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Review

Biological, Nutritive, Functional and Healthy Potential of Date Palm Fruit (*Phoenix dactylifera* L.): Current Research and Future Prospects

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Abstract: Date palm cultivation is highly relevant, especially in the arid and semi-arid regions of the world, mainly due to the fact that it is considered an eco-efficient crop (based on its few growth requirements and the fact that it is economic and sustainable) that produces a nutritious fruit (date fruit). Recently, its implantation has rapidly spread to other areas of the world as a viable option to fight against the consequences of climate change, but also due to several health benefits associated with date fruit (pulp and seeds) which make them a potential source of functional food ingredients. This review provides detailed recent information on the nutrition, nutraceuticals and bioactive properties of date palm fruit (reinforced with in vitro and in vivo evidences) and their potential for developing novel and functional foods as a way to highlight the wide possibilities for this crop. Date fruits are rich in phytochemicals, such as phenolics, anthocyanin, carotenoids, tocopherols, phytosterols and dietary fiber, which have been linked with their biological activities (antioxidant, antibacterial, anti-inflammatory, prebiotic, anticancer and antitoxic properties) and are responsible for their use in the prevention and control of current diseases such as diabetes, cancer and gastrointestinal, cardiovascular and neurodegenerative diseases in industrialized countries.

Keywords: date fruit; date seed; bioactive compounds; dietary fiber; nutraceutical; phenolics

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1. Introduction

The date palm (*Phoenix dactylifera* L.) is the main crop which characterizes, symbolizes and defines the arid and semiarid regions of North Africa and the Middle East. This crop is the oldest of the cultivated perennial fruit trees in the world (dating back to before 4000 B.C.) adapted to tropical or subtropical climates [1]. The historical contribution of date palm fruit to culture, religion, nutrition, the environment, livelihood and small farmer income was essential and played an important role in the economy of millions of rural producers [2,3]. The date palm and its fruits have been considered as an important subsistence crop in most of the desert regions and an important cultural legacy in Arabic countries and some Islamic ones. Date palm already appeared in the literature and religion from Ancient Middle Eastern culture (Assyrian, Egyptian, Hebrew and Phoenician) [1].

Date palm is believed to be native to the ancient Mesopotamia area (Southern Iraq) or western India, and this crop has been domesticated since the end of the Neolithic period through the Bronze Age [4]. The date culture spread to other areas of the world, firstly from the Arabian Peninsula, North Africa and the Middle East and later by southern Spain and Pakistan. The Spanish introduced this crop in America. Currently, date cultivation is found from traditional areas (Arabian Peninsula, North Africa and the Middle East–South Asia) to South Asia, Southern Africa, around the Mediterranean, Australia, Mexico and the United

States with a suitable climate and limited production [4–6]. In Spain (Elche, Valencia) the largest palm grove in Europe can be found (500 ha with more than 200,000 specimens). It is one of the largest in the world, and was declared a World Heritage Site by UNESCO in 2000 (Figure 1).

Figure 1. Elche palm grove (UNESCO World Heritage Site) in full production; a bunch of date fruits has been highlighted.

Date palm grows in hot and dry climates, requiring an environment featuring a long and hot summer, a little rain and low humidity; hence, the most important date-producing countries are situated in the Middle East and North Africa (Table 1).

Table 1. Date production in 2020 (tons) of the main producing countries *.

	Tons	% of de World	Variation 2015–2020 (%)
WORLD	9,454,213	100.00	16.8
ASIA	5,323,876	56.31	22.5
Saudi Arabia	1,541,769	16.31	48.5
Iran (Islamic Republic of)	1,283,499	13.58	24.3
Iraq	735,353	7.78	22.1
Pakistan	543,269	5.75	16.1
Oman	368,577	3.90	6.9
United Arab Emirates	328,669	3.48	−18.4
China, mainland	158,671	1.68	−3.0
Kuwait	111,748	1.18	17.9

Table 1. *Cont.*

	Tons	% of de World	Variation 2015–2020 (%)
Yemen	69,590	0.74	39.8
Israel	48,984	0.52	18.9
Turkey	60,661	0.64	79.9
AFRICA	4,038,691	42.72	9.5
Egypt	1,690,959	17.89	0.4
Algeria	1,151,909	12.18	16.3
Sudan	465,323	4.92	6.0
Tunisia	332,000	3.51	48.9
Libya	177,629	1.88	2.5
Morocco	143,160	1.51	42.6
Mauritania	22,000	0.23	0.5
Chad	20,842	0.22	1.6
EUROPE	14,571	0.15	−11.8
Albania	14,571	0.15	7.1
Spain	1375	0.01	−53.1
AMERICA	77,075	0.82	79.0
Mexico	19,863	0.21	167.4
USA	56,790	0.60	60.5

* Data from FAOSTAT [7].

Unfortunately, these climatic conditions (typical of desert areas) are rapidly spreading to other areas of the world, mainly due to climate change. Considering that desertification reduces agricultural productivity and income and contributes to the loss of biodiversity, the implantation of crops with few requirements, such as date palm, can become a viable option to fight against these negative effects [8]. Worldwide date production in 2020 extended over a surface of 1,235,601 ha, with a total date production of 9,454,213 tones [7]. The main producing area was Asia, which represented 62.43% of the worldwide area harvested (771,509 ha) and Africa with 36.72% (453,775 ha), followed by America (9830 ha) and Europe (487 ha). Egypt is the principal producer of dates, followed by Saudi Arabia, Iran and Algeria [7]. Production of dates palm fruit has increased over the last 5 years by almost 1.4 million tones, which represents a growth of about 16.8 percent (Table 1). This increase is promoted by its health benefits and nutritional value, but also by the innovation in the date sector that allows new presentations and derived products that are available to the market. This production is expected to continue increasing in the future. In addition, the future production of date can be considered as sustainable (without producing waste), since not only can its fruits be used, but many other palm parts could have many potential applications. For instance, date palm seed could be used to obtain fuel and energy; date palm fibers could be obtained from the leaves; paper could be obtained from date palm rachis, which is absorbent for heavy and toxic metals from date palm waste; or it could be used to produce wood composites, furniture, handicrafts and cattle feed [9].

The eco-efficiency in their growth, the sustainability in their production together with their important richness not only in macro and micro nutrients, but also in some bioactive compounds would explain the reason why they have been widely cultivated and used by humans as food and beverages, as well as in traditional medicines, since ancient times [10]. Thus, this review provides detailed recent information on the production, nutrition, nutraceuticals and bioactive properties of date palm fruit (reinforced with in vitro and in vivo evidence) as a way to highlight the wide possibilities for this crop and its potential as source of ingredients for the functional food industry.

2. Date Palm Biology and Date Fruit Anatomy

Phoenix dactylifera L., whose common name is date palm, belongs to the monocot family Arecaceae and genus Phoenix and it is native to South Asian and African regions with tropical or subtropical climates. Most Phoenix species have limited economic value, except the date palm (*Phoenix dactylifera* L.), which is considered a vital subsistence crop in most of the desert regions [5].

There is controversy in species given names, synonyms and nomenclature of the Phoenix genus cultivated worldwide, due to the long history of cultivation and different taxonomic treatments [4]. Taxonomy has accepted about 12–14 species which constitute the genus Phoenix [4,5,11].

It is believed that there are more than 5000 existing cultivars of *Phoenix dactylifera* L., which is due to the differences in numbers of synonyms and homonyms existing between and within countries, let alone the complicated translation from Arabic names. Among all the cultivars, only a few are really important due to their agronomic characteristics and their fruit quality. Table 2 shows some common cultivars and their morphological characteristics.

Table 2. Morphological characteristics of date fruits (*Phoenix dactylifera* L.) from several cultivars.

Cultivar (Synonyms)	Origin	Ripening Stage	Fruit Weight (g)	Length (mm)	Diameter (mm)
Barhi (Barhee. Berhi, Birhi)	Namibia, Iraq	Khalal/Rutab	9–19	30–45	21–30
Deglet Nour	Tunisia, Algerian	Kimri/Tamar	8–9	34–43	18–25
Confitera	Elche (Spain)	Medium-late	13–14	40–55	24–26
Hallawi (Hallawy)	Iraq, Egypt	Early	9–24	38–58	18–27
Fard	UAE	Late Rutab/Tamar	9–15	35–42	20–27
Khadrawi (Khadrawy)	Iraq	Mid-early	11–14	29–38	20–24
Khalas	Saudi Arabia, UAE, Oman	Rutab/Tamar	8–11	32–38	21–23
Khasab (Khesab)	Iraq	Late Rutab/Tamar	10–12	35–38	23–25
Medjool (Mejhool, Medjoul)	Morocco	Rutab	17–40	38–50	23–32
Zahidi	Iraq	Khala	9–12	24–34	23–27
Lulu	Pakistan Oman	Khalal/Rutab	7–10	29–38	20–26

UAE: United Arab Emirates. Adapted from: Al-Hooti et al. [12]; Ghnimi et al. [13]; Habib and Ibrahim [10]; Martínez-Sánchez [3]; Sakr et al. [14]; Zaid and de Wet [15].

The fruit of the date palm, called a date, is a berry. It is generally oblong or ellipsoid with a single seed enclosed by a thin membranous endocarp (Figure 2).

Regarding the morphological characteristics (fruit and seed), colors and tastes of the date differ from cultivar to cultivar. It is also influenced by the agroclimatic conditions. The fruit weight ranges from about 2–60 g, with lengths from 3 to 11 cm and diameters from 2 to 3 cm [13]. The mesocarp, which represents the biggest part the of fruit, is fleshy, formed by parenchymatous cells. It is divided into outer mesocarp and inner mesocarp and it is protected by the pericarp (the fruit skin) [3,5]. The date seed presents a furrow and small hole (micropyle), whose characteristics, depth and position depend on the cultivar [13]. Seed weights between 0.5–4.0 g, lengths between 2.3–3.6 cm and diameters between 0.6–1.3 cm have been reported.

The development of dates follows a sigmoid growth curve early in the season but the growth rate decreases later when the fruit loses water. During their development, the dates pass through five stages of maturation (Hanabouk, Kimri, Khalal, Rutab and Tamar), in order to reach full maturity within seven months [16]. These represent the astringent green, mature full-colored, soft, brown and hard raisin-like stages of development, respectively. During the maturation, the fruits become edible due to decreased bitterness, increased sweetness and an improvement in tenderness and juiciness [1,13]. So, date fruit goes through external and internal changes during its growth and maturation, which has an influence on its quality and nutritive value [17]. These stages of fruit ripening determine the ways in which dates are processed and consumed [18]. Date palm fruits are ready to be consumed in the last three stages (Khalal, Rutab and Tamar), mainly due to their soft texture and sweet flavor [19].

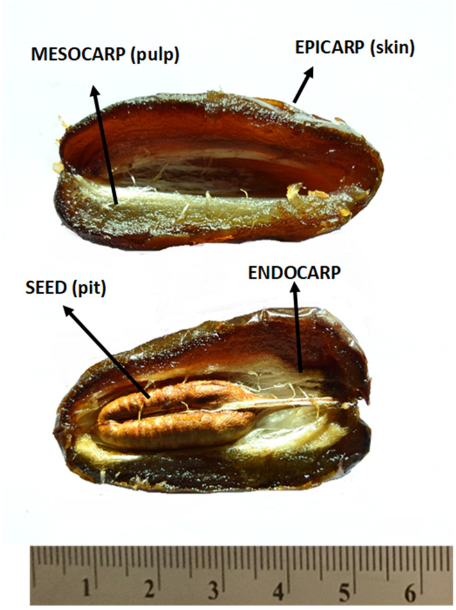

Figure 2. The anatomy of fruit of the date palm (*Phoenix dactylifera* L., *cv. Confitera*) at late Rutab stage.

The Hababouk, initial stage: The period just after pollination when the young fruit is white before gradually turning green in the following stage. This lasts for 1–5 weeks from pollination. At this stage, the fruits are immature. They present between 80–90% moisture content [5,20].

The Kimri, immature green stage: The fruits change from a small berry to an oblong form to reach physiological maturity. This stage has a duration of 14–19 weeks, in which fruits increase in size, weight and acidity and decrease in sugar content (20% dry matter). In this period, fruits are turgid and bitter (rich in tannins) and present high moisture content (75–85%). This stage ends with a change in fruit color to yellow or red (depending upon the cultivar involved). Generally, in this stage the fruits are inappropriate for eating [3,5].

The Khalal (Bisr), physiologically mature stage: This stage has a duration of approximately 6 weeks. The color turns from green to yellow purplish-pink, red or yellow (depending on cultivar) and the fruit is physiologically mature. The fruit reaches its maximum size and weight [3]. The sugar (50% dry matter) and acid content increases, whereas the moisture decreases (40–60%) [5]. The fruit is turgid and astringent and contains an important amount of water-soluble tannins [5]. At this stage, in some cultivars the fruits may be edible due to the fact that tannins start to precipitate (the astringency decreases).

The Rutab stage extends from 2 to 4 weeks and is accompanied by a loss in moisture (35%) and astringency and an increase in insoluble tannins. The protein, fat and ash contents decrease, but total sugars (72–88% of dry matter) and solids increase. The dates present a softer texture and a darker color.

The Tamar, ripe and dried stage: The dates present a brownish color, a soft texture and a wrinkled appearance. The fruits lose much of their moisture (20–25% moisture) and the sugar content reaches values close to 72–88% of dry matter at maturation, due partly to a decreased fruit weight from the dehydration process [5]. Dates become semidry or dry. Soft date fruit is usually harvested commercially at 18–24% water content. Tamar dates presents a maximum total solid, highest sweetness and lowest astringency.

Khalal and Rutab dates are considered as fresh fruit. The choice for harvesting at one stage or another depends on the cultivar, soluble tannins and sugar contents, without forgetting climate conditions and consumer demand [3]. Generally, the dates are harvested during the Rutab and Tamar stages, when the fruits are high in sugar content and low in moisture and tannin, although in some countries of North Africa and Middle East they are consumed during the Khalal stage, where dates are astringent and present high levels of tannin [4,13].

According to the hardness (determined by the moisture content) of the edible part, the dates are classified as soft, semi-soft and dry dates. The soft dates (≥30 moisture) present a soft fleshy consistency and contain 60% of sugar in the form of invert sugars (glucose and fructose) and a little or no sucrose (e.g., Barhi, Halawy, Khadrawi and Medjool) [3,13]. Semi-soft or semi-dry dates (20–30% moisture) present a firm flesh, 45–54% in reducing sugars and 18–30% in sucrose (e.g., Dayri, Deglet Nour and Zahidi). Finally, dry dates (≤20% moisture and <0.65 water activity) present a solid and dry flesh and more sugar than soft and semi-soft dates (equal proportions of sucrose and reducing sugars). Dry dates reach the Tamar stage without going through the Rutab stage and ripen and dry in the tree [3,13]. Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventional studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided the approval and the corresponding ethical approval code.

3. Nutrient Composition of Date Fruit

The increasing interest in date fruits and its derived products is because it is a rich and inexpensive source of many macro- and micronutrients and secondary metabolites that are important for human health. Although the principal chemical constituents of date fruit are carbohydrates (about three-fourths or more of the fruit consists of sugars) dates are not a significant source of proteins and lipids [21]. They have many other nutritious components such as minerals, vitamins, antioxidants and dietary fibers [1,22–24]. Dehydrated dates have a longer shelf life; however, their nutritional value is usually lower than that of the fresh dates [1].

Date fruit is formed of two constituents: flesh (pulp) and seed (or pits) (Figure 2). The date pulp (the only edible part) represents 85–95% of the fruit's total weight [25,26]. On the contrary, date pits (seeds or kernel) constitute between 5–15% of the date fruit's total weight, depending on the cultivar [26–29], and they are the major waste product from date palm processing industries [19]. Sometimes pits are used in animal feed [26] and they have been also used in the Arabian world, Mexico, the USA and Thailand, among others, to make a caffeine-free drink [16,30]. Nevertheless, their composition in nutrients (date pits are rich in protein, fat and dietary fiber when compared to the pulp) [16,26,27,29] and even in bioactive compounds [30–33] is attracting interest in novel functional food applications [29,30,34,35].

Date fruit has a high energy value, between 307 and 354 kcal/100 g [16,25,28,36].

The moisture content in date fruit pulp ranges from 13–25% [24,28,36]. During ripening, the moisture content decreases [17].

Date seeds have lower moisture content (5–10%) than date pulp [28,37].

The carbohydrate content (between 65.2% and 88.02% of dry weight) and composition of date pulp can vary according to the type of cultivar and ripening stages [1,24,31,36,38]. Date pulps contain easily digestible sugars (70%), mainly glucose (35%), fructose (26%) and sucrose (0.5%) [16,30,31,39]. Sugar contents showed a gradual rising trend during the ripening process [17].

Date seeds have 55–65% carbohydrates [28,37].

A wide variation in the dietary fiber content of date pulp is recorded in the literature, ranging from less than 1.9% up to more than 20.25% [21,25], out of which insoluble fiber is recorded as 84–94%, and soluble fiber content ranges between 6–16% [27,36]. The dietary fiber of date flesh is a mixture of non-starch polysaccharides, including insoluble cellulose, partially soluble hemicelluloses and pectin, as well as hydrocolloids and lignin [26]. Insoluble dietary fibers (hemicellulose, cellulose and lignin) are also the main fraction in seed fiber [27]. Several authors have also reported that dates contain a significant amount of β-glucan, a cell wall component [30].

Date seeds show higher dietary fiber content than date flesh, ranging from 67% to 74%, with water-insoluble mannan fiber as the most abundant [26,29]. The results support the fact that date seeds could be used as excellent sources of dietary fiber in food processing.

The amount of proteins in date pulp ranges from 1.2% to 6.5% of the date's fresh [27,36,38,39]. Maqsood et al. [30] and Alharbi et al. [27] have reported that date fruits contain most of the essential and non-essential amino acids. Essential amino acids such as methionine, histidine, tyrosine, isoleucine, serine, phenylalanine, lysine, arginine, alanine, glycine, valine, leucine and proline are included [25]. The protein content decreases during the non-enzymatic browning and tannin precipitation stage (maturation of date palm fruits) [17,27].

On the contrary, the protein percentage in date seeds ranges from 5.1 to 7% [16,28,37]. From the essential amino acids, glutamic acid, aspartic acid and arginine account for about half of the total proteins in date pits [28].

Fat occurs in small amounts in dates (0.12–2% of the fresh weight) [24,25,28,36], concentrated mainly in the skin as a protection [34]. Date flesh contains both saturated fatty acids (capric, lauric, myristic, palmitic, stearic, margaric, arachidic, heneicosanoic, behenic and tricosanoic acids) and unsaturated fatty acids (palmitoleic, oleic, linoleic and linolenic acids) [40].

Regarding date pits, oil content is significantly higher (7.5–10%) [16,37], and as such represents a potential source of edible oil. This oil shows higher proportion of unsaturated fatty acids (mainly oleic acid (42.3%) and linoleic acid (13.7%)) than saturated ones (mainly lauric acid (21.8%) and palmitic acid (9.6%)) [27,28] which is in accordance with current recommendations for a healthy diet.

Date fruits contain interesting amounts of vitamin group B [27], such as thiamine (1.86–20.8 mg/mL), riboflavin (1.563–20.01 mg/mL), nicotinamide (4.2–52 mg/mL), pantothenic acid (4.69–50.4 mg/mL), pyridoxine (1.54–20.04 mg/mL), folic acid (2.54–50.5 mg/mL) and cyanocobalamin (1.87–20.4 mg/mL) [25,28]. Dates are also rich in beta-carotene (vitamin A) [37]. Date fruits have a low vitamin C content [21].

The ash content in date pulp ranged from 1.4 to 6.2% [27]. It is rich in essential minerals: potassium (684 mg/100 g fresh matter), calcium (80.2 mg/100 g, magnesium (68 mg/100 g), phosphorus (57 mg/100 g), sodium, (18.9 mg/100 g), iron, copper, fluorine, sulfur, boron, selenium and zinc [16,30,36,38,39]. It could be said that dates are one of the foods that have high potassium content [27]. In many cultivars, potassium can be found at a concentration as high as 0.9% in the flesh [16]. The amount of sodium in dates is low but ideal when looking at the recommended amount per day for an individual [37].

Date seeds contain many dietary minerals such as potassium, copper, magnesium, calcium, cadmium, chromium, iron, manganese, zinc, nickel, cobalt, calcium and phosphorous [27]. Baliga et al. [16] reported that in many cultivars, potassium can be found at a concentration as high as 0.5%.

4. Bioactive Compounds from Date Fruit

Bioactive compounds are biologically active substances derived from plants, which are not considered essential nutrients. These bioactive compounds had a huge variety of structures ranging from simple molecules to polymers. Among the most important bioactive components in date fruit with the potential to act as nutraceutical agents are phenolic acids, flavonoids, carotenoids, procyanidins, tocopherol and tocotrienols and sterols [41–43]. These bioactive compounds can be found in both the pulp and seeds of date fruits.

4.1. Phenolic Acids and Flavonoids

Polyphenolic compounds, mainly phenolic acids and flavonoids, are one of the main classes of secondary metabolites present in plants. In this sense, date fruits could be considered a great source of these compounds if compared with other fruits [44]. These phytochemicals can be found both pulp and seeds, with a greater concentration and diversity, in general terms, in the pulp than in the seeds. In addition, it is important to notice that the polyphenolic compounds concentration depends on several factors, including the cultivar, ripening stage, environmental and agronomic conditions, location, etc. Thus, in reference to phenolic acids, Mrabet et al. [43] analyzed the phenolic acid composition of date fruit pulp obtained from three common non-commercial Tunisian date cultivars (Smeti, Garen Gazel and Eguwa). They found that the principal phenolic acid found in all samples analyzed were para-coumaric acid, gallic acid, protocatechuic acid, tyrosol, vanillic acid and syringic acid, the gallic acid being the principal compound with values comprising between 1.35 and 1.53 g/kg of the sample. El Arem et al. [45] analyzed the phenolic acids present in date fruit cultivars Alig, Deglet Nour and Horra cultivated in Tunisia. They found, in all samples, twelve different compounds: protocatechuic acid with values ranging from 6.24 to 7.28 mg/100 g of the sample and caffeic acid with values comprising between 5.06 and 5.89 mg/100 g of the sample as the main component. Other phenolic acids found in their composition were gallic acid, syringic acid, 3-hydroxybenzoic acid, isovanillic acid, chlorogenic acid, para-coumaric acid, ferulic acid, meta-coumaric acid, ortho-coumaric acid and cinnamic acid. In a similar study, Alahyane et al. [41] analyzed the phenolic acid content of pulp obtained from 17 dates cultivars and clones cultivated in Morocco. These authors reported that in all samples analyzed, eight phenolic acids—gallic acid, chlorogenic acid, vanillic acid, caffeic acid, syringic acid, tyrosol, ferulic acid, ortho-coumaric acid—were identified. The results revealed that gallic acid was the most abundant phenolic acid with values ranging between 31.41 mg/100 g for Hak Feddan Laaneb and 4.379 mg/100 g DW, for Elahmer Chtoui, respectively. El-Rahman and Al-Mulhem [46] analyzed the phenolic acid content of the pulp of date fruit cultivar Rozez cultivate in Saudi Arabian. These authors revealed that the date fruit had a high level of ferulic acid (9.10 mg/100 g), syringic acid (22.72 mg/100 g), cinnamic acid (4.802 mg/100 g) and para-coumaric acid (2.03 mg/100 g).

As mentioned above, date fruit seeds can also be considered as a source of phenolic acid compounds. In this way, Al Juhaimi et al. [31] reported that gallic acid and syringic acid were present as major compounds of date seeds in eleven different cultivars of date fruit extracts. The gallic acid contents of date seeds varied between 2.43 mg/100 g (Boufgous) and 6.91 mg/100 g (Dore) while syringic acid contents ranged from 1.28 mg/100 g (Talees) to 4.86 mg/100 g (Adwi). Djaoudene et al. [33] analyzed the phenolic acid compounds present in the seeds of eight date fruit cultivars grown in Algeria. They found that the main phenolic compound present in the samples analyzed was ferulic acid with values ranging between 1.10 and 3.86 mg/g, followed by vanillic acid (0.32–2.65 mg/g) and syringic acid (0.04–0.18 mg/g). More recently, Bouhlali et al. [32] studied the phenolic acid composition of the seeds obtained from four date fruit cultivars cultivated in Morocco. They reported that the main phenolic acid found in all samples analyzed was p-coumaric acid, with values ranging between 116.96 and 143.60 mg/100 g, followed by caffeic acid (59.40–88.64 mg/100 g), gallic acid (10.35–7.62 mg/100 g) and ferulic acid (5.51–12.16 mg/100 g).

With regard to flavonoid content, Hamad et al. [47] reported that quercetin was the main flavonoid present in the pulp of date fruits of twelve cultivars grown in the Kingdom of Saudi Arabia, with values ranging from 0.17 to 1.27 mg/100 g followed by rutin and isoquercitrin. Hinkaew et al. [19] reported that the main flavonoids found in date fruit of the Barhi cultivar were isorhamnetin (5.76 mg/100 g), hesperidin, (3.53 mg/100 g) and kaempferol (2.13 mg/100 g).

In reference to the flavonoid content present in date seeds, Hilary et al. [48] analyzed the flavonoid content of date seeds from the Khalas cultivar. They reported that the predominant flavonoids found in the seeds were the flavan-3-ols catechin and epicatechin and the flavonols quercetin and quercetin hexoxide. Bouhlali et al. [32] reported that rutin was the main flavonoid found in four date seed cultivars (Boufgous, Bousthammi, Jihl, Majhoul) cultivated in Morocco, followed by quercetin and luteolin. Djaoudene et al. [49] mentioned that quercetin-3-O-glucoside, rutin, isorhamnetin-3-O-glucoside and kaempferol-3-O-glucoside were the predominant compounds found in the seeds of four date fruit cultivars (Ourous, Ouaouchet, Oukasab and Delat). It is important to notice that the concentration of flavonoids in date seeds is lower than in pulp.

4.2. Carotenoid Content

Carotenoids are a class of chemical compounds synthesized primarily by higher plants and by some algae. In nature, it is possible to find more than 600 different types, and their main function is to act as pigments in flowers, fruits and leaves [50]. In date fruit, the type and concentration of carotenoids is very varied. In general, the principal carotenoids found in date fruit are lutein and β-carotene [51]; however, as occurs with all phytochemicals, the type and concentrations depend on several factors, including location, cultivar and ripening stage.

The principal source of carotenoids is the date pulp. Thus, Hinkaew et al. [19] reported that the main carotenoids found in date pulp were lutein (1.08 g/100 g of the sample), α-carotene (0.30 g/100 g of the sample), β-carotene (0.22 g/100 g of the sample) and β-cryptoxanthin (0.1 mg/100 g of the sample). It is also possible to find carotenoids in the seeds, but in lower concentrations than in pulp.

In this sense, Habib and Ibrahim [52] determined the different carotenoids in oil extracted from seeds of date fruit cultivar Khalas grown in the United Arab Emirates. These authors reported that the main carotenoids identified were β-carotene (3.14 mg/kg), lutein (1.59 mg/kg), β-cryptoxanthin (0.020 mg/kg) and lycopene (0.02 mg/kg). More recently, Habib et al. [53] mentioned that the carotenoid content of oil extracted from date seeds of eighteen cultivars were lutein (0.07–0.27 mg/100 g date seed), β-carotene (1.18–2.68 mg/100 g date seed), α-carotene (0.00–0.08 mg/100 g date seed), γ-carotene (0.03–0.49 mg/100 g date seed), cryptoxanthin (0.03–0.15 mg/100 g date seed) and lycopene (0.00–0.03 mg/100 g date seed).

4.3. Phytosterols Content

Plant sterols are essential components of cell membranes and are present in all plants. They are structurally comparable to cholesterol, with differences in the lateral chain attached to the steroid ring [54]. These compounds represent other group of lipid-soluble phytochemicals existing in date fruit. The edible portion of the fruit contains many phytosterols, although the main sources of phytosterols are the seeds and pollen grains [55].

Thus, Besbes et al. [56] investigated the sterol content present in the oil extracted from seeds of date fruit cultivars Deglet Nour and Allig collected from Tunisia. They reported a total sterol content of 3500 and 3000 mg/kg for Deglet Nour and Allig, respectively. The sterol marker, β-sitosterol, accounted for 83.31 and 78.66% of total sterols in Deglet Nour and Allig seed oils respectively, followed by campesterol (9.10 and 10.19% in Deglet Nour and Alligseed oils) and Stigmasterol (2.42 and 2.29% in Deglet Nour and Alligseed oils). Similarly, Nehdi et al. [57] analyzed the sterols content of oil extracted from fully ripened Phoenix canariensis date seeds. These authors reported that total sterol content value was 336.07 mg/100 g oil; β-sitosterol accounted for 76.06% of the total sterols content in the seed oil, followed by campesterol (8.89%) and Δ5avenesterol (8.79%).

4.4. Tocopherols and Tocotrienols Content

Tocopherols and tocotrienols constituent an important family of compounds for human health because of their antioxidant capacity mainly the lipoperoxyl radical scavenging activities [58]. They are known to be very efficient natural antioxidants, which protect biological membrane components. Therefore, the oil extracted from date seeds could be considered a good source of tocopherols and tocotrienols. In this sense, the tocopherol content of seed oil obtained from 18 leading cultivars of date fruits cultivated in the UAE was analyzed by Habib et al. [53] They found that all seed oils samples depicted considerable concentrations of tocopherols, which ranged between 1.01 mg and 1.86 mg/100 g for α-tocopherol; 0.61 mg and 0.98 mg/100 g for α-tocopheryl acetate and 0.40 mg and 0.70 mg/100 g for γ-tocopherol. More recently, Al Juhaimi et al. [31] analyzed the Tocol content present in the oil extracted from seeds of several cultivars of date fruit with different locations. In all samples analyzed, the predominant Tocol compound found was α-tocotrienol (31.76–37.41 mg/100 g oil), followed by γ-tocopherol (7.61–11.84 mg/100 g), γ-tocotrienol (4.27–8.47 mg/100 g oil), δ-tocopherol (1.13–2.81 mg/100 g) and β-tocopherol (0.69–1.33 mg/100 g oil). In a similar study, Laghouiter et al. [59] analyzed the tocopherol content of the oil obtained from seeds of nine date fruit cultivars grown in Algeria. These authors found that the total tocopherol content varied from 32 to 74 mg/100 g oil; α-tocopherol, which represents the 74% of the composition, (β + γ)-tocopherol (40.56% of the composition) and δ-tocopherol (28.41% of the composition) were the principal components. In an interesting study, Nehdi et al. [60] investigated the tocopherol content of the oil extracted from the seeds of six cultivars of date fruit grown in Saudi Arabia. They reported that the Tocol content of six seed oils analyzed varied between 44.73 and 110.82 mg/100 g oil being α-Tocotrienol the most abundant isomer (30.19%), followed by γ-tocopherol (23.61%), γ-tocotrienol (19.07%) and α-tocopherol (17.52%). As occurs with the rest of bioactive compounds, the concentration and type of tocopherols and tocotrienols depend on several factors, the cultivar, ripening stage and location being the main ones.

5. Nutraceutical Properties of Date Fruits and Potential Health Benefits

It is true that traditionally, date consumption has also been linked with some medicinal properties in folk medicine, but this is without scientific basis. In this sense, dates were used traditionally in the treatment of several health problems, including intestinal disorders, fever, bronchitis, diabetes and hypertension, among others [61–63]. However, recently dates have gained interest due to their relevant health benefits. These health benefits have been attributed to their dietary fiber content and other bioactive compounds including phenolics (phenolic acids, anthocyanins, procyanidins and flavonoids), sterols and carotenoids, as described above (Figure 3).

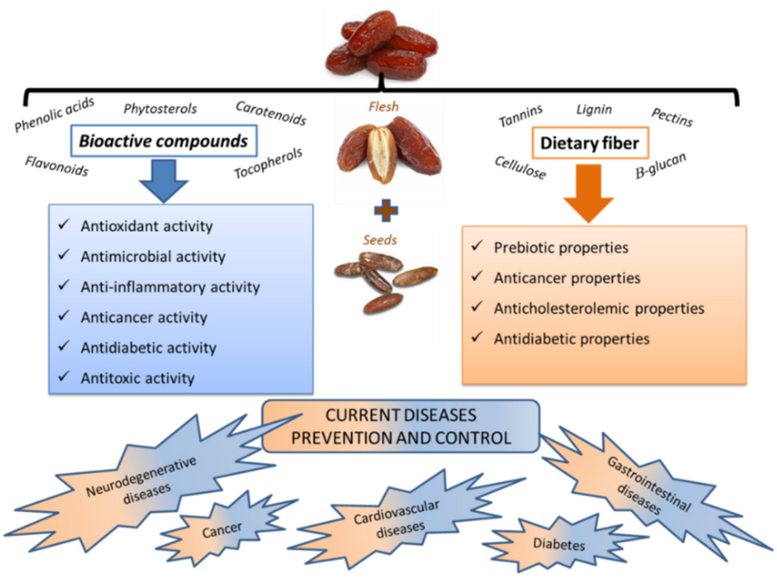

Figure 3. Health benefits of date fruit and the main compounds implied.

Some of this evidence has been confirmed in vitro, or in animal studies or even preclinical studies. All of them confirm that date consumption may exert several beneficial functions in humans, such as antioxidant, antimicrobial, antimutagenic, antihyperlipidemic or anti-inflammatory properties; even anticancer and gastro-, hepato- and nephron-protective properties have been described. In addition, the beneficial impact of date fruits on human gut microbiota and their potential prebiotic activity has been also noticed [64–66].

5.1. Antioxidant Properties

Several researchers have described the antioxidant capacity of date pulp and date seeds (Table 3).

Table 3. Antioxidant activity of pulp and seeds extracts obtained from different date fruit cultivars.

Source	Extraction Methodology	Antioxidant Assay	Antioxidant Activity	Reference
Date pulp cultivars Halwa and Ghazi	1 g lyophilized sample; solvent: aqueous acetone 60% (*v*/*v*), ratio (1/50 *w*/*v*); shake 60 min; centrifuged at 4000× *g* for 30 min.	DPPH radical scavenging capacity Hydrogen peroxide scavenging capacity	At 10 μg/mL DPPH scavenging capacity of 79.1% and 86.0% for Halwa and Ghazi cultivars, respectively. At 10 μg/mL H_2O_2 scavenging capacity of 93.5% and 97.5% for Halwa and Ghazi cultivars, respectively.	Benmeddour et al. [67]
Date pulp cultivars Shahia and Deglet nour	1 g sample; solvent: methanol 80% (*v*/*v*); ratio (1/8 *w*/*v*); shake 1 h water bath; centrifuged at 10,000× *g* for 10 min	DPPH radical scavenging assay. ABTS radical scavenging assay.	For DPPH assay values of 3.27 and 3.54 μmol Trolox equivalents/g sample for Shahia and Deglet nour, respectively. For ABTS assay values of 451.80 and 1350 μmol Trolox equivalents/g sample for Shahia and Deglet nour, respectively.	Al-Jasass et al. [68]
Date pulp cultivars Bourar and Bouzegagh	1 g sample; solvent: methanol 80% (*v*/*v*); ratio (1/25 *w*/*v*); shake 2 h; centrifuged at 5000 rpm for 15 min	DPPH radical scavenging assay. Ferric reducing antioxidant power assay (FRAP)	For DPPH assay, IC_{50} values of 3.01 and 6.46 mg/mL for Bourar and Bouzegagh, pulp extracts, respectively. For FRAP assay, IC_{50} values of 1.20 and 1.45 mg/mL for Bourar and Bouzegagh, pulp extracts, respectively.	Alahyane et al. [41]
Date pulp cultivars Dalt, Deglet nour, Ghar	1 g sample; solvent: methanol 65% (*v*/*v*), ratio (1/4 *w*/*v*); Ultra-Turax T25 homogenizer 2 min;	ABTS radical scavenging assay. Ferric reducing antioxidant power assay (FRAP)	For ABTS assay, values of 57.31, 64.23 and 76.32 mmol Trolox equivalents/kg sample for Dalt, Deglet nour and Ghar cultivars, respectively. For FRAP assay values of 92.23, 116.31 and 108.23 mmol Trolox equivalents/kg sample for Dalt, Deglet nour and Ghar cultivars, respectively.	Tassoult et al. [69]

Table 3. *Cont.*

Source	Extraction Methodology	Antioxidant Assay	Antioxidant Activity	Reference
Date seeds cultivars Aseel, Ajwa and Halawi	1 g sample; solvent: methanol 80% (*v*/*v*); ratio (1/10 *w*/*v*); shake 8 h; concentrated under reduced pressure until dryness	DPPH radical scavenging capacity	At 10 μg/mL DPPH scavenging capacity of 32.78% 55.78% and 73.68% for Aseel, Ajwa and Halawi cultivars, respectively.	Ahmed et al. [70]
Date seeds cultivars Bousthammi and Majhoul	1 g sample; solvent: methanol 80% (*v*/*v*); ratio (1/5 *w*/*v*); shake 12 h; concentrated under reduced pressure until dryness	ABTS radical scavenging assay. Ferric reducing antioxidant power assay (FRAP)	For ABTS assay, values of 8.02 and 5.29 mmol Trolox equivalents/100 g sample for Bousthammi and Majhoul cultivars, respectively. For FRAP assay values of 22.86 and 10.96 mmol Trolox equivalents/100 g sample for Bousthammi and Majhoul cultivars, respectively.	Bouhlali et al. [71]
Date seeds cultivars Tazizaout, Tazarzeit, Tazoughart	1 g sample; solvent: aqueous acetone 75% (*v*/*v*), ratio (1/10 *w*/*v*); shake 24 h; centrifuged at 2500× *g* for 30 min. Concentrated under reduced pressure until dryness	ABTS radical scavenging assay. DPPH radical scavenging capacity	For ABTS assay, IC_{50} values of 24.82, 27.09 and 25.49 μg/mL for Tazizaout, Tazarzeit, Tazoughart seeds extracts, respectively. For DPPH assay, IC_{50} values of 52.55, 68.90 and 63.16 μg/mL for Tazizaout, Tazarzeit, Tazoughart seeds extracts, respectively.	Djaoudene et al. [33]
Date seeds cultivars Sukkari and Khalas	1 g sample; solvent: aqueous acetone 50% (*v*/*v*), ratio (1/12.5 *w*/*v*); shake 1 h; centrifuged at 3500× *g* for 20 min.	DPPH radical scavenging capacity.	IC_{50} values of 680 and 476 μg/mL for Sukkari and Khalas seeds extracts, respectively.	Abuelgassim et al. [72]
Date seeds cultivar Abreme	1 g sample; solvent: methanol (100%), ratio (1/10 *w*/*v*); shake overnight; centrifuged at 10,000× *g* for 12 min.	DPPH radical scavenging capacity ABTS radical scavenging assay	IC_{50} values of 2.2 and 0.6 μg Gallic acid equivalent/mL for DPPH and ABTS assays, respectively.	Barakat et al. [73]

The extracts obtained from both pulp or seeds date fruits showed the ability to inhibit protein oxidation and counteract superoxide and hydroxyl radicals [69,73]. The antioxidant capacity could be endorsed to the bioactive compounds present in their composition, including phenolic acids, flavonoids, anthocyanins, phytosterols, carotenoids, as well as some minerals such as selenium [74,75]. Nevertheless, due to the huge amount of date fruit cultivars present around the world, the antioxidant capacity will be highly variable depending on different factors such as the location, cultivar, part of the fruit used and ripening stage, etc. Consequently, it is very important to keep this variation in antioxidant capacity in mind when attempting to establish the suitability of date fruit as a nutraceutical [30].

As mentioned above, date pulp or date seeds extracts show a considerable antioxidant capacity. As regards the antioxidant activity of date pulp extracts, Haimoud et al. [76] carried out a study to estimate the antioxidant activity of methanolic extracts of date fruit cultivars Tantebouchte, Biraya, Degla Baidha, Deglet-Nour, Ali Ourached, Ghars and Tansine grown in Algeria using the Ferric reducing antioxidant power assay (FRAP) and DPPH radical scavenging assays. These authors reported that all cultivars analyzed showed a good antioxidant capacity with the two methodologies assayed. Thus, in the FRAP assay the values obtained ranged from 18.95 μmol Fe+2/100 g sample in the Tanise cultivar to 56.04 μmol Fe + 2/100 g sample in the Ali Ourached cultivar. On the other hand, in the DPPH assay the concentration at which 50% of radicals are scavenged, (IC50) obtained varied from 206 μg/mL in the Ali Ourached cultivar to 380.66 μg/mL in the Biraya cultivar. Souli et al. [77] analyzed ten date cultivars (Alig, Ammari, BeserHelou, Beyd Hamem, Bejou, Deglet Nour, Horra, Kenta, Kentich and AkwatteAlig) located in Tunisia using the FRAP and ABTS radical scavenging assays. They reported values ranging between 624.16 for Beyd Hamem and 1228.53 μmol TE/100 g sample for Deglet Nour when FRAP assay was utilized, while for ABTS assay the values obtained varied from 865.52 for the BeserHelou cultivar to 1813.80 μmol TE/100 g sample for Deglet Nour. Abdul-Hamid et al. [78] analyzed the DPPH and nitric oxide (NO) scavenging abilities of pulp extracts obtained from four date fruit cultivars cultivated in Saudi Arabia, including Anbara, Sogaai, Shalabi and Berni. In reference to DPPH radical assay, pulp extracts (5 mg/mL) of Anbara, Sogaai, Shalabi and Berni date fruits had inhibition values of 31.5%, 30.2%, 30.7% and 29.6%, respectively whilst in NO scavenging assay the inhibition values of pulp extracts (5 mg/mL) were 15.9%, 65.5, 49.3% and 61.5% for Anbara, Sogaai, Shalabi and Berni date fruit cultivars, respectively. In a more recent work, Djaoudene et al. [49] determined the antioxidant properties of pulp extracts from four Algerian cultivars (Tazizaout, Tazarzeit, Tazoughart and Tamezwert n'telet) of date palm using ORAC assay. These authors reported values ranged between 23.68 and 27.59 mg Trolox equivalents/g sample.

In reference to the extracts obtained from date fruit seeds, Thouri et al. [79] carried out a study to determine the antioxidant activity of seed extracts obtained from two cultivars of date fruits, namely Korkobbi and Arechti, using DPPH and ABTS radical scavenging assays. They reported that the IC50 value was higher in Arechti than Korkobbi, with values of 2.01 and 1.88 mg/mL, respectively in DPPH assay, while in the ABTS assay the IC50 values were 1.40 and 1.13 mg/mL for Arechti and Korkobbi date fruit seed extracts, respectively. In a similar study, Bouhlali et al. [75] analyzed the antioxidant activity, using, two different methodologies (ABTS radical scavenging assay and FRAP assay) of seeds extracts obtained from date fruit cultivar Boufgous cultivated in Morocco. They found that date seeds extracts showed antioxidant properties with all methods utilized with values of 4.87 mmol Trolox equivalents/100 g sample for ABTS assay and 14.23 mmol Trolox equivalents/100 g sample in FRAP assay. More recently, Abuelgassim et al. [72] used the hydroxyl radical scavenging activity to determine the antioxidant activity of seed extracts obtained from date fruits cultivar for Sukkari and Khalas. These authors reported IC50 values of 302.24 and 284.18 μg/mL for Sukkari and Khalas seeds extracts, respectively. In a very interesting research work, Djaoudene et al. [49] determined the antioxidant properties of seed extracts from three Algerian cultivars (Ourous, Ouaouchet and Oukasaba) of date palm using ABTS and DPPH radical scavenging capacity assays. They found that all extracts revealed good antioxidant activity, with ABTS assay values of 565.20, 776.89 and 666.69 mg Trolox equivalents/g sample for Ourous, Ouaouchet and Oukasaba cultivars, respectively. Meanwhile, in the DPPH assay, the values obtained were 578.08, 810.69 and 771.83 mg Trolox equivalents/g sample for Ourous, Ouaouchet and Oukasaba cultivars, respectively.

The results obtained from these in vitro assays encouraged researchers to investigate this activity in vivo against different toxicants in animals [80–84]. All of them reported that this protective effect of dates may be related to the accelerated activities of some antioxidant enzymes (glutathione S-transferase, catalase and glutathione reductase, among others) along with significant reduction in malonaldehyde (MDA). These activities have been shown at different concentrations of date fruit extracts (from 100 to 1000 mg/kg body weight). As can be seen, there are many in vitro studies that support the antioxidant activity of dates (from different cultivars) and/or their extracts, but it would be interesting if these results were also checked by ex vivo and in vivo animal studies. It is true that there are far fewer studies carried out in this regard, but all of them continue to support the antioxidant effect of date products [81,85–88]. Regarding this, some animal models have been used to check the protective effect of dates on free radicals produced by several toxicants (isoproterenol, cadmium, carbon tetrachloride and others). The authors attributed this effect to a greater activity of defense enzymes against oxidation such as catalase, superoxide dismutase and glutathione enzymes (reductase, peroxidase and S-transferase). In addition, a significant reduction in malonaldehyde has also been reported [87].

5.2. Antibacterial Properties

A wide range of antibacterial properties have been reported from both pulp and seeds of different date fruit cultivars in in vitro studies (Table 4). These antimicrobial properties could be attributed to the high content of polyphenolic compounds, including phenolic acids and flavonoids, as well as condensed tannins found in their composition. However, the exact mechanisms behind the antibacterial activity of pulp and seed extracts obtained from date fruit have not been completely elucidated, which warrants further investigation. Despite this, it must be taken into account that the antimicrobial activity will depend on numerous factors such as the cultivar used, the maturity state, the origin, the environmental conditions, etc.

Table 4. Antibacterial activity of pulp and seeds extracts obtained from different date fruit cultivars.

Source	Methodology/Concentration	Bacterial Strains	Antimicrobial Effect	Reference
Dates pulp Cultivars Rothana and Sukri	Agar well diffusion method. 50 µL of methanolic extract (0.1 mg/mL).	*B. subtilis*, *E. coli*, *Ps. aeruginosa*, *S. aureus* and *S. pyogenes*	Inhibition zones diameters (mm) of 19.5, 20.5, 18.00 and 26.75, respectively for Rothana cultivar and 25.5, 22.5, 18.75, and 27.75, respectively for Sukri cultivar.	Perveen and Bokahri [89]
Dates pulp Cultivar Ajwa	Well diffusion assay. 500 mg/mL of methanolic extract (0.1 mg/mL).	*E. coli*, *Salmonella typhi*, *Salmonella typhimurium*, *Shigella flexneri* and *Vibrio cholerae*.	Inhibition zones diameters (mm) of 27.67, 29.00, 25.67, 34.00, and 28.67, respectively.	Abdullah et al. [90]
Dates pulp Cultivars Ajwa and Khalas	Agar well diffusion method. 100 µL of 10 mg/mL ethanol extract solution	*Pasteurella multocida* and *B. subtilis*	Inhibition zones diameters (mm) of 33.00 and 45.00, respectively for Ajwa cultivar and 31.00 and 42.00, respectively for Khalas cultivar	Qasim et al. [91]
Dates pulp Cultivars Akerbouch and Tamesrit	Agar well diffusion method. 100 µL of 0.2 mg/mL methanolic extract	*E. coli*, and *S. aureus*	Inhibition zones diameters (mm) of 27.00 and 35.30, respectively for Akerbouch cultivar and 26.30 and 43.00, respectively for Tamesrit cultivar	Mihoub et al. [92]
Dates pulp Cultivars Alig and Deglet Nour	Broth dilution method. Concentrations ranged from 0.04 to 25 mg/mL of 200 mg/mL methanolic extract	*E. coli*, *S. typhi*, *Ps. aeruginosa*, *B. cereus*, *S. aureus*, *S. epidermidis Listeria monocytogenes* and *E. faecalis*	minimal inhibitory concentration values (mg/mL) of 0.10, 25, >25, 12.50, 3.13, >25, 0.1 and 6.25 for Alig cultivar and 0.4, 12.50, 12.50, 12.50, 3.13, 25, 6.25 and 12.50	El Arem et al. [45]

Table 4. *Cont.*

Source	Methodology/Concentration	Bacterial Strains	Antimicrobial Effect	Reference
Date seed Cultivars Halawi, and Zahdi extracts	Agar well diffusion method. 50 µL of 5 mg/mL methanolic extract	*Cinetobacter baumannii*, *B. subtilis*, *E. coli*, *Klebsiella pneumoni*, *Ps. aeruginosa*, *Proteus mirabilis*, *S. aureus* and *Streptococcus pyogenes*.	Inhibition zones diameters (mm) of 12.00, 12.00, 13.00, 9.00, 10.00, 17.00, 12.00 and 11.00, respectively for Halawy cultivar and 16.00, 12.00, 20.00, 13.00, 22.00, 15.00, 12.00 and 12.00, respectively for Zahdi cultivar	Aljazy et al. [93]
Dates seeds Cultivars Deglet and Bestian	Agar well diffusion method. 100 µL of 0.33 mg/mL methanolic extract	*Ps. aeruginosa*, *Proteus vulgaris* *S. aureus E. coli*, and *Klebsiella pneumoniae*	Inhibition zones diameters (mm) of 15.02, 19.2, 18.3, 14.04 and 13.8, respectively for Deglet cultivar and 15.2, 16.3, 17.5, 6.00 and 18.0, respectively for Bestian cultivar	Labyad et al. [94]
Dates seeds	Agar well diffusion method. 100 µL of 10 µg/mL of ethanolic extract	*S. aureus* and *E. coli*	Inhibition zones diameters (mm) of 15.00 and 24.40, respectively	Idris et al. [95]
Dates seeds Cultivars Khalas and Sukkari	Agar well diffusion method. 100 µL of 0.1 mg/mL methanolic extract	*S. aureus*, *B. subtilis*, *E. coli*, *Enterococcus faecalis*, *S. typhimurium*, and *Ps. aeruginosa*.	Inhibition zones diameters (mm) of 28.00, 21.00, 19.00, 21.00, 19.00 and 18.00, respectively for Khalas cultivar and 25.00, 21.00, 14.00, 20.00, 20.00 and 13.00, respectively for Sukkari cultivar	Abuelgassim et al. [72]
Dates seeds Cultivars Lemsi and Bouhattam	Disc diffusion method. 7.5 mg methanolic extract/disc	*E. coli*, *S. aureus*, *Staphylococcus epidermis*, and *S. typhinurium*	Inhibition zones diameters (mm) of 21.27, 22.23, 21.20 and 19.23, respectively for Lemsi cultivar and 19.43, 22.50, 22.43 and 21.33, respectively for Bouhattam cultivar	Metoui et al. [96]

For instance, Bouhlali et al. [97] analyzed the antibacterial activity of date fruit pulp extracts obtained from date fruit cultivars cultivated in Morocco. They found that the extracts obtained from Bousrdon and Jihl cultivars had potent antibacterial capacity, with Minimum Inhibitory Concentration (MIC) values ranging between 2.5 mg/mL and 10 mg/mL against *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella abony* strains. Similarly, El Arem et al. [45] studied the antibacterial properties of date fruit pulp extracts cultivar Horra cultivated in Tunisia against several strains including *E. coli*, *B. cereus*, *S. aureus*, *Listeria monocytogenes* and *E. faecalis*. These authors reported MIC values of 25 mg/mL for all tested strains analyzed. Perveen and Bokahri [89] carried out a study to analyze the antibacterial properties of methanolic extracts (10 g/100 mL) obtained from the pulp of dates from the Barhi cultivar grown in Saudi Arabia against *B. subtilis*, *E. coli*, *Ps. aeruginosa* and *St. aureus*. These authors reported inhibition zones diameters, of 23.50, 24.75, 18.00 and 20.75 mm for *B. subtilis E. coli*, *Ps. aeruginosa* and *St. aureus*, respectively. More recently, Al-Tamimi et al. [98] analyzed the antibacterial activity of pulp extracts obtained from two date fruit cultivars (Ajwa and Safawi), cultivated in Saudi Arabia. The results obtained showed that all extracts had high antibacterial activity against *E. coli*, *Ps. Aeruginosa*, *Salmonella enteritidis* and *St. aureus*, with MIC values of >100, 90.75, 80.40 and 40.50 µg/mL, respectively for Ajwa cultivar, and MIC values of >100, 88.50, 98.50 and 65.50 µg/mL, respectively for Safawi cultivar.

The date fruit seeds also have demonstrated a high antimicrobial capacity. In this way, Al-Daihan and Bhat [99] analyzed the antibacterial activity of seeds extracts (acetone, methanol and aqueous) obtained from date fruit cultivar Mosaifah cultivated in Arabia Saudi against several Gram-negative (*E. coli* and *Ps. aeruginosa*) and Gram-positive strains (*St. aureus* and *Streptococcus pyogenes*). They learned that all extracts had moderate antibacterial activity, with inhibition zone diameters comprising between 8.00 and 11.60 mm. Bentrad et al. [100] reported that seeds extracts obtained from two different cultivars of dates such as Deglet Nour and Takerbucht, showed a strong or extremely strong antibacterial effect against *E. coli* with inhibition zone diameters of 20.30 and 15.33 mm, respectively. On the other hand, a moderate antibacterial activity against *Ps. aeruginosa*, *St. aureus* and *E. faecalis* with inhibition zones ranging between 11.00 and 14.30 mm was achieved. Labyad et al. [94] analyzed the antibacterial activity of date seeds extracts obtained from cultivar Hamrai and Abel cultivated in Libya. These authors learned that the Hamrai seed extract had a moderate antibacterial activity against *St. aureus* and Methicillin resistant *St. aureus* (MRSA) with inhibition zone diameters of 16.5 and 14.5 mm, respectively, whilst Abel seed extracts showed a low antibacterial activity with inhibition zone diameters of 8.90 and 7.80 mm for *St. aureus* and MRSA, respectively. Anwar et al. [101] reported that methanolic extracts obtained from date seeds cultivar Ajwa had strong antibacterial activity against *St. aureus E. coli*, *Klebsiella pneumoniae*, *Ps. aeruginosa* and *Enterococcus faecalis* with MIC values of 25, 25, 25, 50 and 25 mg/mL, respectively.

The current data present in the scientific literature shows that the extracts obtained from both the pulp and the seeds of the date fruit have a wide spectrum of antibacterial activity, mainly attributed to phenolic compounds which are implied to generate hydrogen peroxide that inhibits bacterial growth. These findings suggest that these fruits, or the extracts obtained from them, could offer an economical mode to protect humans from several forms of bacterial infections.

5.3. Anti-Inflammatory Activity

Inflammation is one of the essential defense systems against several factors, including toxicants, allergens, burn, infection and others. Most of the authors explain the anti-inflammatory activity of date extracts based on their antioxidant properties (Figure 4) [82,102–104]. It is well known that free radicals in the body cause oxidation in normal cells, which ends up inducing the start of inflammation process and diseases [105–108]. In view of this, their content in phenolic and flavonoid compounds could be responsible for the inhibition of prostaglandin endoperoxide formation, avoiding inflammation mediators such as prostaglandins and thromboxane [109] or inhibiting the expression of some inflammatory cytokines [81] such as interleukin 1β (IL-1 β) and TGF-β, produced by lymphocytes and other immune cells when there are inflammatory stimuli [106]. In addition, Hanna and Hafez [110] highlighted the role of the cyclooxygenase pathway in inflammation development. They reported that cyclooxygenase enzymes (COX) are implied in the conversion of phospholipids to arachidonic acid. Concretely, two COX have been identified as implied in this process: COX-1, which is constitutively expressed and plays a role in the protection of the gastric mucosa, and COX-2, which is expressed inducibly by inflammatory stimulus [111]. All these compounds (cytokines IL-1β and TFG β and COX-1 and COX-2) are identified as proinflammatory mediators (Figure 4).

Saryono et al. [105,106] reported that date palm seeds could show anti-inflammatory activity and improve the immune system performance, which has been attributed mainly to the decrease in these proinflammatory mediators. In the case of the aqueous extracts of date palm seeds, this effect has been related to some polyphenols such as hydrocaffeic acid, caffeoyl hexoside, 5-O-caffeoyl shikimic acid isomers and isorhamnetin [79,112,113].

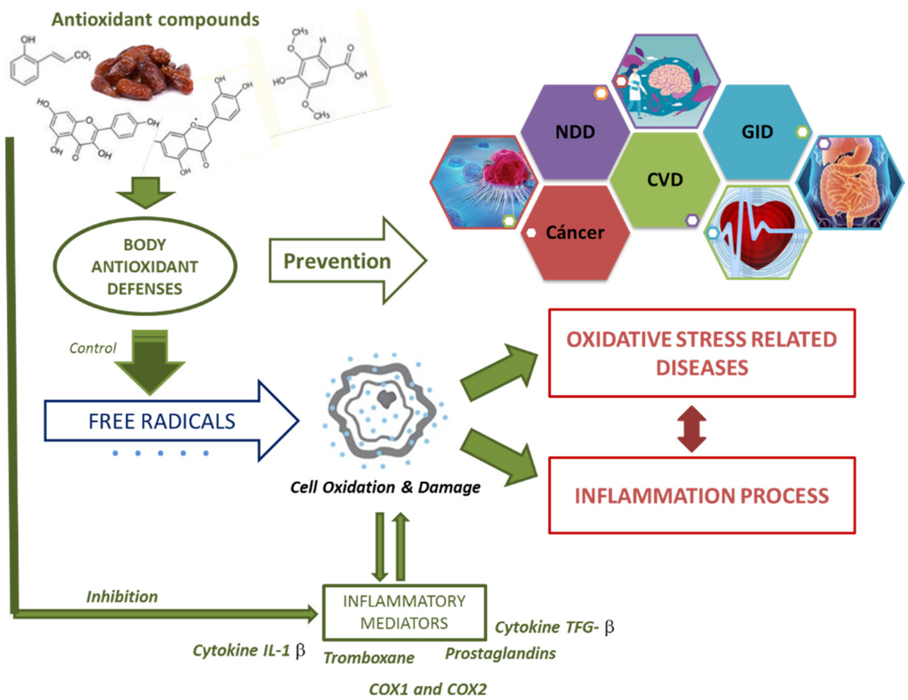

Figure 4. Anti-inflammatory activity of date compounds based on their antioxidant properties. NDD: neurodegenerative diseases; CVD: cardiovascular diseases; GID: gastrointestinal diseases.

Al-Qarawi et al. [103] reported that both ethanolic and aqueous extracts of date palm (4 mL/kg) were able to suppress the inflammation in animal arthritis model. In a study using mice, Haimoud et al. [76] reported a noticeable reduction in paw edema volume after the oral administration (250 mg/kg) of a methanolic extract from date palm. The recent study of Al-Dashti et al. [87] also supports the anti-inflammatory potential of dates. In this case, the authors used a lyophilized date extract from Ajwa cultivar, which was administrated (orally) at a dose of 250 and 500 mg/kg body weight in rats with a previously induced heart tissue injury, resulting in downregulation of the expression of pro-inflammatory cytokines.

5.4. Cardiovascular Protective Activity

To evaluate this activity, several vascular-related effects attributed to date palm fruit such as antihypertensive, modulator of cholesterol absorption and metabolism, and also blood lipid levels have been studied. In addition, their oxidant defense and inflammatory responses also seem to be implied [87].

Regarding the antihypertensive effect, Braga et al. [114] and Vayalil [115] reported that date fruit is a potent angiotensin-converting enzyme inhibitor (mainly attributed to some polysaccharides presents in date fruits) and so contributes to reduced blood pressure. In addition, date fruit is rich in potassium and low in sodium, which can also contribute to controlling blood pressure by maintaining the electrolyte balance [116,117].

In reference to the antihypercholesterolemic effect, several authors have attributed it to its dietary fiber and phytochemical content, which exerted this effect with three mechanisms: reduction in cholesterol absorption and reabsorption of bile acids, and inhibition of hepatic cholesterol biosynthesis after production of short-chain fatty acids due to fiber fermentation in colon [118–120].

It is well known that insoluble fibers (predominant in date fruits, as has been noted above) [121] can bind to cholesterol and triacylglycerols in the intestine facilitating their excretion, and so contribute to lower circulating cholesterol levels [122,123]. Thus, there are lower amounts of lipoproteins, which reduces atherogenesis risk [124]. The protective effect of high-fiber diets on cardiovascular problems has been widely reported. Marques et al. [125] related this protective effect to the increase in acetate producing microbiota, blood pressure decrease and reduction in cardiac hypertrophy and fibrosis. In the case of diets rich in prebiotic soluble fiber, several beneficial effects have been attributed to the short-chain fatty acids produced by their bacterial fermentation. Some of these effects are differentiation of immune regulatory T cells and regulation of peroxisome proliferator-activated receptor (reduction in both its expression and activation) [126,127]. These actions interfere the metabolism in both tissues (adipose and hepatic), affecting not only lipogenesis but also fatty acid oxidation [126].

The content in phytochemicals (mainly proanthocyanidin, catechin, quercetin, anthocyanins, beta-sitosterol, among others) has also been responsible for their antihyperlipidemic effect. From dietary phytochemicals, polyphenols have been the most studied regarding cardiovascular health, and within this group the most relevant effects have been attributed to anthocyanins, flavanols and proanthocyanins [128]. Some of the physiological effects that seem to be involved are the inhibition of some important prooxidants, free-radical quenching, reduction in the activity of the ET-1 vasoconstrictor and the induction of NO as a mediator of vasodilation in blood vessels [87,129].

Apart from the important cardiovascular effects attributed, on the one hand, to dietary fiber and, on the other hand to phytochemicals, we must also highlight the effects on vascular function derived from the interaction of both compounds. Polyphenols can be associated with some polysaccharides that conform dietary fiber and so their interactions can affect digestion process and so their bioaccessibility and bioavailability [130,131]. Several authors have reported that this bioavailability can be enhanced during the digestion process because the gut microbiota metabolize the glycosylated form of polyphenols (typical form of dietary polyphenols but not well absorbed in the small intestine) [132] to other polyphenols with low molecular weight, which are easily absorbed in the small intestine [133,134]. Several polyphenols transformations have been reported due to gut microbiota activity such as esterification of hydroxycinnamic acids, acylation of flavanol-3-ols or hydrolysis of glycosylated flavonoids, among others [135].

Ahmed et al. [70] demonstrate that this effect of lowering some hyperlipidemic markers in blood such as triacylglycerol, LDL and VLDL was similar to those reported for atorvastatin (which is pharmacologically used for reducing hyperlipidemic markers). Beneficial effects of dates on plasma lipids have been suggested by several studies in animals [136–139]. Mehraban et al. [138] reported a significant reduction in some cardiovascular blood markers (triglycerides and LDL-cholesterol) in hamsters fed with a high-cholesterol diet supplemented (for 13 weeks) with Khalas date pulp (50% *w*/*w*) in contrast to those fed the high-cholesterol diet alone. A similar effect on serum cholesterol levels has been reported by El-Kashlan et al. [136] in rats fed with hyperlipidemic diets supplemented with an Aseel date fruit suspension (300 or 600 mg/kg body weight) for eight weeks. In this case, as a positive control group, the authors used some rats receiving a drug normally used for lipid regulation (atorvastatin 2.1 mg/kg), which showed a similar response to animals fed with dates. A more complete study was designed by Al-Jaouni et al. [140], and tried to evaluate not only cholesterol serum behavior but also electro-cardiological and biochemical changes. In this case the authors used a nanopreparation mix from date fruits and seeds (Ajwa) for the feeding (1.4 g/kg) of Wistar rats with induced cardiotoxicity. They reported very positive results about the protective effects of this nanopreparation on the induced cardiotoxicity in contrast to the control group. Some of these effects were the control on the left ventricular pressure, prevention of ischemia and an increase in the antioxidant capacity in cardiac tissue. Alhaider et al. [141] also reported interesting effects of extracts (with high polyphenols concentration) from dates (Reziz, Khenizi, Berhi and Khalase cultivars) on repairing cardiac tissue injury. In this case, the authors used a rodent model with induced myocardial infarction and reported that rodents fed with these date extracts showed higher antioxidant activity and mobilization of circulating progenitor cells involved in cardiac tissue repair than the control group.

These effects have also been supported by others in in vitro studies using human intestinal cells. In this case, a freeze-dried date extract (from Deglet Nour and Medjool cultivars) rich in proanthocyanin (13%) showed different effects related to vascular health (triglyceride and cholesterol blood levels) [142]. These authors demonstrated that this date extract could act as a potent co-agonist ligand for the farnesoid x receptor (FXR), which primary function is the suppression of cholesterol 7 alpha-hydroxylase (CYP7A1), the rate-limiting enzyme in bile acid synthesis from cholesterol. It could be one of the mechanism responsible for the hypotriglyceridemic effect attributed to dates.

It is also interesting to highlight the effect on vascular function of different polyphenolic compounds isolated from dates, and not only the date itself or its extracts. In reference to this, the most studied compounds have been the anthocyanin cyanidin-3-glucoside and some of its metabolites (protocatechuic acid and ferulic acid). Amin et al. [143] reported that when these compounds were used at concentrations of 100 nmol, they were effective at controlling cytokine IL-6 production (implied in inflammatory process) and vascular cell adhesion protein-1 (implied in atherosclerosis development). Krga et al. [144] reported that both ferulic acid and anthocyanins reduced monocyte adhesion to human vascular endothelial cells, which is considered a relevant factor for reducing the risk of developing atherosclerosis.

There are not too many or significant human studies on date intake and its healthy effect. Rock et al. [145] studied the effect of date consumption (from Medjool or Hallawi cultivars; seven dates for 4 weeks) on cardiovascular markers in a healthy person, with interesting results. These authors reported good results regarding markers of oxidative stress related to date consumption compared to control groups, but with differences between the type of date; in this case, the consumption of Hallawi dates showed better results than Medjool dates. These differences were attributed to the polyphenols content and composition: the total polyphenol content in Hallawi dates was 31% and only 20% in Medjool dates, and again, Hallawi dates showed greater catechins concentration, to which potent oxidant defense actions have been attributed. Another interesting human study was reported by Alalwan et al. [146] about the consumption of dates from Khudary cultivar, in this case by diabetic adults. Although the results were not statically significant, the authors reported that the date group improved cholesterol data in plasma (reduced LDL-C) in relation to control group.

Based on all these studies (in vitro, in vivo in animals and humans) it could be said that dates show an interesting trend to be used as a control tool for cardiovascular diseases, mainly due to their effect on markers of cholesterol plasma levels, oxidative stress, human vascular endothelial cells and repairing cardiac tissue.

5.5. Hypoglycemic Activity

This activity has also been related to their phytochemicals content through the modulation of metabolic and molecular pathways. Specifically, it has been reported that some phytochemicals found in date palm (saponins, phenols, steroids and flavonoids) are all antidiabetic agents [147] which can control the functions of pancreatic cells by enhancing insulin production and reducing glucose absorption [148]. Although insulin is commonly known as the major hormone involve in diabetes, several studies have been focused on the behavior of another hormone, human Islet Amyloid Polypeptide (hIAPP of amylin), that also seems to be implied in diabetes [149]. In this context, many studies have suggested that hIAPP and its cytotoxicity is a causative agent associated with type 2 diabetes mellitus, and so, several studies about the hypoglycemic activity attributed to some natural compounds found in certain foods are focused on evaluating whether these compounds are able to interfere with the amyloid proteins involved.

Sing et al. [150] reported that diosmetin glycosides derived from dates would contribute to improve insulin excretion and stimulate glycogen synthase, helping to maintain blood-glucose homeostasis. These effects have been associated with their free-radical scavenging activity (through multiple diabetic rat studies) [151,152] and also with the fact that these compounds inhibit alpha-glucosidase (or even alpha-amylase), thus affecting glucose absorption in both the small intestine and kidneys [153]. El Fouhil et al. [154] reported than an aqueous extract of date palm seeds was effective in the glycemic control of type 1 diabetes mellitus in animal models. Chakroum et al. [155] reported the same effect for hydro-alcoholic extracts from date leaves. Date seed oil has also been studied in reference to its antidiabetic properties. In this way, Lammari et al. [156] reported that oleic acid (the main fatty acid in date seed oil) may inhibit the action of two enzymes (α-amylase and α-glucosidase) implied in glucose metabolism and alleviate some of the side effects (skin reactions, gastrointestinal discomfort, nausea and weight gain, among others) derived from the use of some traditional hypoglycemic drugs. Chaari et al. [149] reported that date flavonoids, mainly catechin and quercetin, showed interesting effects on the inhibition of the amyloid aggregation and decreasing their cytotoxicity. They attributed this effect to the presence of different aromatic moieties that may disturb aromatic interactions during hIAPP aggregation, as well as the presence of consecutive poly-hydroxy groups and their antioxidant potential.

5.6. Hepatoprotective, Nephroprotective and Neuroprotective Effect

These antitoxic effects affecting the liver, kidneys or neuronal system seem to be related both to the effect of date palm compounds against oxidative stress (induced by free radicals generation) but also to the specific toxicity induced by several xenobiotics.

Antioxidants from plant-derived foods have been widely studied due to their capability to counteract free radicals generated and neutralize them, thus contributing to hepatoprotection, nephroprotection and neuroprotection [82]. Regarding date palm, these effects have been attributed to its polyphenolic constituents, such as flavonoids and plant sterols, as well as its ascorbic acid.

In the case of liver, Saafi et al. [157] reported a protective effect of an aqueous fruit flesh extract of date palm (4 mL/kg) on rat liver with a high oxidative stress (induced) which could be verified by the inhibition of the hepatic lipid peroxidation and the restoration of normal hepatic biomarker enzymes; that is, preventing hepatocellular damage. Similar date flesh extracts were also administrated to rats with a high level of induced kidney toxicity, and showed a significant reversal effect in this toxicity which was attributed to melatonin, vit. E and ascorbic acid present in the extracts. These compounds were revealed as the base of the nephroprotection effect due to their action (synergistically) to counteract the overwhelming effect of the free radicals generated. In reference to the effect of date palm extracts on the pathogenesis of several neurological diseases mediated by oxidative stress, interesting results have also been obtained in animal assays.

During the development of hepatoprotective drugs for the treatment of hepatocellular injuries, the inhibition of the aromatase activity of cytochrome P-450 (so allowing liver regeneration) has been revealed as the key action. In this way, several authors have suggested that the flavonoids content of date palm could act as inhibitors of this enzyme (cytochrome P-450 aromatase). This effect has been checked in rat models with hepatic injury induced and the authors attributed the hepatoprotective effect to beta-sitosterol added to drinking water [158].

Recently, several authors also attributed some nephroprotective effects to date fruits [33,151,159–161]. Al-Qarawi et al. [161] studied this effect in rats feeding with an aqueous suspension of date pulp and seeds (50%). In this case, the nephroprotective effect (lower levels in plasma creatinine and urea and, reduction in proximal tubular damage) was attributed to the date antioxidant compounds. In other cases, the authors used rats with nephrotoxicity induced (using several toxicants) to evaluate if date consumption could repair these negative effects on kidney. In the study of Ahmed et al. [159] the toxicant used was CCl_4 and they applied a date extract (50–100 mg/kg/rat) which exerted a potent protection on the kidneys of rats and interestingly, this effect was dose-dependent. It can be supposed that during CCl_4 metabolism a large amount of free radical were generated on which the antioxidant compounds (mainly proanthocyanidins) of date extracts would act. In another study the nephrotoxicant used was aflatoxin B1 (potent inductor of histopathological changes in the kidney with several changes in the renal function) [160].

In this case the use of an aqueous date extract administrated to these rats for two weeks resulted in a significant recovery of kidney tissues and their function (reduction of creatinine and urea levels). Similar behavior was obtained by Al-Qarawi et al. [161] when gentamicin was used as a nephrotoxicant in a rat model. The antioxidant compounds in date extracts was identified as responsible for the nephroprotective effect of date extracts in these three study cases.

On the other hand, Hasan and Mohieldein [152] used diabetics rats with renal dysfunction as models to evaluate the nephroprotective effect of dates. They concluded that the use of date aqueous extracts (100 g/L) for rat feeding (10 mL/day/rat) slowed the progressive deterioration of renal function in diabetic rats, helping to restore kidneys.

This review has noticed an increasing interest about the neuroprotective effect of dates in view of its beneficial effects in various neurological diseases such as Alzheimer's disease, Parkinson's disease, Huntington's disease and amyotrophic lateral sclerosis, among others; all of them are frequent neurodegenerative disorders that cause dementia, mainly in the elderly [162–165]. Li et al. [166] noticed that the regular consumption of dates was usually associated with lower risk of neurodegenerative disorders and better cognitive performance in the elderly. Majid et al. [167] reported that a date fruit extract (aqueous) was able to prevent neuronal circuitry against focal cerebral ischemia. Several authors have identified the high phenolic and flavonoid content in dates as responsible for their neuroprotective effect, mainly due to their protection against the inflammation and oxidative stress (which has been previously discussed) in the brain. These effects of date polyphenols and flavonoids have been demonstrated not only in in vitro studies, but also in several animal models such as transgenic mouse model of Alzheimer disease [163–165,168]. These authors reported that the supplementation with dated fruits (4%) for mouse feeding decreased inflammatory response (pro-inflammatory cytokines such as IL-1β, IL-2, IL-3, IL-4, IL-5, IL-6,IL-9, IL-10, TNF-α and eotaxin activity) and delayed the formation of senile plaques in brain due to a decrease in the content of amyloid proteins Aβ1–40 and Aβ1–42 in these transgenic mouse model of Alzheimer disease, in contrast to control mouse. This neuroprotective effect of dates has also been reported by Pujari et al. [169] in rats in which neuronal damage was previously induced, resulting in symptoms such as anxiety and deficits of spatial learning and memory. When these rats were feeding for 15 days with a date extract at a dose of 100 and 300 mg/kg, these symptoms were significantly reduced, which was associated with a decrease in malondialdehyde levels (responsible for oxidative stress) in the rats' brains and prevention of neuronal necrosis (confirmed by histopathological analysis).

5.7. Anticancer Activity

The role of several bioactive compounds of plants, such as flavonoids and other phenolic substances in cancer control through the regulation of several genetic pathways without relevant side effects has been widely reported [18,30]. Regarding date fruits, anticancer effect against many types of cancer has also been reported in both in vivo and in vitro assays [30,114,147,170]. Regarding in vitro assays, Zhang et al. [170] reported that methanolic date extracts (100 μg/mL) were able to inhibit cell proliferation in several tumor cell lines including human gastric, colon, breast, lung and prostate. In the case of in vivo assays, Ishurd and Kennedy [171] studied the antitumor (allogenic solid Sarcoma-180) effect in mice of an extract of β-glucan isolated from date (Lybian). This compound showed a potent antitumor effect when it was administrated at a dose of 1 mg/kg body weight, suggesting that this effect could be related to the (1 → _3)-β-d-glucan linkages. This anticancer effect was also reported by Al-Sayyed et al. [172] in rats that had mammary cancer induced (using 7, 12-dimethylbenz (α) anthracene). In this occasion, rats whose diet was supplemented with 30% date fruit showed a great improvement in cancer development, such as reduction in tumor size and weight and palpable tumor multiplicity. This anticancer effect was similar to that obtained when usual anticancer drugs such as 17-β-estradiol or tamoxifen were used. These positive effects of dates against cancer have also been confirmed in human studies. Eid et al. [173] developed a randomized, cross-over human intervention study with the objective of demonstrating that fruit intake could reduce cancer risk. They reported that date consumption significantly reduced genotoxicity in human fecal water (cancer risk reduction indicator) without inducing changes in the microbiota. Subsequent studies also confirmed this effect; in this case, the studies were made using date extracts (from Ajwa cultivar) which sowed potent anticancer activities against hepatocellular carcinoma and prostate cancer [174,175].

Although the mechanisms of action of dates in cancer prevention are not exactly known, it is widely accepted that their richness in bioactive compounds such as quercetin, luteolin, apigenin, proanthocyanidins and other polyphenols can be effective against cancer. In addition, other properties associated with these biocompounds present in date fruits, such as antioxidant and anti-inflammatory activities, are also related to cancer prevention [115,170].

5.8. Prebiotic Properties

Currently, one of the most important challenges in nutrition science is improving gut health using functional food as a health-promoting tool. In this way, the promotion of foods or food ingredients based on their prebiotic properties is a useful strategy. Prebiotics are defined as "non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of health promoting bacteria in the colon, and thus improving the host's health" [176].

In view of the high content in carbohydrates, especially non-digestible carbohydrates such dietary fiber, found in date seeds, Al-Thubiani and Ahmad Khan [64] studied the potential prebiotic properties of dietary fiber concentrates obtained from date seeds. These dietary fiber concentrates showed the potential to be used as a novel source of prebiotic by increasing the population of probiotic Lactobacillus paracasei spp. with a concomitant decrease in the pH values of the medium.

6. Conclusions and Future Views

Many scientific papers described in this review have demonstrated the interest in date fruit production, highlighting that nowadays they are not only an eco-efficient, sustainable and economic source of nutrients and energy in our diet, but also a promising source of functional food ingredients. Most of the beneficial effects associated with their consumption are related to their content in dietary fiber (mainly insoluble dietary fiber) and bioactive compounds, including polyphenols, carotenoids and flavonoids. Recently, there has been an increasing interest in the extraction of these bioactive compounds (understudied by the use of novel extraction techniques) to be used as functional ingredients in the development of date-based foods. The health benefits associated with their consumption has been attributed to some biological activities linked to both constituents, dietary fiber and bioactive compounds, such as antioxidant, antimicrobial, anti-inflammatory, antitoxic and antimutagenic properties. All these properties are responsible for the prevention and control of some of the most important diseases in industrialized countries such as cancer, diabetes, gastrointestinal diseases, cardiovascular diseases and neurodegenerative diseases. More and more studies (in vitro, in vivo, in animals and humans) are being conducted in view of demonstrating these effects and to elucidate the biological mechanisms implied, taking into account that sometimes this is a difficult task because there are a lot of variables implied. Some of them have been mentioned in several studies such as date composition (depending on cultivar, growth region and conditions and ripening stage), bioactive compounds extraction (extraction type, conditions, yield, etc.), behavior of these compounds during gastro-intestinal digestion (release, bioavailability, bioaccessibility) and nutraceutical properties to combat several common diseases.

All these properties attributed to date fruits could be used to encourage their consumption not only directly, but also as an ingredient for the development and innovation of healthy date-based foods. In both cases, the recommendation of their consumption or applications should be based not only on their nutritional quality but also on the benefits they provide for health and well-being, and even some of the technological properties associated to their main components. In this case, another great potential is the possibility to use not only the whole fruit but also their high value-added compounds (dietary fiber, bioactive compounds and industrial or technological ingredients) obtained from the coproducts derived from their industrialization, contributing to their valorization.

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