Review article

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

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A B S T R A C T

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 are 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.

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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

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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 tanniferous 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.](https://example.com/fig1.jpg)
### Table 1
Origin, ripening behavior, and quality characteristics of selected varieties of date fruit (*Phoenix dactylifera* L.).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Meaning of the name</th>
<th>Origin</th>
<th>Ripening</th>
<th>Color</th>
<th>Shape</th>
<th>Skin</th>
<th>Size</th>
<th>Flesh texture</th>
<th>Flavor</th>
<th>Calyx (cap)</th>
<th>Further comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barhi</td>
<td>Maturity affected by summer winds at Basra Date of the light</td>
<td>Iraq</td>
<td>Medium-Late</td>
<td>Amber to reddish brown</td>
<td>Broadly ovate to rounded</td>
<td>Medium thick</td>
<td>30 × 21 mm</td>
<td>Soft, smooth and translucent</td>
<td>Rich and delicate</td>
<td>Small size, slightly protruding and inclined</td>
<td>Recognized for excellent flavor, eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Deglet Noor</td>
<td>Date of the light</td>
<td>Tunisia, Algeria</td>
<td>Medium-Late</td>
<td>Slightly deep brown</td>
<td>Oblong-ovate</td>
<td>Medium thick</td>
<td>40–50 × 20–25 mm</td>
<td>Semi-dry, firm, soft, reddish white pulp, medium level of fiber</td>
<td>Delicate and distinctive</td>
<td>Large size, protruding</td>
<td>Well known internationally, eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Hallawy</td>
<td>Sweet dates</td>
<td>Iraq</td>
<td>Early</td>
<td>Golden brown</td>
<td>Oblong with rounded apex</td>
<td>Thin, shrinking with flesh in irregular wrinkles</td>
<td>38 × 21 mm</td>
<td>Soft, caramel-like, translucent, low fiber and pigments</td>
<td>Very rich, sweet, distinctive</td>
<td>Mid-size, protruding</td>
<td>Fruit has good keeping quality and moisture tolerance but wrinkles during ripening more than other dates Semi-dry variety, eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Fard</td>
<td>Defined, price Grees (when it starts to soften)</td>
<td>Saudi Arabia, UAE</td>
<td>Late</td>
<td>Dark brown</td>
<td>Thick cylindrical</td>
<td>Separating from flesh, wrinkled</td>
<td>38–39 × 22–23 mm</td>
<td>Medium thick, white pulp with low fiber and pigments</td>
<td>Sweet, pungent Sweet and Pleasant, delicious</td>
<td>Mid-size, protruding slightly inclined and slightly protruding</td>
<td>Mid-size, <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Khadrawi</td>
<td>Quintessence</td>
<td>Iraq</td>
<td>Mid-early</td>
<td>Reddish brown</td>
<td>Oblong-elliptical to oblong-ovate</td>
<td>Medium thick, tender, sometimes blistered but shrinking more or less with flesh</td>
<td>32 × 23 mm</td>
<td>Soft, melting, caramel-like, free from fiber and pigments</td>
<td>Rich, delicious</td>
<td>Mid-size, protruding, inclined</td>
<td>Recognized as excellent quality, eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Khalas</td>
<td>Quintessence</td>
<td>Saudi Arabia, UAE, Oman</td>
<td>Mid-season</td>
<td>Deep amber to reddish brown</td>
<td>Oblong-oval</td>
<td>Thin, usually adhering to flesh</td>
<td>36 × 23 mm</td>
<td>Melting, tender, translucent, thick and white flesh with some yellowness, free from fiber and pigments</td>
<td>Rich, delicious</td>
<td>Mid-size, protruding, inclined</td>
<td>Eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Khasab</td>
<td>The abundant producer</td>
<td>Iraq</td>
<td>Very late</td>
<td>Deep red to dull reddish brown or even black</td>
<td>Rounded oval</td>
<td>Tough separating from flesh in blisters</td>
<td>38 × 25 mm</td>
<td>Thick, white flesh with some yellowness, mid-level of fiber and pigments</td>
<td>Delicate and pleasant</td>
<td>Large size, slightly protruding Eaten at <em>rutab</em> and <em>tamr</em> stages. Preferred to be eaten at <em>Rutab</em> stage</td>
<td>Large soft dates, Eaten at <em>rutab</em> and <em>tamar</em> stages.</td>
</tr>
<tr>
<td>Majdool</td>
<td>Unknown</td>
<td>Mid-season</td>
<td>Early</td>
<td>Amber to reddish brown</td>
<td>Oblong-oval to ovate</td>
<td>Medium thick adhering to flesh forming coarse irregular wrinkles rather thick &amp; tough, tend to adhere to flesh</td>
<td>38–40 × 26–32 mm</td>
<td>Moderately soft, white flesh, low in fiber and pigments</td>
<td>Mildly rich, pleasing Large size, located on a hollow hole</td>
<td>Large size, Eaten at <em>rutab</em> and <em>tamar</em> stages.</td>
<td>Large soft dates, Eaten at <em>rutab</em> and <em>tamar</em> stages.</td>
</tr>
<tr>
<td>Zahidi</td>
<td>Small quantity and cheap</td>
<td>Iraq</td>
<td>Mid-season</td>
<td>Lower part dry &amp; faded yellow, soft part reddish brown</td>
<td>Oblong-ovate</td>
<td>Separating from flesh</td>
<td>33 × 27 mm</td>
<td>Semi-dry, soft part thick, firm, of smooth consistency, drier part more or less fibrous and rather hard</td>
<td>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.</td>
<td>Eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
<td>Eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
<tr>
<td>Lulu</td>
<td>The pearl</td>
<td>Pakistan Oman</td>
<td>Mid-late</td>
<td>Dark amber</td>
<td>Oblong-oval</td>
<td>Separating from flesh</td>
<td>38 × 26 mm</td>
<td>Thick, less fibrous flesh</td>
<td>Sweet and soft Small size, slightly protruding</td>
<td>Eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
<td>Eaten at <em>rutab</em> and <em>tamr</em> stages.</td>
</tr>
</tbody>
</table>
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 firmer 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 arabininoxylan 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, dates fruit 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 β-D-glucose and β-D-Glc-(1→3)-O-Glc groups for the lowest molecular mass polysaccharide or β-D-Glc-(1→3)-O-Glc 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-mannanase (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 mannann fraction (45.8%, 12,000 Da) is formed by mannolosidic residues linked to each other by β-1,4-glycosidic linkages together with small amounts of glucose, arabino-, 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 α-(1 → 4)-β-D-linked α-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 α-mannose and β-galactose in a molar ratio of 2:7:1 [42]. Mannans are storage compounds that are

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Moisture</th>
<th>Protein</th>
<th>Fiber</th>
<th>Ash</th>
<th>Glucose</th>
<th>Fructose</th>
<th>Sucrose</th>
<th>Energya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barhi</td>
<td>29.5</td>
<td>2.3</td>
<td>0.1</td>
<td>1.4</td>
<td>28.7</td>
<td>27.6</td>
<td>ND</td>
<td>9.4</td>
</tr>
<tr>
<td>Deglet Noor</td>
<td>21.2</td>
<td>2.4</td>
<td>0.1</td>
<td>2.3</td>
<td>14.8</td>
<td>12.3</td>
<td>38.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Fard</td>
<td>27.7</td>
<td>2.1</td>
<td>0.1</td>
<td>1.8</td>
<td>30.2</td>
<td>30.2</td>
<td>ND</td>
<td>8.0</td>
</tr>
<tr>
<td>Hallawi</td>
<td>12.2</td>
<td>2.3</td>
<td>0.5</td>
<td>1.9</td>
<td>34.3</td>
<td>34.3</td>
<td>6.7</td>
<td>7.8</td>
</tr>
<tr>
<td>Khadrawy</td>
<td>9.5</td>
<td>2.2</td>
<td>0.4</td>
<td>1.9</td>
<td>30.3</td>
<td>31.9</td>
<td>ND</td>
<td>23.8</td>
</tr>
<tr>
<td>Khasab</td>
<td>22.3</td>
<td>2.1</td>
<td>0.1</td>
<td>1.4</td>
<td>36.5</td>
<td>31.7</td>
<td>0.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Lulu</td>
<td>16.5</td>
<td>1.6</td>
<td>0.1</td>
<td>1.6</td>
<td>35.3</td>
<td>36.5</td>
<td>ND</td>
<td>2.7</td>
</tr>
<tr>
<td>Madjool</td>
<td>21.0</td>
<td>1.8</td>
<td>0.1</td>
<td>1.7</td>
<td>34.3</td>
<td>33.9</td>
<td>0.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Zahidi</td>
<td>8.3</td>
<td>2.0</td>
<td>0.4</td>
<td>1.7</td>
<td>30.1</td>
<td>35.9</td>
<td>11.6</td>
<td>11.0</td>
</tr>
</tbody>
</table>

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.
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 \((1 \rightarrow 4)\)-linked D-
xylopyranosyl residues having branches at O-2 consisting of 4-O-
methyl-\(\alpha\)-D-glucopyranosyluronic acid and D-xylopyranosyl groups
[43]. Recently, phoenixoside A (\((6S,7Z,9R)\)-hydroxy-3-oxo-ionol-9-
O-\(\beta\)-D-glucopyranosyl-\((1^\prime \rightarrow 6')\)-D-xylopyranosyl-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 activ-
ity of dates, measured using the ORAC-fluorescent assay, ranged 8212–
12,543 \(\mu\text{M/g}\) 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 phe-
nolic 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 am-
bient 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-
caffeoylshikimic 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
dihexoside and acetylated flavonols [36].

Flavonoid glycosides of luteolin, quercetin and apigenin were identi-
fied in Deglet Noor, 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. 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.](image)

![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].](image)
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].

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 maturation 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 khulaf 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

### Table 3

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

<table>
<thead>
<tr>
<th>Date varieties</th>
<th>Method(s)</th>
<th>Antioxidant findings</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amir Haji, Barhee, Deglet Noor, Halawy, Hayany, Hilali, Khadrawy, Khalasa, Medjool, Zahidi, Khalasa, Shaishi, Sukari, Gur, Kahunzi (Saudi Arabia)</td>
<td>Antioxidant capacity. 2.2’Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS radical assay)</td>
<td>Total phenolic content ranged 225–507 mg GAE/100 g fresh weight</td>
<td>[14]</td>
</tr>
<tr>
<td>Allig, Deglet Nour, Kertchi, Khouet Kenta (Tunisia)</td>
<td>Total phenolic content Antioxidant activity by the Folin –Ciocalteu method, antioxidant activity by the ABTS radical assays</td>
<td>Total phenolic content ranged 210–450 mg equivalent gallic acid/100 g fresh weight</td>
<td>[76]</td>
</tr>
<tr>
<td>Khalas, Sukkari and Ajwa (Saudi Arabia)</td>
<td>Total phenolic content by the Folin–Ciocalteu method and HPLC</td>
<td>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).</td>
<td>[77]</td>
</tr>
<tr>
<td>Tazizzaut, Akerbouche, Deglet-Nour, Ougherrouss, Tantbouchte, Taiziouine, and Tazerzait (Algeria)</td>
<td>Total phenolic content by the Folin–Ciocalteu method LC–DAD–MS (ESI +)</td>
<td>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–caffeoylshikimic acid. Different types of flavonoids (mainly flavones, flavanones and flavonol glycosides) were variably present in the different varieties. No quantitative data was given.</td>
<td>[59]</td>
</tr>
<tr>
<td>Fard, Khasah, and Khalas (Oman)</td>
<td>Total phenolic content by the Folin–Ciocalteu method, total anthocyanins by pH differential method, and phenolic acids by HPLC</td>
<td>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.</td>
<td>[6]</td>
</tr>
<tr>
<td>Deglet Noor (USA)</td>
<td>LC-ESI/MS/MS</td>
<td>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 tri-glycosyl 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.</td>
<td>[39]</td>
</tr>
</tbody>
</table>

### Table 4

Phenolic Classes of and identified compounds in date fruits.

<table>
<thead>
<tr>
<th>Class</th>
<th>Identified compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzoic acids and derivatives</td>
<td>Gallic acid, protocatechuic acid, p-hydroxybenzoic acid, vanillic acid, sinapic acid, and syringic acid</td>
</tr>
<tr>
<td>Cinnamic acids and derivatives</td>
<td>Caffeic acid, hydrocaffeic acid, ferulic acid, p-coumaric acid, syringic acid, dactyliceric acid, 2 caffeoylshikimic acid hexosides, 3-caffeoylshikimic acid, 4-caffeoylshikimic acid, 5-caffeoylshikimic acid, caffeoylshikimic acid, and dicafeoylshikimic acid</td>
</tr>
<tr>
<td>Flavonoid glycosides and esters</td>
<td>Luteolin, quercetin and apigenin, quercetin rhamnosyl-hexoside sulfate, quercetin 3-O-rutinoside (rutin), quercetin hexose sulfate, quercetin acetyl-hexoside, isorhamnetin-3-O-rutinoside, isorhamnetin hexoside, chrysoeriol rhamnosyl-hexoside, isorhamnetin acetyl-hexoside, quercetin 3-O-glucoside (isocoueritin), chrysoeriol hexose sulfate, and chrysoeriol hexoside</td>
</tr>
<tr>
<td>Flavan-3-ols</td>
<td>(+)-catechin, and (−)-epicatechin</td>
</tr>
<tr>
<td>Proanthocyanidins</td>
<td>Procyanidin oligomers based on (+)-epicatechin including procyanidin B1, procyanidin B2, procyanidin trimer, procyanidin tetramer, procyanidin pentamer, and procyanidin polymers based on (−)-epicatechin (decamers to heptadecamers)</td>
</tr>
<tr>
<td>Anthocyanins</td>
<td>Cyanidin (in some dark varieties)</td>
</tr>
</tbody>
</table>

References: [57,75,6,59,87,23,36,72].
Kirmi 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 steel 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 imaging, 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, Safr Al-Riyadh, Mashwali Hada Al-Sham, Zghalaloo 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.
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

