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Review

Dates palm fruits: A review of their nutritional components, bioactivities and functional food applications

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Abstract: Date palm (*Phoenix dactylifera L.*) is a fruit bearing tree with a lot of prospects. Its fruits, and seeds otherwise known as pit and byproducts are made up of nutritional and medicinal potentials. In terms of commercial value, date fruit have not been fully utilized as a good functional ingredient to produce numerous health promoting diets. Meanwhile, date fruits and seeds are rich in nutrients such as amino acids, vitamins, minerals, dietary fiber, phenolics, etc. Dates possess a lot of bioactivity potentials e.g. antimicrobial, antioxidant, anticancer, antidiabetic, etc. These bioactivities are enhanced by the presence of phytochemicals such as carotenoids, phenolic acid, flavonoids, tocopherol, phytosterols, etc. In ancient times, date fruits were widely applied for orthodox and traditional therapeutic purposes. Similarly, dates have been used as functional ingredients in some newly developed foods and for other purposes. All of this were reviewed and presented in this article. This detailed information will improve the worth of date fruits, seeds and byproducts as cheap sources of natural diet that can function both as nutritive and bioactive ingredients in the food sector, pharmaceutical industries and for other purposes.

Keywords: dates, antioxidants, nutritional value, nutraceuticals and food applications

1. Introduction

Fruits have been pivotal part of human diet from ancient time [1]. It is also known that certain people pay special attention to some fruits in daily diets due to their religious beliefs [2]. For instance, Muslims around the globe break their Ramadan fast by eating date fruits to fulfil ethereal law [3]. Thus, the nutritional value of fruits in promoting good health of the populace cannot be under-estimated [4,5]. Over the years, enormous population growth have been reported and it has simultaneously resulted to increased demand for good health as well as wellness promoting fruits [6]. This has culminated in expansive scientific studies on the bioactivity, nutraceutical properties and health benefits of fruits. Some of the results obtained from those studies indicated a symbiotic positive link between healthy eating of vegetables and fruits and reduction in death rate due to heart-related, cancer and other deteriorating illness [7]. This was attributed to bioactive compounds, dietary fiber and antioxidants they possess [8].

Dates palm widely referred to as *Phoenix dactylifera L*. is one of the earliest (5500–3000 BC) farmed variety of palm trees that possess economic, nutritional, ornamental and environmental values [9]. It is associated with the family of *Areacaceae* (*Palmae*) and is produced as sweet berries with high sugar content that is above 50% [10]. Historically, Romans and Greeks used date tree as a sign of triumph, while for the Christian and Hebrew tradition, it was observed as a sign of peace [11]. Etymologically, the word "Phoenix" is coined from the Phoenicians who were part of the first to characterize this plant on their trips [12]. *Dactylifera* is coined from *dactylus* which means "date" from Greek word *dactylos*, and *fero* for "date bearing" [12].

Date fruit is regarded to as a pivotal crop that is extensively farmed in the Middle East and Africa [13], and these regions are responsible for the exportation of date products worldwide [14]. From records, five dominant countries (Iran, United Arab Emirates (UAE), Algeria, Saudi Arabia and Egypt) reported an increase in production of date fruit from 710,000 to 1, 352, 950 metric tonnes as at 2010 [15]. In 2016, it was reported that its global production had increased to over 8, 619, 600 metric tonnes [12]. Date palm is monocotyledonous and can be grown to a height of 1500m on a good soil [16]. A pictorial collection of some Deglet Noor variety of dried dates fruits are shown in Figure 1.

Figure 1. Collection of dried Deglet Noor variety of date fruits**.**

Date palms differ from other fruits because they have four botanical phases of development after cultivation. Those stages are *Kimri*, *Khalaal*, *Rutab* and *Tamr* [17]. In agrarian communities, dates can serve as rich sources of cheap food as well as energy for the growing population, thereby improving food security [18]. They contribute to health by providing carbohydrates (including soluble sugars), proteins, lipids as well as minerals and certain essential vitamins to the body [4]. They are known to be rich in polyphenols and functional dietary fiber that help to maintain the digestive tracts [19,20]. Antimutagenic, antioxidant, anticarcinogenic and anti-inflammatory bioactivities have been attributed to the contribution of polyphenols [18].

With the continuously increasing demands for natural, cheap and nutritive food, creating more awareness about the health benefits of fruits such as dates could help to increase their commercial and nutritive importance. As a result, this review focuses on nutritional and bioactivities potentials as well as some functional food applications of dates as highlighted in Figure 2.

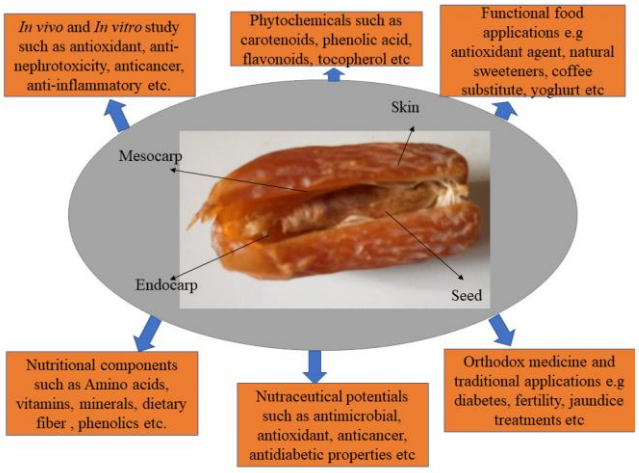

Figure 2. Health benefits and applications of a typical date fruit containing seed.

2. Health benefits components of dates

2.1. Nutritional components

Dates are abundant sources of carbohydrates, with sucrose, maltose, glucose and fructose which constitute >80% of its dry matter. Features such as compositions and sugar content differ with variety and fruit maturation [18]. Some of the countries associated with the production of date fruit and their varieties are highlighted in Table 1. Dates varieties of Red soft, Tempo 2 and Tempo 3 have an initial moisture content of 59.2%, 59.9% and 64.5% (wet basis), respectively. However, during drying season, a gradual decline in moisture contents of date fruits is usually observed [21]. The Deglet Noor variety has higher sucrose but lower simple sugar (fructose and glucose) concentrations than Allig dates fruits [22]. In a study carried out by Al-Farsi and Lee [23], ten date seed varieties were investigated and it was observed that total carbohydrate content was highest in Fard, Khunaizy and Gash-Gaafar. In another study on total carbohydrate of ten date varieties, it was observed that Bumi possessed the highest amount of (81.4%), followed by Suqaey (79.7%) and Khodari (79.4%), while Labanah possessed the least amount of 71.2% [14]. The monosaccharide profile of dates as studied by

Al-Farsi et al. [24] revealed that Khalas Al Kharj possessed an elevated glucose content (95.4%) out of the twelve date varieties that were evaluated. Generally, the amounts of fructose, glucose and sucrose in date fruits are different [23]. Dates have also been described to be good sources of essential amino acids [24]. These amino acids including histidine and arginine are pivotal in the proper physiological functioning of the human body [25,26]. In a study on amino acid sequencing of dates protein twenty-three different amino acids were detected, some of which are uncommon in other notable fruits [24]. According to Assirey [14], alanine (78–105 mg/100 g DW), glycine (83–102 mg/100g), proline (86–113 mg/100g), arginine (37–93 mg/100g), asparagine (127–225 mg/100g) and glutamate (158–265 mg/100g) were observed as the major essential amino acids while tryptophan contained the least (13–46 mg/100g) in ten dates studied. Another investigation revealed that amino acids profile of fresh dates were reported to contain glycine (65 μmoL/g FW) as the most plentiful amino acid, next to it was proline (16 μmoL/g FW), alanine (9.2 μmoL/g FW) and lysine (7.3 μmoL/g FW) while cysteine (0.001 μmoL/g FW) occurred as the least abundant [27]. The presence of non-proteinogenic amino acids in dates have been studied with ion exchange chromatography of the Ajwa variety [28]. This class of amino acids which are linked with antibodies to form T lymphocytes, aid in the removal of toxins in the liver and lower creatinine in human health [18]. Some of the identified non-proteinogenic amino acids are 1-aminocyclopropane-1-carboxylic acid, g-amino-n-butyric, (2S, 5R)-5-hydroxypipecolic acid, g-amino-n-butyric acid, L-pipecolic acid, 2-aminoethanol and (2S, 4R)-4-hydroxyproline. Trace amounts of (S)-b-aminoisobutyric acid, b-alanine, 5-hydroxylysine, L-allo-isoleucine and L-ornithine were also discovered [19]. Protein content in date fruits is low in proportion and it ranges from 2.5–6.5 g/100g [29]. Press cakes, byproduct of three different varieties of date fruits (Mabseeli, Um-sellah, and Shahal), had protein content, ranging in concentration from 3.62–5.23 (g/100 g) [30]. Minerals such as magnesium (64.2 mg/100g), zinc (0.5 mg/100g), iron (0.3–6.03 mg/100g) have been observed in dates [24]. Date fruits also consist of vitamins like thiamine, folic acid, ascorbic acid, riboflavin and retinol in different proportion. These vitamins play certain function in the human body [19]. The trace nutrient are important for biological functions in humans. For instance, zinc enhances the performance of the immune system, iron assists to tackle physical fatigue and sodium is important in the respiration process [31].

Date seeds are derived from date fruit processing. Usually these seeds are considered to be of low market value and are used as animal feed ingredient or turned into non-caffeinated coffee by the Arabs[32]. Date seed consist of about 11–18% of date fruit weight [32]. Deglet Noor and Allig variety of date seed consist of protein 5.56 and 5.17%, oil 10.19 and 12.67%, Ash 1.15 and 1.12% and total carbohydrate 83.1 and 81.0% on dry basis [33] whereas, crude oil from date seed of Khalas variety was reported to be about 10% [34]. The variation in nutritional composition of date varieties could be due to differences in harvesting time, origin, and the type of fertilizer used [32,35,36]. Major mineral nutrient in date seed are: potassium (255.43), magnesium (62.78), calcium (48.56) and phosphorus (41.33) (mg/100 g of oil) [37]. Date seeds consist of trace amount of selenium, which can serve as antioxidant in human health, detoxify the body to make the liver and other organs healthy, [38–40]. Deficiency of selenium have been associated with infertility in men and women [41]. In the study carried out by Al-Showiman et al. [42] on the selenium content in ten date varieties grown in Saudi Arabia, selenium levels were found to range from 1.48–2.96 mg/g in those cultivars.

Generally, date seed oil is a source of saturated (myristic, palmitic, and lauric acids), mono-unsaturated (oleic and palmitoleic acids), and polyunsaturated (linolenic and linoleic acids) fatty acids at about 50, 43, and 8%, respectively [43–45]. Some of the studies on date seed oil using gas–liquid

chromatography showed that the main unsaturated fatty acid was oleic acid (41.3–47.7%), while the major saturated fatty acid was lauric acid (17.8%) for the Deglet Noor cultivar and palmitic acid for the Allig cultivar (15.0%). Myristoleic, myristic, palmitoleic, Capric, linoleic stearic and linolenic acids were also found in varying proportion [33]. In another study, Al-Shahib and Marshall [46] reported that oleic and lauric acid showed the highest percentage of unsaturated and saturated fatty acids, respectively. Meanwhile, the degree of unsaturation of date seeds is lower than that of common olive oils [45]. Therefore, date seed oil is a good source of oleic acid and the content of this fatty acid is similar to the content found in rice bran oil [32]. Generally, oils with high oleic acid contents are of significant interest because of their high stability and nutritional benefits. Oleic acid is known as one of the most vital unsaturated fatty acids in human food because of its preventive effects on distinct heart vascular diseases, its high oxidative stability, its low saturation level, and its potential for lowering cholesterol in the blood [47]. In addition, dietary oils, rich in unsaturated fatty acids have been reported to prevents cardiovascular and inflammatory diseases [48].

Table 1. Location and varieties of some dates fruits.

Origin	Date varieties	References
Morocco	Medjool, Khalt, Jihel, Bousekri, Boufeggouss and Bousthammi	[12,49]
Tunisia	Kenta, Smiti, Bekrari, Mermella, Garn ghzal, Nefzaoui, Baht, Korkobbi, Bouhattam, Rotbi, Deglet Noor, Kentichi and Allig	[29,50]
Saudi Arabia	Ajwa, Reziz, Khudari	[4,51,52]
Egypt	Zaghlool	[53]
United Arab Emirate (UAE)	Buchibal, Naghal, Khunaizy, Khulas, Gush rabei, Hilali ahmr, Barhi, Lulu, Fard, Naghal Hilali,	[23,54]
Oman	Fard, Khalas and Khasab, Mabseeli, Um-sellah, and Shahal	[24,30]
Nigeria	Red soft type, Tempo 2 and Tempo 3 (Zabia)	[21]

2.2. Dietary fibre (DF) content

This is the edible portion of analogous or plants carbohydrate that resist absorption and breakdown in the human small intestine with partial or complete fermentation in the large intestine [55,56]. DF offers some vital health benefits such as reduction in cholesterol present in the body by reducing low-density lipoprotein, or "bad," cholesterol levels, anti-obesity, less risk of developing hemorrhoids, enhancement of gut-health and bowels through faecal bulk as well as production of short-chain fatty acids and antidiabetic property [18,57]. DF also possessed some functional properties such as gel formation, oil/water retention and emulsifying capacities that are applied for novel food development [18]. Different studies have reported that date palm possessed high DF, which indicated that date products are superior source of DF than cereal products [58,59]. Date seeds in particular, can serve as a rich source of fiber without any negative impact on sensory quality of end-products if the seeds are properly milled [40]. In an experiment carried by Mrabet et al. [60], it was revealed that Tunisian date varieties had 4.7–7 g/100 g of DF, water retention of >17 mL/g fiber and oil retention capacities of >4 mL/g fiber, respectively. Thus, dates could serve as a useful source of fiber enrichment in some food products. Shafiei et al. [61] reported that the antioxidant and antimicrobial activities of dates are related to its specific tannin and lignin component. Meanwhile, tannin and lignin are important parts of dietary fiber [62]. Dates also consist of non-cellulosic fiber (75% total fiber), made up of arabinoxylan,

xylan and pectin [22]. Nevertheless, the amount and composition of fiber differ with ripening stages of the dates, due to the high activity of fiber-hydrolyzing enzymes such as pectinase and cellulase [18]. Apart from fiber, β-glucan is another compound found in dates [18]. β-glucan is a "biological response modifier" and a component of its cell-wall with a lot of benefits such as gut-health enhancement as well as anti-inflammatory activities [63]. Application of β-glucan in food as additive include cheese spreads, frozen desserts, salad dressings and sour cream [18].

A byproduct of date seed called defatted date seed powder (DDSP) has been investigated [64]. DDSP was obtained after the removal of oil from date seed and it consist of total digestible fiber (78.60 g/100g) richer than fibrex (65.74 g/100g), a commercial fiber obtained from sugar beet after sugar extraction [64]. Thus, indicating that DDSP can serve as a rich source of fiber in bakery products. Date pulp obtained after cooking of sun-dried date fruit (Deglet noor variety) without seed was investigated after processing into powder [65]. The date pulp powder reportedly had 83.7 g/100 g of fiber (dry basis) and was recommended for use in confectioneries.

2.3. Phytochemicals contents of date fruits

Phytochemicals are products of plant chemicals that are therapeutic in action when consumed as medicinal drugs or as components of daily diets [66]. As observed in most fruits, bioactive compounds like carotenoids, polyphenols majorly phenolic acids and flavonoids, sterols and tannins are observed in varying quantities in dates [67,68]. The proportion and concentration of these components enormously vary with respect to some parameters such as stage of fruit picking, date variety, postharvest processing, storage, soil conditions and geographical origin of the dates [69,70] Some of these bioactive compounds in dates are explored and reported in this section.

2.3.1. Phenolic compounds

Phenolic compounds include non-flavonoids as well as flavonoids that enhanced their antioxidant capacities [18]. Examples of non-flavonoids are benzoic acid and cinnamic acid derivatives, while flavonoids are subdivided into flavones, flavonols, isoflavones and anthocyanidins [71]. Part of the identified phenolic compounds in dates are apigenin, luteolin, quercetin, malonyl derivatives, chrysoeriol, isorhamnetin, 3-methyl-isorhamnetin and kaempferol [72]. The presence of these phenolic compound affirmed the antioxidants potentials of dates [18]. However, the formulation, distribution and nature of phenolic compounds in dates rely on environmental conditions, growth stage, and variety [73]. Soluble phenolic compounds such as flavonols, hydroxybenzoates and hydroxycinnamates have also been described in dates [74]. Dactyliferic acid with its isomers, alongside flavonoids glycosides (apigenin, luteolin and quercetin) were observed in Deglet Noor and other Algerian varieties [72,75]. Dates also had about 3% DW of condensed tannins otherwise known as proanthocyanidins [75]. Soluble tannins present in unripe dates are responsible for their astringent taste [74].

2.3.2. Carotenoids

Carotenoids have been recorded as a key part of phytochemicals found in the lipid portions of date fruit [67]. They are vitamin A precursors, which performs a key function in vision and shield the cells from deteriorating impacts of reactive radicals by acting as antioxidants [76]. Classification of carotenoids is dependent on the availability or absence of oxygen in the molecule. Thus, they are

categorized into two sub-sections: Xanthophylls (presence of oxygen atom) and carotenes (absence of oxygen atom) [67]. According to Boudries et al. [77], dates is made up of β-carotene and lutein as vital carotenoids. In a study carried out by Habib and Ibrahim [78], diverse carotenoids in dates from Khalas type gotten from United Arab Emirate were analyzed. Carotenoid obtained were zeaxanthin (10.8 μg/kg), lycopene (19.5 μg/kg), β-cryptoxanthin (20.4 μg/kg), lutein (1599 μg/kg), β-carotene (3142 μg/kg). However, postharvest processes such as sun-drying could impact negatively on total carotenoid from about 4%–30% in comparison to the fresh dates [67]. Nevertheless, dates can still be regarded as a moderate source of carotenoids.

2.3.3 Phytosterols and phytoestrogens

Phytosterols belongs to the class of phytochemicals that are located in the lipid soluble fraction of date fruit [17]. They are generally found in plants and they possess a similar chemical structure with cholesterol [54]. The amount of phytosterols in vegetable oils is often used to assess the oil quality and to detect alterations [79,80]. In general, phytosterols are available in oils in their esterified forms [45].

Date seed or pit consist of large proportion of phytosterols and have been applied for years to cure hormone related health challenges [81]. Total sterol content found in Deglet Noor and Allig variety of date seed were 3500 and 3000 mg/kg, respectively [82]. The types of phytosterols in dates includes esterone, ergosterol, estrogen and brassicasterol [18]. In another study, phytoestrogens such as daidzein, formononetin, glycitein, genistein, pinoresinol, matairesinol, lariciresinol, coumesterol and secoisolariciresinol were identified in date fruit [83].

2.3.4. Phenolic acids

They are regarded as part of the vital aromatic secondary plant metabolites, that consist of hydroxyl function found on aromatic benzene ring joined to one or more carboxylic acid groups [67]. Phenolic acids such as caffeic acid, protocatechuic acid and coumaric acid have been observed in Khalas date variety from United Arab Emirates (UAE) [20]. Generally, type of solvent used for extraction of phenolics may affect their quantity in fruits [18]. An investigation on the impact of solvent types on phenolic acids of dates concentrate showed that the use of water extract purified with butanone as well as 50% acetone extracts purified using butanone as extraction solvents yielded increased phenolic acids in comparison with other solvents such as methanol and ethanol. In addition, phenolic acid such as caffeic, ferulic protocatechuic acids were found to be predominant [84].

2.3.5. Flavonoids

Flavonoids are major part of polyphenolic plant derived secondary metabolites [67]. They possessed antioxidant activities that can help to prevent chronic and cardiovascular diseases [85]. Investigations on three Moroccan dates varieties (Bousthammi, Majhoul and Boufgous) showed that they possessed flavonoid contents of about 1224–1844 mg Rutin equivalent/100 g DW [49]. Polymeric and monomeric forms of flavan-3-ols have been detected as a key member of compounds, which constituted about 99% of total polyphenols which were dispersed as epicatechin (46.8 g/kg) and catechin (3.38 g/kg) during the study to ascertain the amount and type of flavonoid compound in dates [20]. In another report, flavonoids such as catechin and rutin were observed in thirteen varieties of Saudi

Arabian dates [68]. The presence of flavonoids in dates further confirmed their ability to function as antioxidant.

2.3.6. Tocopherols and tocotrienols

Tocopherols and tocotrienols are located in the lipid portion of dates fruits and seeds [32]. They belong to the vitamin E group and are vital to some degree owing to their antioxidant potentials [86]. Due to these antioxidant potential, they can protect the biological membrane component [45]. Watson and Preedy [87] showed that the benefits of tocotrienols are more than ά-tocopherol. Furthermore, tocols also protect oil from free radical damage which contributes to their stability. They are more effective than the synthetic antioxidant butylated hydroxytoluene (BHT) [88]. Tocol (tocopherol and tocotrienol) vary from one vegetable oil to another [45]. Also, different forms of tocol (ά, β, γ and δ) are found in vegetable oil [89]. The predominance of one tocol or another depends on the origin of the oil [90].

ά-tocotrienols were found in Tunisian date seeds to be 34.01 mg/100g, γ-tocotrienol (4.63 mg/100g), γ-tocopherol (10.30 mg/100g) as reported by Nehdi et al. [37]. ά-tocopherol acetate which is another form of vitamin E have been reported in moderate amount in the oil of date fruit [43]. ά-tocopherol in date seed oil (243.00 ppm) obtained from Khalas variety have been reported to be higher than that of palm kernel oil (198.00 ppm) [34]. ά-tocopherol content of Deglet Noor and Allig date seed variety was reported to be about 24.97–38.85% [82].

3. Nutraceutical potentials of date fruit

Generally, dates are excellent source of chemical compounds like phenolic acids, tannins, flavonoids, phytosterols and carotenoids [18,75,91]. The presence of these compounds in varying proportions could promote their nutraceutical potentials. These nutraceutical potentials include antimicrobial activities, antioxidant capacities, anticancer etc and they are explored and summarized in this section.

3.1. Antimicrobial activities

Antimicrobial property of a solid or liquid substance entails its potential to go inside cytoplasmic membrane, disrupt permeability and then destroy the cytoplasmic membrane, resulting to vulnerability of cytoplasm or cytoplasm coagulation and decrease in shape followed by cell lysis and then termination of microorganisms [92–94]. Therefore, the application of natural antimicrobial agents is preferred in tackling resistant bacteria and viruses because they are less expensive and have no side effects [95]. Various experiments have been carried out to validate the antibacterial activities of different date varieties. For example, Aamir et al. [96] reported the effectiveness of acetone and methanolic Ajwa dates extracts to resist Gram-negative and Gram-positive bacteria. Jassim and Naji [97] investigated and discovered that extracts from date palm possessed antiviral activity. According to El Sohaimy et al. [53], extracts obtained from Egyptian dates using ethanol and aqueous solutions possessed antimicrobial property against some pathogenic bacterial strains. Also, extracts from Ajwa dates variety fruit resisted the activity of *Serratia marcescens, Staphylococcus aureus, Bacillus cereus* and *Escherichia coli* [98]. Date extracts improved the antifungal potency of amphotericin B drug [99].

Date seed extracts indicated antiviral properties against lytic *Pseudomonas* phage ATCC 14209-B1, lowered the phage function and totally disrupted bacterial lysis [97]. Therefore, dates could be used as a natural antimicrobial agent in food products.

3.2. Antioxidant activities

Antioxidants plays a pivotal role in food systems, human body cells and tissues by protecting against oxidative damage of toxic molecules called free radicals [93]. Those free radicals are closely related with some known diseases such as cancer, heart disease, Parkinson's and Alzheimer's disease [100]. In a food system, reactive oxygen species and free radicals are responsible for lipid oxidation in food products during processing and storage which form the toxic reaction products and undesirable off-flavour [101]. To tackle this problem, chemical formulated antioxidants e.g propyl gallate (PG), butylated hydroxyl toluene (BHT), butylated hydroxyl anisole (BHA), and tertiary butyl hydro quinone (TBHQ) are applied as antioxidants against lipid peroxidation [102]. However, chemical formulated antioxidant have been reported to induce cancer. [103]. Thus, natural antioxidants from food source are mostly preferred. Dates are good source of antioxidant like tannins, carotenoids, sterols and polyphenols [104]. Boudries et al. [77] observed the availability of carotenoids, majorly β-carotene and lutein in the fruit's oil fraction. These carotenoids are common precursors of vitamin A and active antioxidants. Antioxidant potentials varies with different dates cultivars, date type and origin. In addition, ripening stage of dates varies in antioxidants from one location to another [18]. Therefore, it is expedient to consider these variations when selecting date fruit as a nutraceutical. In this context, the antioxidant capacities of some date varieties are reported. For instance, Ajwa dates extracts showed 91, 70 and 88% inhibition against lipid peroxidation using aqueous, methanolic and ethyl acetate as the extraction mediums [105]. Arshad et al. [106] described the antioxidant activity of extracts from Ajwa date variety to be 74.19 mg/mL of gallic acid equivalent based on lipid peroxidation and DPPH assays. The mechanism of these assays is such that extracts from Ajwa date scavenge the free radicals that is responsible for lipid oxidation [105,107].

Dates variety from Oman (a southeast Asian country) such as Khasab, Khalas and Fard were reported to possess phenolic concentrations which ranged between 217–343 mg of ferulic acid equivalent/100 g [19]. Seeds from date varieties (Mabseeli, Um-sellah, and Shahal) in Oman showed high antioxidant activity (580–929 μmol of Trolox equivalents/g fresh weight) [30]. In China, dates was rated the second most potent in terms of antioxidant activity out of 28 different fruits that were extensively studied [108]. Thus, antioxidant properties of dates can used in foods as a replacement for the synthetic ones.

3.3. Anticancer properties

Dates have been reported in experimental trials to be effective in lowering the growth of cancerous cells [67]. For example, methanolic extracts from Ajwa dates resisted the proliferation of marginal cell in colon, breast, prostrate, lung and gastric tumor lines [67]. Also, eating of dates could enhanced the colon in human body as a result of the increment in the growth of beneficial gut bacteria with resultant reduction in tumor cell procreation [109]. Dates consist of β-glucan, of which its irradiated form, β-d-glucan was able to resist proliferation in three cancer cell lines such as MCF7,

Colo-205 and T47D [110]. However, more investigations is necessary to explore the anticancer properties of dates in details.

3.4. Antidiabetic properties

Current medications used for management of diabetics are effective but possess some negative side effects such as disruption of genetic and metabolic pathway [18]. Thus, extracts from natural plant that can elevate insulin generation and retard intestinal glucose intake are used presently in diabetes management [111]. Meanwhile, dates are rich sources of active compounds such as flavonoids, phenols, steroids and saponins that can function as antidiabetic ingredient [4]. These compounds possess free-radical scavenging abilities as shown in several diabetic rat experiments [105,112]. Ajwa date extracts, when consumed could assist to lower oxidative stress and stabilize the proper functioning of the kidney and liver [112]. This could be partly because phenolic compounds in dates retard ά-glucosidase, therefore controlling glucose intake in the kidneys and small intestines [4]. Thus, the antidiabetic property of dates can be utilized for medical applications.

3.5. Orthodox medicine and traditional therapeutic applications

Traditionally, dates are used as a prophylactic and therapeutic ingredients since ancient times in different nations like Morocco, Iraq, India, Algeria, Iran and Egypt [113]. In south-eastern Morocco, dates were used for the treatment of diabetes and hypertension according to historical facts [114]. In another instance, kernels from dates were linked to reduction of skin wrinkling and anti-aging in women [115]. According to Zaid and De Wet [116], dates have been suggested to help in hardening of infant gum. In addition, dates can also assist to reduce dry cough, mild fever, headaches and lethargy when cooked with cardamom and black pepper [116]. In traditional medicine, consumption of dates was recommended for people with jaundice ailment as well as pregnant women [3]. Its extensive application for traditional cure of liver and malaria infection in the Arab Peninsula have been denoted [3]. Demulcent, diuretic, expectorant, restorative and laxative properties have been linked to date [113]. It is widely known that there was less availability of scientific research to experimentally prove the medicinal effects of date palm in ancient time, however recent investigations are beginning to validate these claims to show their therapeutic mechanism.

3.6. Other nutraceutical values of dates

Dates are known to function as anti-hypertensive ingredient for centuries [18]. They can lower hypercholesterolemia, oxidation of lipoproteins and hypertension, thus reducing series of reaction that could triggers cardio-vascular diseases initiation and progression [31]. Al-Alawi et al. [67] reported the efficacy of date syrup to tackle angiogenesis and inflammation. According to Zhang et al. [117], rat studies suggested that the constituents of date extracts like steroids, fiber, minerals and polyphenols are likely to be pivotal for their anti-inflammatory activities.

4. Applications of bioactive components of date in *in vivo* and *in vitro* experiments

Several report on *in vivo* experiments have been done to ascertain the pharmacological activities of dates as highlighted in Table 2. For instance, Habib and Ibrahim [78] investigated the antioxidant capacity and oxidative disintegration of male Wistar rats when given basal diets which possessed varying date seed concentrations (140 or 70 g DS/kg diet) for 30 days. It was observed that food efficiency ratio, serum biochemical parameters, liver antioxidants and body weight gain were not negatively impacted by the incorporation of date seed. Meanwhile, date seed significantly lowered serum and liver malondialdehyde (MDA) and serum dehydrogenase. The presence of flavonoids and phenolics in dates could have been linked to reduction in MDA [118]. Habib and Ibrahim [78] showed that date seed extract had a nephron-protective effect against kidney damage triggered by oxidative stress from carbon tetrachloride (CCl_4) on rats (1g/kg/day). Al-Qarawi et al. [119] examined the curative properties of date pit aqueous extracts on CCl_4 induced hepatoxicity in Wistar rats. It was observed that rats given aqueous extracts from date pit possessed lesser bilirubin concentration, plasma enzyme and histological liver damage initiated by CCl_4. Meqbaali and Saif [125] investigated the antioxidant and anti-inflammatory effect of date seed powder (2, 4 or 8 g/kg) consumed by Wistar rats. The result indicated the powder greatly improved the antioxidant defense systems of the serum and organs in those rats fed with date seed powder. Furthermore, date seed powder reduced oxidative damage in the muscle, liver and brain of the rat without altering the functions of the organs. Mohamed and Al-Okbi [120] reported the antioxidant and anti-inflammatory activity of methanolic and water extracts of edible portion of date fruits in adjuvant arthritis in rats. The result indicated that mouth feeding of the methanolic and aqueous extracts from edible part of date fruits reduced the swelling in the foot remarkably. In addition, antioxidative state (plasma vitamin C, A, E and β-carotene) increased on feeding with significant decrease in plasma levels of MDA, indicating reduction in oxidative stress. Al-Shoaibi et al. [3] recommended the consumption of date palm fruits to lower the danger of liver, cancer, and cardiovascular diseases after administering date syrup to CCl_4 induced liver injuries in rabbits. Diab and Aboul-Ela [121] reported the efficiency of aqueous extract from dates to lower N-Nitroso-N-methylurea (NMU) produced mutagenic effect in mice. The hepatoprotective activity of aqueous date extract (ADE) against dichloroacetic acid (DCA)-triggered liver damage in rats showed that ADE attenuated oxidative stress by lowering the level of hepatic TBARS (thiobarbituric acid reactive substances) formation [126]. Khan et al. [127] studied the hepatoprotective and hypolipidemic ability of crushed Ajwa date extract on the toxicity triggered by atorvastatin in high-fat diet (HFD) induced hyperlipidemic rats. The study showed that Ajwa seed extracts reduced the serum cholesterol level in HFD tars and showed hepatoprotective effect in addition with atorvastatin. Futhermore, Ajwa extracts protected the tissues from deteriorating effect of hyperglycemia and it improved their antioxidant activity. Al-Yahya et al. [51] revealed that Ajwa date extracts were able to exhibit strong antioxidant, anti-inflammatory, hypolipidemic, cardioprotective and anti-apoptotic ability against myocardial damage which further affirmed dates extracts as a medicinal ingredient. Hot water extract from matured date fruit were able to invigorate the cellular immune system in mice [123]. Extracts from Deglet Noor date variety were able to protect against hepatotoxicity and oxidative destruction in rat liver sub-chronically exposed to dimethoate [122]. Also, Khan et al. [128] reported the anti-cancer properties of Ajwa dates extracts (ADE) in diethylnitrosamine (DEN) induced hepatocellular carcinoma (HCC) in Wistar rats. These studies further strengthened the nutraceutical properties of dates and their potential application for functional use.

Table 2. Applications of date parts for *in vivo* and *in vitro* experiments.

Dates part	*In vivo* and *in vitro* experiments conducted	References
Seed	Antioxidant capacities and lowered oxidative disintegration	[78]
Seed extract	Nephron-protective effect against kidney damage	[118]
Aqueous extracts from seed	Lowered CCl_4 induced hepatotoxicity	[78]
Seed powder	Showed antioxidant and anti-inflammatory	[119]
Methanolic and water extracts from edible part	exhibited antioxidant and anti-inflammatory effect	[120]
Syrup	Lowered CCl_4 induced liver injuries	[3]
Aqueous extracts	Reduced mutagenic effect	[121]
Aqueous extract	hepatoprotective activity	[51,122]
Aqueous extracts	antioxidant, anti-inflammatory, hypolipidemic, cardioprotective and anti-apoptotic ability	[51]
Hot water extract from matured fruit	invigorate the cellular immune system	[123]
Extracts	Anti-cancer effect	[124]

5. Functional food applications of date palm

Considering several health benefit components of dates, different studies on various applications of dates were elucidated in this part as highlighted in Table 3. For instance, Ambigaipalan and Shahidi [129] reported the incorporation of date seed flour hydrolysate (DSFH) (2.5%) or date seed flour (DSF) (2 and 5%) into muffin production. The result indicated that the incorporated DSFH and DSF brought about an increase in total dietary fiber as well as ash content. In addition, significant increase in radical scavenging activity against DPPH and hydroxyl radicals was recorded, while muffin with DSFH possessed higher angiotensin I converting enzyme (ACE) inhibition. The study demonstrated that DSFH and DSF could serve as functional food ingredient. Similarly, date fruit fiber concentrate was converted into a new product enriched in antioxidant soluble fiber through enzymatic hydrolysis [60]. In another study, Rahman et al. [36] reported a commercial date seed product in powdered form used as coffee substitute launched into the market. Jridi et al. [50] studied the effect of incorporating Tunisian date by-products such as syrup and powders as sweeteners into dairy desserts. The date by-products were able to enhance apparent viscosity and instant exudation with enhanced antioxidant activities. Gad et al. [130] evaluated the nutritional value of functional yoghurt resulting from addition of date palm syrup and skim milk. The yoghurt obtained had higher sweetness, increased antioxidant values, higher HCl-soluble minerals and folate concentration than the plain yoghurt. Date seed powder incorporated into functional pita bread at different levels (20, 10 and 5%) showed higher proportion of phenolics and antioxidant activities at higher levels (20 and 10%) than the regular whole wheat bread [131]. Date seeds in addition to mango peels showed improvement in dietary fiber of Arabic bread [132]. The result correlated well with other investigations on the effect of defatted date seed powder on bread quality as enhancement in dietary fiber was obtained [64,133]. In another study, dates pulp (Deglet noor variety), processed into powder and incorporated into bread showed an enhancement in dietary fiber [65]. Date pit extracts used for oxidative stability of ground beef showed an improvement in total polyphenol and antioxidant activity and decrease in TBARS of the product in

contrast with the control [134]. With increasing demand in functional and healthy food, it is expected that new food products can be developed using dates as a nutraceutical ingredient. Freeze-dried date powder obtained from fermented date fruits puree using *Lactobacillus plantarum* strains exhibited high concentration of γ-amino butyric acid, conjugated fatty acids, and insoluble dietary fibers. Thus, it was recommended as a dietary supplement that can be used in food industries [135]. According to Basuny and Al-Marzooq [34], oil from the seeds of Khalas dates were used in comparison with the conventional vegetable oil for the production of mayonnaise. The study indicated that mayonnaise from date seed exhibited higher oxidative stability and sensory acceptability. In addition, date paste, a byproduct from fresh date palm incorporated into pork liver pate lowered lipid oxidation and enhanced sensory acceptability [136]. Deglet Noor date by-products (discarded dates), packed in a bed bioreactor using a new thermostable invertase derived from *Aspergillus awamori* at a set immobilized condition was used to produce high-fructose syrup [137]. Immature date fruit with less commercial value were used for production date juice concentrate through enzymatic means with 0.1% pectinase enzyme for 120 min to obtain the maximum juice. The obtained juice consisted of reducing sugars (16.1%) and could be applied for beverage production [138]. Date hydrolysates were enzymatically processed from grounded date seeds using Alcalase, Flavourzyme and Thermolysin. The hydrolysates obtained were found to be useful for enhancement of water-holding capacity and cooking yield in a fish model system. In addition, incorporation of hydrolysates (200 ppm) in fish model systems resulted in the highest inhibition (30%) of oxidation in comparison to synthetic antioxidant butylated hydroxytoluene (BHT; 9%) [139]. Date seed oil exhibited a valuable chemical composition and physicochemical characteristics for its use as edible oil. It is rich in oleic acid which provides nutritional benefits. Its content of saturated fatty acids and the presence of many other antioxidants (phenolic compounds, tocols, carotenoids, etc.) make it highly stable against oxidative rancidity [37]. Thus, date seed oil can serve as a seasoning, frying or cooking, oil and also as an alternative to palm olein [140].

Table 3. Functional application of dates in food products.

Date type	Products	Result	References
DSFH (2.5%) or DSF (2 and 5%)/Date fruit fiber	Muffins	Increase in total dietary fiber and ash content, increase in radical scavenging activity against DPPH and hydroxyl radicals, muffin with date seed flour hydrolysate possessed higher angiotensin I converting enzyme (ACE) inhibition	[60,129]
Date seed	Date pit powder	Function as coffee substitute	[36]
Date syrup and powders	Dairy desserts	Function as a natural thickening agent, improved apparent viscosity and instant exudation with improved antioxidant activities	[50]
Date syrup (10%)	Yogurt	Increase in sweetness and antioxidant values, higher HCl-soluble minerals and folate concentration	[130]
Date seed powder	Pit bread	High amount of phenolics and antioxidant activities	[131]

Continued on next page

Date type	Products	Result	References
Date seed powder	Bread	Increase in dietary fiber	[132]
Defatted date seed powder	Bread	Increase in dietary fiber	[64,133]
Date pulp powder	Bread	Increase in dietary fiber	[65]
Date pit extracts	Oxidative stability of ground beef	Increase in total polyphenol and antioxidant activity and lowered TBARS value	[134]
Fermented date fruit puree	Functional dietary supplement	Concentration of γ-amino butyric acid, conjugated fatty acids, and insoluble dietary fibers	[135]
Date seed	Mayonnaise	Higher oxidative stability and sensory acceptability	[34]
Date paste	Pork liver pate	Lowered lipid oxidation and enhanced sensory acceptability	[136]
Discarded date fruit	High fructose syrup	-	[137]
Immature date fruit	Date juice concentrate	-	[138]
Grounded date seed	Date hydrolysate	Improved water holding capacity and antioxidant activities	[139]
Date seed oil	-	Higher oxidative stability than palm olein and can serve as edible oil	[140]

6. Conclusion

Date palm fruits, seeds and byproducts can be regarded as a promising medicinal fruit owing to its therapeutic, nutritive and bioactivity potentials. It can function as a cheap source of natural diet majorly in the agrarian communities where diseases outbreak and malnutrition are common. Industrially, it can serve as an additive for development of health promoting products for the emerging food and pharmaceutical market. Overall, the consumption and utilization of date palm should be further endorsed.

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Conflict of interest

The authors declare that they have no conflict of interest.

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