dietary fibers in date flesh and seeds

Carbohydrates, including soluble sugars and dietary fiber, are the predominant components in date fruits followed by moisture with only small amounts of lipids, proteins, and ash (Table 2). Date fruits are appreciated as rich sources of dietary fiber, which is defined as the polysaccharides and lignin components of plant foods that are indigestible by enzymes in the human gastrointestinal tract. The content of total dietary fiber in dates ranges 6.5–11.5% depending on the variety and climate [12]. Insoluble and soluble dietary fiber types amount for 84–94% and 6–16%, respectively, to the total dietary fiber in date fruits. Soluble dietary fibers contribute to the formation of a viscous gel in the intestine that slows the intestinal absorption of anti-nutritional factors such as cholesterol. Insoluble fibers, on the other hand, provides bulking and aids fermentation and generation of short chain fatty acids in the intestine [70].

Up to date, there is no available information on the exact carbohydrate polymers constituting the insoluble and soluble fibers of the date fruits. However, hydrolysis of dates dietary fiber releases neutral sugars (15.6–25.7%), uronic acids (10.7–16.7%), cellulose (17.0–24.8%) and Klason lignin (33.3–50.4%) [65]. Dalaki fiber obtained by hot water extraction contained acid-soluble lignin (2%), acid-insoluble lignin (48%) and polysaccharides (21%). The polysaccharides are composed of glucan (10%), xylan (5%), galactan (4%), arabinan (2%) and mannan (0.5%) [77]. Xylose was the major neutral sugar (ca. 50%) in 11 Tunisian date varieties occurring together with arabinose (17–22%), galactose (8–16%), mannose (5%), glucose (5%), rhamnose (2–3%) and fructose (1–2%). Thus, pectin, xylan, and arabinoxylan are the major non-cellulosic fibers in dates representing about 75% of total fiber. Pectin was found to accumulate in dates until it reaches the Rutab stage with minimal activity of pectin esterase enzyme [67]. In general, high pectin and low lignin are indicative of good quality fruits while the opposite is an indicator of inedibility. The amount of fiber in date fruits declines during ripening because of fiber degrading enzymes, i.e. *cellulase* and *pectinase*, that hydrolyze insoluble fibers to smaller soluble molecules. Date fibers have high antioxidant and antimicrobial activities due to associated lignin and tannins [78].

Extraction of Libyan date fruit pulp with water gave a polysaccharide that on complete acid hydrolysis yielded only glucose indicating a linear β-glucan containing both (1 → 3) and (1 → 4)-linkages [45]. In addition, date fruits contain two anticarcinogenic glucans having molecular masses of *Mr* ~ 10,000 and *Mr* ~ 200,000 characterized as a mixture of linear (1 → 3)-β-D-glucan with various (1 → 6)-linked mono-, di- and tri-saccharide branches with 0, 1, or 2 (1 → 3)-β-D-glucopyranosyl residues (Fig. 2). The two glucans differed by the presence of (1 → 6)-branched chains consisting of D-glucose and D-Glc*p* -(Glcp-(1 → 3)-D-Glc*p* groups for the lowest molecular mass polysaccharide or D-Glc*p*-(1 → 3)-D-Glc*p* for the highest-molecular-mass polysaccharide [44,46,47]. (See Fig. 3.)

As mentioned above, date seeds (also called pits, stones, or kernels) represent about 10–15% of the weight of the fruit depending on the variety. Date seed carbohydrates are mainly of the insoluble fiber types, e.g. seeds of Deglet Noor contain about 50% cellulose and 20% hemicelluloses [24]. Date seeds comprise an abundant endosperm present as living cells that store carbohydrates mainly in the form of (1 → 4) β-D mannan [27]. The endosperm of mature date seeds is extremely hard because of two thick cell wall structures, an outer fibular layer and a thin inner granular layer.

Different hemicellulose fractions were identified in date seeds including water-soluble gluco- and galacto-mannans and an alkali-soluble heteroxylan. The hardness of the endospermic cells was attributed to water-insoluble mannan having <10% galactose side chains as well as less hard cells containing soft hydrophilic galactomannans with abundant (1 → 6)-α-D-galactose residues which are mobilized during germination by β-D-mannase (EC 3.2.1.78), β-D-mannosidase (EC 3.2.1.25) and α-D-galactosidase (EC 3.2.1.22) [62]. A neutral mannan fraction (45.8%, 12.000 Da) is formed by mannosyl residues linked to each other by β-1,4-glycosidic linkages together with small amounts of glucose, arabinose, and rhamnose (molar ratio 84:6:6:4) and also contained protein (0.08%) and uronic acid (0.05%). This fraction was found to comprise a (1 → 4)-β-linked D-mannan having a mannose/glucose ratio of 93:7, a total hexose content of 70% and an acetyl content of 18% [41]. Date seeds also contain a galactomannan based on a backbone of (1 → 4)-β-D-mannopyranosyl residues carrying a single (1 → 6)-α-D-galactopyranosyl residue. Upon acid hydrolysis, the purified galactomannan was degraded to D-mannose and D-galactose in a molar ratio of 2.7:1 [42]. Mannans are storage compounds that are

Table 2
Proximate composition, sugar, and fiber contents (g/100 g FW), and energy values (kcal/100 g FW) in the fruit flesh of selected dry dates.

Cultivar	Moisture	Protein	Lipid	Ash	Glucose	Fructose	Sucrose	Fiber	Energy[a]
Barhi	29.5	2.3	0.1	1.4	29.7	27.6	ND	9.4	239
Deglet Noor	21.2	2.4	0.1	2.3	14.8	12.3	38.0	8.9	271
Fard	27.7	2.1	0.1	1.8	30.2	30.2	ND	8.0	251
Hallawi	12.2	2.3	0.5	1.9	34.3	34.3	6.7	7.8	315
Khadrawy	9.5	2.2	0.4	1.9	30.3	31.9	ND	23.8	261
Khalas	22.3	2.1	0.1	1.4	36.5	31.7	0.0	5.9	282
Khasab	16.5	1.6	0.1	1.6	36.7	35.1	0.0	8.4	295
Lulu	21.3	2.5	0.1	1.6	35.3	36.5	ND	2.7	298
Madjool	21.0	1.8	0.1	1.7	34.3	33.9	0.5	6.7	283
Zahidi	8.3	2.0	0.4	1.7	30.1	35.9	11.6	11.0	322

Data from Borchani et al. [22].
[a] Energy values were calculated by multiplying the contents of protein, glucose, fructose, and sucrose by 4 and lipids by 9.

(A)

[→3-β-D-G-Glc*p*-(1→3)-β-D-G-Glc*p*-(1→3)-3-β-D-G-Glc*p*-(1→3)-β-D-G-Glc*p*-(1→]$_n$
6
↑
[3-β-D-G-Glc*p*-(3→1)-β-D-G-Glc*p*]$_{0\text{-}2}$

(B)

[→4)-Xyl*p*-(1→4)-Xyl*p*-(1→4)-Xyl*p*-(1→4)-Xyl*p*-(1→4)-Xyl*p*-(1→→4)-Xyl*p*-(1→]$_n$
2 2
↑ ↑
1-Xyl*p* 1-GlcA4Me

Fig. 2. Date fruit fibers (A) Structure of branched β-D-glucan part of the soluble fibers in date fruit ($n = 10$–250); and (B) Structure of alkali soluble heteroxylans isolated from date palm seeds.

slowly degraded by *endo*-β-mannanase (EC 3.2.1.78) and β-mannosidase (EC3.2.1.25) to release mannose that is used for embryo development [48,61]. Mananns also provide mechanical protection to the embryo against damage during the long germination of palm seeds.

An alkali-soluble heteroxylan in date seeds is mainly composed of xylose (82%) and 4-*O*-methylglucuronic acid (17%) with small amount of arabinose and traces of galactose, glucose and mannose (Fig. 2). It was found to be a polymer of (1 → 4)-linked D-xylopyranosyl residues having branches at O-2 consisting of 4-*O*-methyl-α-D-glucopyranosyluronic acid and D-xylopyranosyl groups [43]. Recently, phoenixoside A ((6S,7Z,9R)-hydroxy-3-oxo-ionol-9-O-β-D-glucopyranosyl-(1″ → 6′)-β-D-glucopyrano-side), a new megastigmane glycoside has been identified in the n-butanol extract of date seeds [15].

3.2. Natural antioxidants in date flesh and seeds

Studies on antioxidant properties of some date fruits obtained from various countries are summarized in Table 3. The total antioxidant activity of dates, measured using the ORAC-fluorescent assay, ranged 8212–12,543 μM/g and was higher than other fruits including elderberry and bilberry [71]. In fact, date fruits were found to have the second highest antioxidant activity among 28 fruits commonly consumed in China [90]. Date fruits are known to contain high levels and wide range of phenolic antioxidants, e.g. the total content of soluble phenolic compounds in three sun-dried Omani date varieties ranged 217–343 mg of ferulic acid equivalents/100 g, which are high when compared to other fruits [6]. The total antioxidant activity in dates decreased upon storage at ambient temperature possibly due to the conversion of soluble tannins into insoluble tannins [68] and/or to enzymatic oxidation and disappearance of flavans and caffeoyl shikimic acid [55,56].

The ethanol and acetone extracts of nine date varieties (Amari, Barhi, Deglet Noor, Deri, Hadrawi, Hallawi, Hayani, Majdool, and Zahidi) were found to contain soluble phenolic compounds including hydroxybenzoates, hydroxycinnamates and flavonols [23]. The levels of phenolic acids in ripe dates were 20 mg/100 g in Khasab, 35 mg/100 g in Fard, and 63 mg/100 g in Khalas varieties with ferulic acid being the dominant phenolic acid [75]. The phenolic classes and member phenolic compounds identified in date fruit are summarized in Table 4. 5-O-caffeoylshimic acid (dactyliferic acid) and its isomers isodactyliferic and neodactyliferic were identified in Deglet Noor and other Algerian dates [59] and were suggested to contribute to browning during the ripening of the fruits [57]. Other phenols that were found in date fruits include caffeoylshikimic acid hexoside, caffeoyl-sinapoyl monohexoside and dihexoside and acetylated flavonols [36].

Flavonoid glycosides of luteolin, quercetin and apigenin were identified in Deglet Nour, including methylated and sulfated forms of luteolin and quercetin present as mono-, di- and tri-glycosylated conjugates whereas apigenin is only present as diglycoside. In addition, quercetin and luteolin were found to form primarily *O*-glycosides whereas

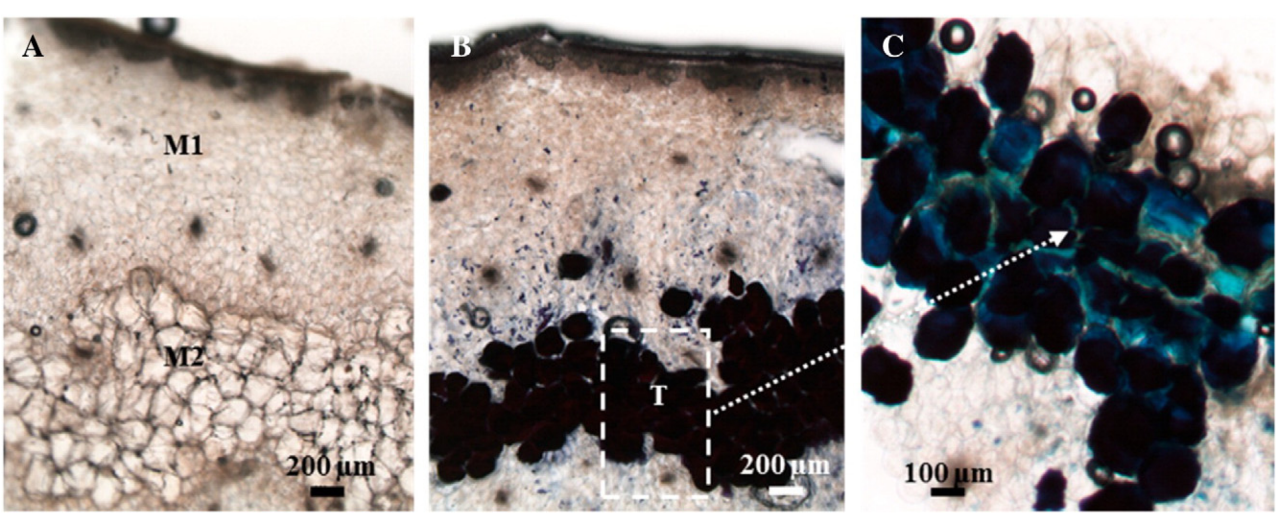

Fig. 3. Tannins localization with p-Dimethylaminocinnamaldehyde (DMACA) staining. Light micrographs of Deglet Nour dates pericarp cross sections M1 + M2 (thick sections): (A) witness pericarp, (B) pericarp stained with DMACA, and (C) pericarp stained with DMACA at higher magnification. T, tannins; M1, external zone of the pericarp; M2, mesocarp zone. Reprinted from Hammouda, et al. [37] with permission from American Chemical Society Copyright [2014].

Table 3
Selected studies on the antioxidant properties of date fruits summarizing studied date cultivars, antioxidant activity methods used and findings.

Date varieties	Method(s)	Antioxidant findings	References
Amir Hajj, Barhee, Deglet Noor, Halawy, Hayany, Hilali, Khadrawy, Khalasa, Medjool, Zahidi, Khalasa, Shaishi, Sukari, Gur, Khunizi (Saudia Arabia)	Antioxidant capacity, 2,2'Azino-bis (3-ethylbenzo-thiazoline-6-sulfonic acid) diammonium salt (ABTS radical assay)	Total phenolic content ranged 225–507 mg GAE/100 g fresh weight	[14]
Allig, Deglet Nour, Kentichi, Khouet Kenta (Tunisia)	Total phenolic content Antioxidant activity by the Folin–Ciocalteu method, antioxidant activity by the ABTS radical assays	Total phenolic content ranged 210–450 mg equivalent gallic acid/100 g fresh weight Trolox-equivalent antioxidant activity ranged 870–1150 μmol Trolox equivalents/100 g fresh weight (ABTS)	[76]
Khalas, Sukkari and Ajwa (Saudia Arabia)	Total phenolic content by the Folin–Ciocalteu method and HPLC	Total phenolic content ranged 240–455 mg/100 g. Caffeic acid (0.5–0.7 mg/100 g), catechin (0.5–0.75 mg/100 g), rutin (0.4–0.8 mg/100 g).	[77]
Tazizaout, Akerbouche, Deglet-Nour, Ougherouss, Tantbouchte, Tafiziouine, and Tazerzait (Algeria)	Total phenolic content by the Folin–Ciocalteu method LC–DAD–MS (ESI+)	The total phenolic content was in the range of 2.5 to 8.4 mg gallic acid equivalents (GAE) per 100 g fresh fruit. All the varieties contained *p*-coumaric, ferulic and sinapic acids and some cinnamic acid derivatives and three different isomers of 5-*o*-caffeoylshikimic acid. Different types of flavonoids (mainly flavones, flavanones and flavonol glycosides) were variably present in the different varieties. No quantitative data was given.	[59]
Fard, Khasab, and Khalas (Oman)	Total phenolic content by the Folin–Ciocalteu method, total anthocyanins by pH differential method, and phenolic acids by HPLC	Total contents of phenolic compounds (134–343 mg of ferulic acid equiv/100 g and total anthocyanins (0.24–1.52 mg of cyanidin 3-glucoside equiv/100 g). The content of free phenolic acids (protocatechuic acid, vanillic acid, syringic acid, and ferulic acid) ranged 2.6–12.3 mg/100 g), and bound phenolic acids (gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, vanillic acid, caffeic acid, syringic acid, *p*-coumaric acid, ferulic acid, and *o*-coumaric acid) ranged 6.8–30.2 mg/100 g.	[6]
Deglet Noor (USA)	LC-ESI/MS/MS	Thirteen flavonoid glycosides of luteolin, quercetin, and apigenin were identified. Mass spectra indicate that both methylated and sulfated forms of luteolin and quercetin are present as mono-, di-, and triglycosylated conjugates whereas apigenin is present as the only diglycoside. Quercetin and luteolin formed primarily *O*-glycosidic linkages whereas apigenin is present as *C*-glycoside. No quantitative data was given.	[39]

apigenin was present as *C*-glycoside [87]. Date tannins belong to the class of condensed tannins (or proanthocyanidins), mainly procyanidin oligomers based on (−)-epicatechin structure ranging from decamers to heptadecamers [87]. The proanthocyanidins are the major phenols in the edible parts of ripe dates amounting to ca. 1.5% and representing about 95% of total polyphenols. Soluble tannins are responsible for the astringent taste of date fruits before full ripening but their concentration decreases during maturation [36]. On the other hand, the condensed tannins (proanthocyanidins) may act together with other phenolic compounds as free radical scavengers or metal chelators, but their effects on human health cannot be interpreted [73].

Table 4
Phenolic Classes of and identified compounds in date fruits.

Class	Identified compounds
Benzoic acids and derivatives	Gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, vanillic acid, sinapic acid, and syringic acid
Cinnamic acid and derivatives	Caffeic acid, hydrocaffeic acid, ferulic acid, *p*-coumaric acid, syringic acid, dactyliferic acid, 2 caffeoylshikimic acid hexosides, 3-caffeoylshikimic acid, 4-caffeoylshikimic acid, 5-caffeoylshikimic acid, caffeoylsinapoyl hexoside, and dicaffeoylsinapoyl hexoside
Flavonoid glycosides and esters	Luteolin, quercetin and apigenin, quercetin rhamnosyl-hexoside sulfate, quercetin 3-O-rutinoside (rutin), quercetin hexoside sulfate, quercetin acetyl-hexoside, isorhamnetin-3-O-rutinoside, isorhamnetin hexoside, chrysoeriol rhamnosyl-hexoside, isorhamnetin acetyl-hexoside, quercetin 3-O-glucoside (isoquercitrin), chrysoeriol hexoside sulfate, and chrysoeriol hexoside
Flavan-3-ols	(+)-catechin, and (−)-epicatechin
Proanthocyanidins	Procyanidin oligomers based on (−)-epicatechin including procyanidin B1, procyanidin B2, procyanidin trimer, procyanidin tetramer, procyanidin pentamer, and procyanidin polymers based on (−)-epicatechin (decemers to heptadecemers)
Anthocyanins	Cyanidin (in some dark varieties)

References: [57,75,6,59,87,23,36,72].

Phenolic compounds of dates as either soluble or linked to fiber with considerable variations between varieties [65]. Although several studies have reported high total antioxidant activity in date fruits (Table 3), knowledge about the identity of these phenolic compounds and their association with fiber is limited and incomplete. There is great variation in the analyzed contents of phenolic compounds due to limitations in extraction methods, fruit genetics, environmental factors and fruit maturity making it not possible to estimate their daily intake. However, the consumption of 100 g of dates is estimated to provide 250–450 mg of total phenolic compounds. Date seeds contain very high levels of phenolic antioxidants (3100–4400 mg gallic acid equivalents/100 g) giving 580–930 μM Trolox Equivalents Antioxidant Activity (TEAC) [54]. Date seeds also contain an antibiotic oxytetracycline whose formation is inducible by *Streptomyces spp.* [2–4,8,16].

4. Potential industrial applications and patented processes

Date fruits may provide an opportunity to improve human health and support economic development. However, this fruit is undervalorized and requires intensive research efforts in order to develop a sustainable date palm industry [83]. Many products such as pickles, chutney, jam, jelly, date-in-syrup, date butter, candy, date bars and confectionary products could be prepared from date fruits. Dates at the *kimri* and *khalal* stages of maturity may be used for preparing pickles and chutney. Pickles-in-oil are prepared using pitted, sliced *kimri* fruit with various spices, condiments, and mustard oil [79]. Brine and salt-stock pickles are other popular products that could be prepared from *kimri* dates. Dates at *Khalal* stage are ideal for meat products, which need the use of antioxidants but not a sweet taste. It may be recommendable to blanch unripe date fruits to improve their functional properties through the inhibition of some enzymes and stabilization of phenolic compounds and color. Blanching may also enhance some technological properties such as water holding capacity and emulsion stability, which are very important to obtain desirable texture in meat and baked products. Dates at *Rutab* stage have higher sugar content and a lower phenolic content and can be used as natural sweeteners in dairy and pastry products. At the *Tamr* stage of maturity, date fruits are processed into jam, date bars, date paste, or date syrup. Because of their low glycemic index and possible *anti*-diabetic effect and antioxidant properties, date fruits and their syrup, paste, and jelly products could add value to many foods [32,52]

Date pastes with the desired moisture content, texture and softness provide opportunities for combination and supplementation with other ingredients. Date paste, an intermediate moisture (20–23% moisture) product with water activity <0.6, is widely used in the baking industry as a filling in pastries and biscuits, as well as an ingredient in cereals, puddings, breads, cakes, cookies, ice cream, and confectionaries. Replacement of sucrose by date paste in breads and cookies improves their nutritional quality by increasing levels of minerals, vitamins, and phenolic antioxidants. Date sugars, mostly invert sugars, increase the softness and sweetness of bread and cookies. The addition of up to 15% date paste in the formulation of bologna-type meat products led to the enhancement of the nutritional (lower fat content and higher fiber content than the control) and technological quality (redder-colored and less hard, chewy and cohesive product than the control) together with a satisfactory sensory quality attributes [58].

When added to yogurt, at levels up to 10%, date syrup provides unique functionalities including sweetness, flavor, and increased nutritional value. Date syrup has been also used to replace sucrose in yellow and chocolate-flavored layer cakes. Date syrup is also used as a sweetening agent, with the characteristic flavor of mature date fruit, to substitute malt syrup, molasses, glucose syrup, invert sugar, high fructose syrup, and all forms of crystalline sugars. Date juice enriched with pectin and lemon flavoring could be used to prepare firm jellies with higher adhesiveness, chewiness, and cohesiveness. The use of date juice in jellies resulted in significantly lesser quantities of sugar (73° Brix) and decreased pH of 3.57 [7,81].

Dates containing high sugar contents are suitable for the preparation of jam, with ca 65% sugars, 1% pectin, and pH of 3.0–3.2, and date butter, which is similar to peanut butter in usage [79]. Date candies are prepared using date paste, roasted nuts, and coconut, and may be coated with chocolate to give a unique sensory quality. Date bars with almonds, coconut, groundnuts, and pistachios can be fortified with sesame, skim milk powder, and oat flakes, and coated with chocolate. Different desserts are prepared from date fruits, e.g. ice creams, puddings, date sherbet, and fruit yogurt. Other products include macerated date, fiber filled date, date sauces such as steak sauce containing up to 10% ground date [81]. Incorporation of finely and coarsely milled date seed powders in flat bread enhanced their fiber contents. Bread containing 10% coarse date seed fiber was found to have comparable sensory properties while bread containing fine date seed powder had lower color, flavor, odor, chewing, uniformity and overall acceptability sensory scores compared to a control enriched with wheat bran [10,21,35,51,86].

Roasted and powdered date seeds are used by certain rural communities as coffee substitutes and coffee-like preparations made from date seeds are available in some Arabian markets in Saudi Arabia and United Arab Emirates. Ghnimi et al. [33] prepared a coffee-like beverage from roasted date seeds and compared it with traditional Arabic coffee. The date seed beverage is caffeine free and has lower amount of total phenolic compounds than Arabic coffee. Sensory evaluation revealed that the date seed coffee-like preparations were acceptable but were lower in quality compared to Arabic coffee. Before roasted date seed extracts will be approved for human consumption, their possible estrogenic effects need to be evaluated [33].

There are many published patent applications on date fruits (Table 5). These inventions relate to new functional ingredients, methods, and formulations with certain therapeutic or nutritional characteristics incorporating date pulp, seeds and/or bioactive ingredients. These patents mostly refer to ethanol production, fruit wine, fiber concentrates, coffee-like beverage, and tablets for nutritional and/or therapeutic value.

5. Future research needs

Only a few date varieties of dates are known in the international market with Deglet Noor, exported mainly by Tunisia and Algeria, being the best known variety in the European market. Less known are other varieties including Majdool, Deglet Beidha, Hallawi, Saher, Khadrawi, and Barhi. Unfortunately, a large number of excellent date varieties are not well known outside their countries of production as there is no internationally agreed system for their identification and classification. These include soft, semi-hard, and hard fruit types that can be used in different food applications.

Date variety identification is still an empirical process dependent on the knowledge and experience of traditional inspectors and is based on fruit morphological features, which are sensitive to environmental factors. Research on date variety identification of potential varieties is needed to provide distinctive description including phenotypical, sensory, biochemical, and other complementary features such as pictorial signatures and DNA molecular markers. This system can be developed using advanced equipment for physicochemical characterization including hyperspectral imagining, electronic tongue, and electronic nose. In addition, detailed analysis of the date fruit moisture, sugars, fibers, pigments, organic acids, and phenolic compounds types and levels in key date varieties is required. Research also needs to correlate the chemical composition of date fruits with color, texture and taste.

Date seeds constitute a surplus by-product of date fruit processing and its exploitation in food and feed would provide an economical advantage. As mentioned above, date seeds can be used as ingredients in e.g. bread but there is number of reports proposing that date seeds possess an estrogen-like activity imparted by phytoestrogens and/or estrone [20]. Estrone was found in seeds of some date varieties while being absent in others, e.g. it was present in Thamani and Sukkari seeds at 1.4 and 3.3 mg/100 g, respectively, but was absent in Sebakat Al-Qaseem, Rothanat Al-Qasem, Saffr Al-Riyadh, Mashwal Hada Al-Sham, Zaghalool and Helwet El-Goof cultivars [38]. Estrone as well as other estrogenic compounds including estradiol, esteriol, β-sitosterol, apiginin, and luteolin, has been isolated from date pollen [1]. Date seed extracts were reported to induce contraction of the uterus and to stimulate vaginal orifice opening. These effects were not blocked by atropine or cyproheptadine but partially by indomethacin and hydrocortisone suggesting that the extract's action is similar to that of estrogen [30]. The aqueous extracts of date seeds induced uterus contraction in vitro and increased uterine weight in immature rats in a way similar to estrogens [9]. Consideration of dose is important since date seeds were found to suppress estrogen secretion from ovaries of female rats and to inhibit the secretion of gonadotrophic hormones from the anterior pituitary possibly due to an estrogen negative feedback mechanism [5]. Thus ingestion of date seeds in the right dose may help post-menopausal women as a hormone replacement therapy.

For men, ingestion of foods rich in estrogens would be expected to lead to feminization effects. In contradiction, date fruit extracts were reported to increase sperm count in guinea pigs to enhance spermatogenesis and increase the concentration of testosterone, follicle stimulating hormone, and luteinizing hormone in rats [31]. Addition of date seeds in animal feed is known to increase growth rate and levels of testosterone in rats [17]. Thus, the utilization of date seeds in foods requires more elaborated studies on safety and sex functionality.

Table 5
Patents related to Date fruit valorization through different products, uses and technologies.

Product	Field of invention	Effects/uses/benefits	Technologies to prepare products/ingredients	Publication number	Inventor
Highly concentrated date syrup	A method for processing pitted dates into sweetening ingredient	The date syrup can then further be processed to produce a sugar or, after a conventional purification, can be subjected to a fermentation for ethanol production.	Pitted dates suspended in water + homogenization & grinding at 50-60 °C + addition of pulverulent cellulose + filtration + Residue pressing and dehydration	US4428969	[66]
Sweetener ingredient + fiber concentrates	Process for extracting fructose, sucrose, glucose and fiber dates and for making novel food products	The sugar enriched solution can be used as a sweetener, for example, for sweetening soft drinks.	Liquid sugars: Freezing of pitted dates + subdivision to small particles + Diffusion in hot water + removal of press date fiber + sugar juice purification + evaporation. Fiber concentrate: grinding of date seeds + mixing with press date fiber + drying + packaging.	US583488	[82]
Dried dates	A process of improving the appearance of a dried date fruits	Deepening the coloration, increasing the brightness, removing sugar spots and/or reducing or eliminating sloughing of dried date fruits	Washing with tap water + incubation at ambient air from 1 to 24 h + treatment in rotating vacuum cabinet (10 rpm, 600 mm Hg, 2–15 min) + air drying (2 m/s, 40 °C, 2–30 min) to attain water content in the fruit of 22% ($a_w = 0.64$) + packaging in polyethylene bags + storage at 4 °C.	US6824812	[53]
Nutraceutical (Liquid or Tablets)	A process for making date material in a finely divided form for nutritional and/or therapeutic value	The formulation may be of nutritional and/or therapeutic value. Alternatively, the processed dates in the liquid and solid form may function purely as an excipient, in particular as an agent capable of improving the palatability of a pharmaceutically active substance with an unpleasant taste.	Liquid: Dispersion of dates in hot or warm water + sieving to remove large particles + homogenization + cooling and filling Tablets: washing and sorting of date material + Dispersion in hot or warm water + homogenization or high shear mixing + sieving + further homogenization + final sieving + granulation of tablet excipients with homogenized dates granulating agent (dates dispersion) + sieving and drying of granules + further granulation + sieving and drying of granules + mixing with lubricants, disintegrants and flow aids.	WO2007107787	[49]
Ethanol	Production of ethanol using date palm	Low grade dates could be valorized to produce ethanol	Removal of impurities & crushed stone from date pulp + addition of diluted date palm syrup (40°Brix) + heating at 75 °C for 2 h + cooling to 45 °C + addition of pectic enzyme + holding for 12 h + precipitation and filtration to get the net sugar solution + modulating the pH to 4.0–6.0 + fermentation at 30 °C for 80 h + distillation.	CN101475966	[63]
Coffee-like beverage	A method for processing pits to prepare a roasted date kernel blend and coffee-like beverage	Preparation of a coffee-like beverage using an espresso machine	Roasted date kernel blend: Drying + Roasting of date kernel (180 °C–260 °C) + grinding + sieving Date kernel preparation: mixing roasted date kernel blend (89%) + ground roasted coffee (2%) + burnt sugar powder (4%) + thickener (5%) Coffee-like beverage: mixing date kernel preparation + steamed milk (60–70 °C) + water + sweetener	US20110143001	[28]
Date Fruit wine	A method for producing a fruit wine using dry date palm	Producing a date fruit wine (rich in vitamins and calcium) using dry date palm, which contains 1 ppm or less of total amino acids and has an alcohol degree of 10–15 v/v% without methanol	Removing seeds from dry date palm and pulverizing to obtain fruit powder + adding water to the fruit powder and heating at 85–90 °C for 20–30 min + cooling at 25–30 °C and preparing juice + adding water to the juice in a ratio of 1:1 + adding 0.5 w/w% of yeast with respect to 1000 g of the fruit powder + fermenting at 25–30 °C for 20–30 days.	KR20130808	[85]

6. Conclusions

Date fruits are widely produced and represent rich sources of sugar, fiber and phenolic antioxidants. Date fruits provide high variability food raw materials due to its possible consumption at three development stages from a very wide range of varieties. Despite high production, date fruits are underutilized and more focused research is needed to add value to this crop. Industrial utilization of date fruits should be based on their distinct phenotypical and biochemical features responsible for shape, taste, flavor, and nutritional value. Three areas for research and development are prioritized, (i) establishing an identification and classification system for potential date varieties, (ii) understanding the relationship between chemical composition of date fruits and its contribution to fruit color, texture, and taste, and (iii) evaluation of the nutritional value of date fruits and seeds including the assessment of antioxidant and estrogenic activity in humans.

References

[1] F.A. Abbas, A.-M. Ateya, Estradiol, esteriol, estrone and novel flavonoids from date palm pollen, Aust. J. Basic Appl. Sci. 5 (8) (2011) 606–614.
[2] A.-Z.A. Abou-Zeid, N.A. Baeshin, A.O. Baghlaf, The formation of oxytetracycline in a date-coat medium, Bioresour. Technol. 37 (2) (1991) 179–184, http://dx.doi.org/10.1016/0960-8524(91)90208-2.

[3] A.-Z.A. Abou-Zeid, N.A. Baeshin, A.O. Baghlaf, Utilization of date products in production of oxytetracycline by Streptomyces rimosus, J. Chem. Technol. Biotechnol. 58 (1) (1993) 77–79.

[4] E.S. Ahmed, Z.W. Sharawi, The formation of tetracycline in date medium by mutants of Streptomyces aureofaciens induced by nitrosogiuanidine, Egypt. J. Hosp. Med. 22 (2006) 174–187.

[5] A. Aldhaheri, G. Alhadrami, N. Aboalnaga, I. Wasfi, M. Elridi, Chemical composition of date pits and reproductive hormonal status of rats fed date pits, Food Chem. 86 (1) (2004) 93–97, http://dx.doi.org/10.1016/j.foodchem.2003.08.022.

[6] M. Al-Farsi, C. Alasalvar, A. Morris, M. Baron, F. Shahidi, Comparison of antioxidant activity, anthocyanins, carotenoids, and phenolics of three native fresh and sun-dried date (Phoenix dactylifera L.) varieties grown in Oman, J. Agric. Food Chem. 53 (19) (2005) 7592–7599, http://dx.doi.org/10.1021/jf050579q.

[7] S.N. Al-Hooti, J.S. Sidhu, J.M. Al-Saqer, A. Al-Othman, Chemical composition and quality of date syrup as affected by pectinase/cellulase enzyme treatment, Food Chem. 79 (2) (2002) 215–220, http://dx.doi.org/10.1016/S0308-8146(02)00134-6.

[8] A.-Z. Ali, N. Abdelrahman, A. Baghlaf, Use of date products in production of Oxytetracycline by Streptomyces rimosus, Biosci. Biotechnol. Biochem. 57 (6) (1993) 987–988.

[9] B.H. Ali, A.K. Bashir, G. Alhadrami, Reproductive hormonal status of rats treated with date pits, Food Chem. 66 (4) (1999) 437–441, http://dx.doi.org/10.1016/S0308-8146(98)00060–0.

[10] H.A. Almana, R.M. Mahmoud, Palm date seeds as an alternative source of dietary fiber in Saudi bread, Ecol. Food Nutr. 32 (3–4) (1994) 261–270, http://dx.doi.org/10.1080/03670244.1994.9991406.

[11] I.S. Al-Mssallem, S. Hu, X. Zhang, Q. Lin, W. Liu, J. Tan, et al., Genome sequence of the date palm Phoenix dactylifera L, Nat. Commun. 4 (2013) (Retrieved from) http://dx.doi.org/10.1038/ncomms3274.

[12] W. Al-Shahib, R.J. Marshall, The fruit of the date palm: its possible use as the best food for the future? Int. J. Food Sci. Nutr. 54 (4) (2003) 247–259, http://dx.doi.org/10.1080/09637480120091982.

[13] S.S. Al-Showiman, Chemical composition of date palm seeds (Phoenix dactylifera L.) in Saudi Arabia, Arab. Gulf. J. Sci. Res. 8 (1990) 15–24.

[14] S. Al-Turki, M.A. Shahba, C. Stushnoff, Diversity of antioxidant properties and phenolic content of date palm (Phoenix dactylifera L.) fruits as affected by cultivar and location, J. Food Agric. Environ. 8 (2010) 253–260.

[15] S. Azmat, A. Zahoor, R. Ifzal, V.U. Ahmad, F.V. Mohammed, A new megastigmane glycoside, phoenixoside A, from Phoenix dactylifera, Nat. Prod. Commun. 7 (1) (2012) 3–4.

[16] N.A. Baeshin, A.-Z.A. Abou-Zeid, A.O. Baghlaf, The production of oxytetracycline in a date medium by different mutants of Streptomyces rimosus induced by dry and wet heat, Bioresour. Technol. 44 (3) (1993) 259–261.

[17] S. Bahmanpour, T. Talaei-Khozani, Z. Vojdani, M.R. Panjehshahin, A. Poostpasand, S. Zareei, M. Ghaeminia, Effect of Phoenix dactylifera pollen on sperm parameters and reproductive system of adult male rats, Iran. J. Med. Sci. 31 (4) (2006) 208–212.

[18] M.S. Baliga, B.R.V. Baliga, S.M. Kandathil, H.P. Bhat, P.K. Vayalil, A review of the chemistry and pharmacology of the date fruits (Phoenix dactylifera L.), Food Res. Int. 44 (7) (2011) 1812–1822.

[19] W.H. Barreveld, By-products of date packaging and processing, Date Palm Products, FAO, 1993.

[20] R.D. Bennett, S. Ko, E. Heftmann, Isolation of estrone and cholesterol from the date palm, Phoenix dactylifera L, Phytochemistry (1966)http://dx.doi.org/10.1016/S0031-9422(00)85122-5.

[21] S. Besbes, L. Drira, C. Blecker, C. Deroanne, H. Attia, Adding value to hard date (Phoenix dactylifera L.): compositional, functional and sensory characteristics of date jam, Food Chem. 112 (2) (2009) 406–411.

[22] C. Borchani, S. Besbes, C. Blecker, M. Masmoudi, R. Baati, H. Attia, Chemical properties of 11 date cultivars and their corresponding fiber extracts, Afr. J. Biotechnol. 9 (2010) 4096–4110.

[23] H. Borochov-Neori, S. Judeinstein, A. Greenberg, N. Volkova, M. Rosenblat, M. Aviram, Date (Phoenix dactylifera L.) fruit soluble phenolics composition and anti-atherogenic properties in nine israeli varieties, J. Agric. Food Chem. 61 (18) (2013) 4278–4286, http://dx.doi.org/10.1021/jf400782v.

[24] M.A. Bouaziz, W.B. Amara, H. Attia, C. Blecker, S. Besbes, Effect of the addition of defatted date seeds on wheat dough performance and bread quality, J. Texture Stud. 41 (4) (2010) 511–531, http://dx.doi.org/10.1111/j.1745-4603.2010.00239.x.

[25] B. Camara, Biochemistry of fruit ripening, Plant Sci. 97 (2) (1994) 227, http://dx.doi.org/10.1016/0168-9452(94)90061-2.

[26] A. Chafi, R. Benabbes, M. Bouakka, A. Hakkou, N. Kouddane, A. Berrichi, Pomological study of some date palm varieties cultivated in Figuig oasis, J. Mater. Environ. Sci. 6 (2015) 1266–1275.

[27] K.N. Chandra Sekhar, D. DeMason, Qualitative ultrastructure and protein composition of date palm (Phenix dactylifera) seeds: a comparative study of endosperm and embryo, Am. J. Bot. 75 (1988) 323–329.

[28] H.S. Cohen, G. Habermann, H. Kshuk, S. Gendler, Date Kernel Preparation, 2011 (US20110143001).

[29] J. Cook, J. Furr, Kinds and relative amount of sugar and their relation to texture in some American-grown date varieties, Am. Soc. Horticult. Sci. 61 (1953) 286–292.

[30] E.A. Elgasim, Y.A. Alyousef, A.M. Humeid, Possible hormonal activity of date pits and flesh fed to meat animals, Food Chem. (1995) http://dx.doi.org/10.1016/0308-8146(94)P4195-L.

[31] S.A. El-Mougy, S.A. Abdel-Aziz, M. Al-Shanawany, A. Omar, The gonadotropic activity of Palmae in mature male rats, Alex. J. Pharm. Sci. 5 (1991) 156–159.

[32] S. Ghnimi, A. Kamal-Eldin, Fruit nutraceuticals seeking clinical evidence and technological exploitations, J. Bioequival. Bioavail. 7 (6) (2015) 525–5526.

[33] S. Ghnimi, R. Almansoori, B. Jobe, M.H. Hassan, K.E. Afaf, Quality evaluation of coffee-like beverage from date seeds (Phoenix dactylifera, L.), J. Food Process. Technol. 6 (2015) 525–531.

[34] A. Goor, The history of the date through the ages in the holy land, Econ. Bot. 21 (4) (1967) 320–340, http://dx.doi.org/10.2307/4252895 (CR – Copyright #169; 1967 New York Botan).

[35] J. Hamada, I. Hashim, F. Sharif, Preliminary analysis and potential uses of date pits in foods, Food Chem. 76 (2) (2002) 135–137, http://dx.doi.org/10.1016/S0308-8146(01)00253-9.

[36] H. Hammouda, J.K. Chérif, M. Trabelsi-Ayadi, A. Baron, S. Guyot, Detailed polyphenol and tannin composition and its variability in Tunisian dates (Phoenix dactylifera L.) at different maturity stages, J. Agric. Food Chem. 61 (13) (2013) 3252–3263, http://dx.doi.org/10.1021/jf304614j.

[37] H. Hammouda, C. Alvarado, B. Bouchet, J. Kalthoum-Chérif, M. Trabelsi-Ayadi, S. Guyot, Tissue and cellular localization of tannins in Tunisian dates (Phoenix dactylifera L.) by light and transmission electron microscopy, J. Agric. Food Chem. 62 (2014) 6650–6654.

[38] F.M. Harraz, E.A. Sattar, A. Khedr, Z.M.H. Al-Marzouki, M.A.R. Shaheen, Determination of estrone in the date pits of the major cultivars of date palm (Phoenix Dadctylferal) grown in Saudi Arabia and possible use as natural hormonal source, Elec. J. Env. Agricult. Food Chem. Title 7 (2008) 3115–3125.

[39] Y.J. Hong, F.A. Tomas-Barberan, A.A. Kader, E.M. Alyson, The flavonoid glycosides and procyanidin composition of Deglet Noor dates (Phoenix dactylifera), J. Agric. Food Chem. 54 (2006) (2405–241).

[40] F.M. Hussein, S. El-Khatny, Y.A. Wallyn, Date palm growing and date production in the Arab and Islamic world (in Arabic), Ain Shams Press, Egypt, 1979.

[41] O. Ishrud, M. Zahid, V.U. Ahmad, Y. Pan, Isolation and structure analysis of a glucomannan from the seeds of Libyan dates, J. Agric. Food Chem. 49 (8) (2001) 3772–3774, http://dx.doi.org/10.1021/jf0103976.

[42] O. Ishrud, M. Zahid, H. Zhou, Y. Pan, A water-soluble galactomannan from the seeds of Phoenix dactylifera L, Carbohydr. Res. 335 (4) (2001) 297–301, http://dx.doi.org/10.1016/S0008-6215(01)00245-2.

[43] O. Ishurd, Y. Ali, W. Wei, F. Bashir, A. Ali, A. Ashour, Y. Pan, An alkali-soluble heteroxylan from seeds of Phoenix dactylifera L, Carbohydr. Res. 338 (15) (2003) 1609–1612, http://dx.doi.org/10.1016/S0008-6215(03)00202-7.

[44] O. Ishurd, J.F. Kennedy, The anti-cancer activity of polysaccharide prepared from Libyan dates (Phoenix dactylifera L.), Carbohydr. Polym. 59 (4) (2005) 531–535, http://dx.doi.org/10.1016/j.carbpol.2004.11.004.

[45] O. Ishurd, C. Sun, P. Xiao, A. Ashour, Y. Pan, A neutral β-D-glucan from dates of the date palm, Phoenix dactylifera L, Carbohydr. Res. 337 (14) (2002) 1325–1328, http://dx.doi.org/10.1016/S0008-6215(02)00138-6.

[46] O. Ishurd, F. Zgheel, A. Kermagi, M. Flefla, M. Elmabruk, Antitumor activity of beta-D-glucan from Libyan dates, J. Med. Food 7 (2) (2004) 252–255.

[47] O. Ishurd, F. Zgheela, A. Kermagia, N. Flefleaa, M. Elmabruka, J.F. Kennedy, A. Ashour, (1–3)-β-D-Glucans from Lybian dates (Phoenix dactylifera L.) and their anticancer activities, J. Biol. Sci. 7 (3) (2007) 554–557.

[48] M.C. Jarvis, The 13C-n.M.R. spectrum Of (1 → 4)-β-D-mannans in intact endosperm tissue of the date (Phoenix dactylifera), Carbohydr. Res. 197 (1990) 276–280, http://dx.doi.org/10.1016/0008-6215(90)84151-J.

[49] K.A. Khan, Liquid and Solid Dosage Formulations Containing Date Fruit (Phoenix Dactylifera), 2007 (WO2007107787).

[50] H. Khan, S.A. Khan, Date palm revisited, Res. J. Pharm., Biol. Chem. Sci. 7 (3) (2016) 2010–2019.

[51] H.A. Khatchadourian, W.N. Sawaya, J.K. Khalil, A.S. Mashadi, Processing of five major Saudi Arabian date varieties into date butter and dates in syrup, Date Palm J. 2 (1) (1983) 103–119.

[52] A. Kamal-Eldin, I.B. Hashim, I.O. Mohamed, Processing and utilization of palm date fruits for edible applications, Recent Pat. Food Nutr. Agric. 4 (2012) 78–86.

[53] J. Kanner, S. Navarro, A. Daos, Process of Treating Dates, 2004 (US6824812).

[54] J. Larrauri, B. Borroto, U. Perdomo, Y. Tabares, Manufacture of a powdered drink containing dietary fibre: FIBRALAX, Alimentaria 260 (1995) 23–25.

[55] V.P. Maier, D.M. Metzler, Changes in individual date polyphenols and their relation to browning, J. Food Sci. 30 (5) (1965) 747–752, http://dx.doi.org/10.1111/j.1365-2621.1965.tb01835.x.

[56] V.P. Maier, D.M. Metzler, Quantitative changes in date polyphenols and their relation to browning, J. Food Sci. 30 (1) (1965) 80–84, http://dx.doi.org/10.1111/j.1365-2621.1965.tb00267.x.

[57] V.P. Maier, D.M. Metzler, A.F. Huber, 3–0-Caffeoylshikimic acid (dactylifric acid) and its isomers, a new class of enzymic browning substrates, Biochem. Biophys. Res. Commun. 14 (2) (1964) 124–128, http://dx.doi.org/10.1016/0006-291X(64)90241-4.

[58] A. Manickavasagan, E.M. Mohamed, E. Sukumar, Dates: Production, Processing, Food, and Medicinal Values (Medicinal and Aromatic Plants – Industrial Profiles), CRC Press, Boca Raton, Florida, 2012.

[59] A. Mansouri, G. Embarek, E. Kokkalou, P. Kefalas, Phenolic profile and antioxidant activity of the Algerian ripe date palm fruit (Phoenix dactylifera), Food Chem. 89 (3) (2005) 411–420, http://dx.doi.org/10.1016/j.foodchem.2004.02.051.

[60] G.S. Markhand, A.A. Abul-Soad, A.A. Mirbahar, N.A. Kanhar, Fruit characterization of Pakistani dates, Pak. J. Bot. 42 (6) (2010) 3715–3722.

[61] D. Mason, R. Sexton, J.S.G. Reid, Structure, composition and physiological state of the endosperm of *Phoenix dactylifera* L, Ann. Bot. 52 (1) (1983) 71–80, http://dx.doi.org/10.2307/42757318.

[62] H. Meier, On the structure of cell walls and cell wall mannans from ivory nuts and from dates, Biochim. Biophys. Acta 28 (2) (1958) 229–240, http://dx.doi.org/10.1016/0006-3002(58)90468-2.

[63] L. Mingquan, W. Yingbin, Method for Preparing Ethanol From Date, 2008 (CN101475966).
[64] J.S. Mossa, M.S. Hifnawy, A.G. Mekkawi, Phytochemical and biological investigations on date seeds (Phoenix dactylifera L.) produced in Saudi Arabia, Arab Gulf J. Sci. Res. 4 (4) (1986) 495–507.
[65] A. Mrabet, R. Rodríguez-Arcos, R. Guillén-Bejarano, N. Chaira, A. Ferchichi, A. Jiménez-Araujo, Dietary fiber from Tunisian common date cultivars (Phoenix dactylifera L.): chemical composition, functional properties, and antioxidant capacity, J. Agric. Food Chem. 60 (14) (2012) 3658–3664, http://dx.doi.org/10.1021/jf2035934.
[66] H. Muller, R. Gayler, N. Rapsomanikis, Process for the Extraction of Date Fruits, 1984 (US4428969).
[67] A.B. Mustafa, D.B. Harper, D.E. Johnston, Biochemical changes during ripening of some sudanese date varieties, J. Sci. Food Agric. 37 (1) (1986) 43–53, http://dx.doi.org/10.1002/jsfa.2740370107.
[68] H.H. Mutlak, J. Mann, Darkening of dates: control by microwave heating, Date Palm J. 3 (1) (1984) 303–316.
[69] R.W. Nixon, The date palm: “tree of life” in the subtropical deserts, Econ. Bot. 5 (3) (1951) 274–301.
[70] S. Otles, S. Ozgoz, Health effects of dietary fiber, Acta Sci. Pol. Technol. Aliment. 13 (2) (2014) 191–202.
[71] B. Ou, M. Hampsch-Woodill, R.L. Prior, Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe, J. Agric. Food Chem. 49 (10) (2001) 4619–4626, http://dx.doi.org/10.1021/jf010586o.
[72] S. Ouafi, N. Bounaga, Analysis of Phenolic Compounds Extracted from Date of Phoenix dactylifera L (Cultivar: Deglet Nour). Search Analgesic ActivityFifth International Date Palm Conference, Abu Dhabi, UAE, 2014.
[73] A. Pompella, H. Sies, R. Wacker, F. Brouns, T. Gune, H.-K. Biesalski, J. Frank, The use of total antioxidant capacity as surrogate marker for food quality and its impact on health is to be discouraged, Nutrition 30 (2013) 791–793.
[74] B.N. Porter, Sacred Trees, Date Palms, and the Royal Persona of Ashurnasirpal II, J. Near Eastern Stud. 52 (2) (1993) 129–139, http://dx.doi.org/10.2307/545566 (CR – Copyright © 1993 The University).
[75] C. Regnault-Roger, R. Hadidane, J.-F. Biard, K. Boukef, High performance liquid and thin-layer chromatographic determination of phenolic acids in palm (Phoenix dactilifera) products, Food Chem. 25 (1) (1987) 61–71, http://dx.doi.org/10.1016/0308-8146(87)90054-9.
[76] E.B. Saafi, A. El-Arem, M. Issaoui, M. Hammami, L. Achour, Phenolic content and antioxidant activity of four date palm (Phoenix dactylifera L.) fruit varieties grown in Tunisia, Int. J. Food Sci. Technol. 44 (2009) 2314–2319.
[77] E.A. Saleh, Phenolic contents and antioxidant activity of various date palm (Phoenix dactylifera L.) fruits from Saudi Arabia, Food Nutr. Sci. 02 (10) (2011) 1134–1141, http://dx.doi.org/10.4236/fns.2011.210152.
[78] M. Shafiei, K. Karimi, M.J. Taherzadeh, Palm date fibers: Analysis and enzymatic hydrolysis, Int. J. Mol. Sci. 11 (11) (2010) 4285–4296, http://dx.doi.org/10.3390/ijms11114285.
[79] J. Shi, C. Ho, F. Shahidi (Eds.), Asian Functional Foods, CRC Press, New York 2005, pp. 508–516.
[80] I. Shomer, H. Borochov-Neori, B. Luzki, U. Merin, Morphological, structural and membrane changes in frozen tissues of madjhoul date (Phoenix dactylifera L.) fruits, Postharvest Biol. Technol. 14 (2) (1998) 207–215, http://dx.doi.org/10.1016/S0925-5214(98)00029-5.
[81] M. Siddiq, S.M. Aleid, A.A. Kader (Eds.), Dates: Postharvest Science, Processing Technology, and Health Benefits, John Wiley & Sons, Hoboken, NJ, USA, 2014.
[82] B.S. Silver, Processes for Extraction Sugars From Dates and Making Novel Food Products, 1998 (US583488).
[83] S. Sirisena, K. Ng, S. Ajlouni, The emerging Australian date palm industry: date fruit nutritional and bioactive compounds and valuable processing by-products, Compr. Rev. Food Sci. Food Saf. 14 (6) (2015) 813–823.
[84] H. Simon, The Date Palm Bread of the Desert, first ed. Dodd, Mead, 1978.
[85] O.C. Sung, S.K. Hyung, D. Sang, Method for Preparing Wine Using Dried Date Palm, 2013 (KR20130808).
[86] M. Wasif, Date kernels wheat flour supplement, Bulletin of the National Nutrition Institute of the Arab Republic of Egypt, 16, 1996, pp. 132–147.
[87] J.H. Yun, F.A. Tomas-Barberan, A.A. Kader, A.E. Mitchell, The flavonoid glycosides and procyanidin composition of Deglet Noor dates (Phoenix dactylifera), J. Agric. Food Chem. 54 (6) (2006) 2405–2411, http://dx.doi.org/10.1021/jf0581776.
[88] A. Zaid, P.F. de Wet, Botanical and systematic description of the date palm, in: A. Zaid (Ed.), Date Palm Cultivation, Food and agricultural organization of the United Nations 2002, pp. 1–28.
[89] A. Zaid, P.F. de Wet, Origin, geographical distribution and nutritional values of date palm, in: A. Zaid (Ed.), Date palm cultivation, Food and agricultural organization of the United Nations, 2002.
[90] C. Guo, J. Yang, J. Wei, Y. Li, J. Xu, Y. Jing, Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay, Nutrition Research 23 (2003) 1719–1726.