



An Overview of the Date Palm (*Phoenix dactylifera*): A Natural Powerhouse for Human Nutrition and Health

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Abstract

Date palm (*Phoenix dactylifera* L.), an ancient crop of the Arecaceae family, is an angiosperm and monocotyledon encompassing over 200 genera and 2,500 species. Valued for its nutritional and health benefits, date palm fruits have traditionally provided instant energy, aided digestion as a source of dietary fiber, and helped manage gastrointestinal disorders. Products such as date syrup or honey have been used for respiratory illnesses, while the fruits are known to reduce inflammation in arthritis. Various date varieties are rich in phytochemicals, which contribute to antimicrobial, cardioprotective, anti-inflammatory, neuroprotective, antioxidant, and anti-diabetic effects. Despite extensive studies on its phytochemical composition and long-standing traditional use, the application of these compounds in nutrition and health remains limited. Further research is needed to fully explore the potential of date palm as a nutritional and therapeutic resource.

Keywords: *Phoenix dactylifera* L.; Arecaceae; Phytochemical compounds; Nutrition; Health benefits.

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1. Introduction

The date palm is one of the oldest and most significant trees, playing a crucial role in the economic, social, cultural, religious, and environmental aspects of people living in arid and semi-arid regions of the world for over 7,000 years.^[1] Archaeobotanical evidence indicates that the oldest date seeds found on Delma Island date back to 5110 BC.^[2] The date palm tree is a member of the Arecaceae family, a group with over 200 genera and 2,500 species of mainly angiosperms and monocots. The genus “Phoenix” (family Arecaceae, subfamily Coryphoideae, tribe Phoeniceae) comprises about 14 species, including *Phoenix dactylifera* L., which are native to tropical and subtropical regions of southern Asia and Africa.^[3] The species name “*dactylifera*” is derived from the term “finger-bearing”, referring to how the plant produces its fruit clusters. In ancient times, the date palm tree provided food, shelter materials, ornaments, fiber and more. The different parts of the

date palm tree can be put to many uses. Wood can be used as fuel while leaves and fibers can be used to make mats, ropes, bags, camel saddles, baskets, trays and twines. Dried bundles of date palm leaves can be used to make roofs, shades, and separating walls. The terminal buds of the tree can be cooked or used in salads. Date palm seeds can be used as livestock feed and strung as beads for decoration.^[4] Dates fruit is widely recognized as a source of nutrient-rich food.

The phytochemical composition of the date palm fruit indicates that it contains about 70% of carbohydrates, mainly in the form of fructose and glucose, occurring in near-equivalent proportions. The proteins within date fruit contain an abundance of amino acids with acidic side chains. However, they show notable deficiencies in methionine and cysteine, both of which are characterized by sulfur-containing side chains. The mineral profile of date fruits encompasses a range of essential elements, including Ca, Mg, Fe, Se, P, Cu, K, S, Co, Zn, Mn, F and B.^[3-6] In recent years, growing recognition of the health benefits of date fruits has driven extensive pharmacological research, including both *in vitro* and *in vivo* studies, leading to the identification and quantification of diverse classes of phytochemicals.^[4] These phytochemicals have increasingly attracted the attention of various researchers, including clinical practitioners, because of their cholesterol-

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lowering properties, antioxidant activity, and potential for conferring health advantages, including but not limited to chemoprevention of cancer, cardiovascular diseases and diabetes.^[4,5,7] The Sukkari date, a popular variety from Saudi Arabia, exhibits a rich chemical composition that contributes to its nutritional and functional properties. This variety is characterized by high sugar content, essential minerals, and bioactive compounds, making it a valuable food source.^[8]

2. Presence of phytochemicals in different growth stages of date palm

Extensive phytochemical investigations of *Phoenix dactylifera* have demonstrated that nearly all plant parts—including the roots, leaves, pollen, fruits, sap, and seeds—contain substantial quantities of bioactive constituents. These studies confirm the date palm as a rich reservoir of diverse compounds such as phenolics, alkaloids, saponins, carotenoids, terpenes, phytoestrogens, phytosterols, and sterols. For example, the bark is particularly abundant in alkaloids, phenolics, flavonoids, and tannins.^[9] The leaves contain high levels of β -carotene, phenolics, tannins, and flavonoids, including quercetin-3-O-rhamnoside and apigenin, alongside saponins, alkaloids, and steroids.^[10–13] Date palm pollen also exhibits a rich phytochemical profile, featuring phytoesters, saponins, terpenes, triterpenoids, phenolics, flavonoids, and alkaloids.^[14–16] Seeds contain phenolic acids, flavonoids, pyrogallol, and a range of carotenoids such as β -carotene, β -cryptoxanthin, lutein, lycopene, zeaxanthin, and α -carotene.^[17–19] The phytochemical composition of date fruits varies widely according to cultivar, harvesting time, ripening stage, and environmental conditions.^[20] These compounds influence colour, flavour, and astringency, contributing significantly to the sensory profile of the fruit.^[21] During maturation, dates undergo notable biochemical changes. At the Khimri stage, fruits are hard, green, and highly astringent due to elevated tannin levels. As the fruit enters the Khalal stage, it expands, changes colour, and retains high procyanidin and condensed tannin content. Further ripening into the Rutab and Tamar stages results in softening and increased sweetness, with tannins undergoing polymerisation and polyphenols oxidizing to produce the darker characteristic colour.^[22]

Date palm fruit ripening involves a coordinated biochemical transformation process where the fruits' sugar concentration increases, moisture content decreases and extractable phenolic & tannin content decrease through oxidation and polymerization during the ripening of the fruits. As illustrated in Fig. 1, carotenoid levels peak at the khalal stage which indicates that fruit ripening is a metabolite transformation driven process rather than a simple linear accumulation of metabolites. Maturation also affects carotenoid and phenolic profiles. Among the Fard, Khasab, and Khalas cultivars, Khalas exhibits the highest carotenoid concentrations, a finding consistent with its yellow pigmentation; however, sun drying can reduce carotenoid

levels by 4–30%.^[23] Tamar-stage fruits additionally contain various phytosterols such as β -sitosterol, campesterol, isofucosterol, and stigmasterol (Kikuchi and Miki, 1978). Generally, phenolic and flavonoid levels decline from the Khalal to Tamar stages.^[24–26] Interestingly, storage conditions can reverse this trend—Khalas and Shishi dates stored at 4 °C for 6–12 months show significant increases in total phenolics.^[27] Dates also contain a broad array of amino acids, including essential ones such as glutamine and aspartic acid.^[28] Fat content is typically low but varies across studies, ranging from 1.05% to 3.15%, depending on cultivar, developmental stage, and environmental factors.^[29–32] Soil characteristics, fertilizer application, and irrigation practices further influence mineral accumulation and ash content.^[33]

Carbohydrates represent the major constituent of dates, comprising 69.2–84.2% of their composition. Glucose and fructose dominate the sugar profile, with Saudi cultivars showing glucose levels of 10.4–39.5 g/100 g and fructose levels of 8.2–36.1 g/100 g.^[34] While sucrose levels are usually low, some varieties such as Nabtit Ali and Sokary show higher sucrose content.^[35] Total sugar content ranges from 61.7% to 78.6%.^[36] Despite their sweetness, several cultivars—including Shaqra, Sukkary, and Sag'ai—display low glycemic indices (42.8–44.6), making them suitable for populations requiring glycemic control.^[37] Ripening stage further affects glycemic response, with Tamar fruits generally showing lower GI values and Rutab fruits displaying higher glycemic loads.^[38] Dietary fibre contributes significantly to the functional properties of dates. Mature dried dates contain 4.4–6.5% fibre.^[32,39] Total dietary fibre ranges between 5.67% and 10.33%, of which insoluble fibre forms the majority (77.8–91.6%), while soluble fibre accounts for 8.4–22.2%.^[40] Fibre levels vary among cultivars, ripening stages, and postharvest handling conditions.^[31,41] Pectin content peaks during the Khalal stage (7.0–14.3%) and declines at the Tamar stage (1.3–1.9%) due to enzymatic degradation.^[42]

Dates are also rich sources of essential minerals, including iron, potassium, calcium, and magnesium, as well as moderate amounts of chloride, phosphorus, copper, sulfur, and silicon.^[43] These nutrients, combined with antioxidant compounds such as GSH (reduced glutathione), ASC (ascorbic acid), tocopherols, phenolics, caffeic acid, and ferulic acid, contribute to the health-promoting potential of dates. Antioxidant activity varies with cultivar, ripening stage, and environmental conditions.^[20,35,44] Cultivars such as Khalas and Khezaizi demonstrate particularly strong DPPH radical-scavenging activity.^[44] High phenolic content supports the use of dates as natural antioxidants in food and pharmaceutical applications, with extraction methods also influencing phenolic yield.^[31,45–48] Overall, the nutritional and phytochemical composition of dates is shaped by cultivar genetics, developmental stage, environmental factors, and postharvest conditions. Despite this variability, dates consistently emerge as nutrient-dense fruits with significant functional and health-promoting potential.^[49]

Phytochemical Dynamics During Date Palm Fruit Ripening

Stage-dependent shifts in nutritional and bioactive composition

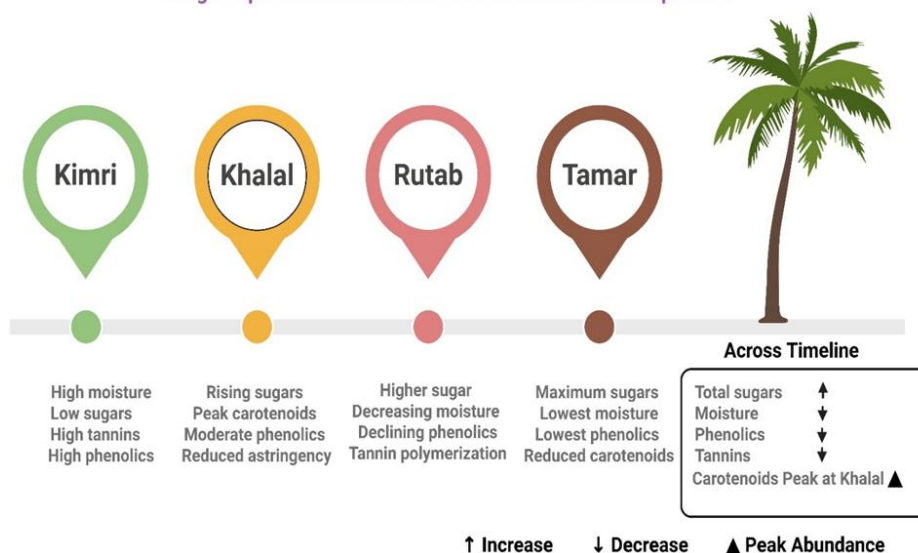


Fig. 1: The development of phytochemicals in the date palm fruit (*Phoenix dactylifera*) alters the fruit's transition from the Kimri to Tamar stage. In addition to an increase in sugars and a decrease in water content, a reduction of phenols and tannins is found as they undergo chemical polymerization and precipitation. Also, carotenoids exhibited different trends depending on which stage the fruit was at; they reached their highest levels of concentration at the Khalal stage and then decreased as the fruit continued to ripen, indicating that there is a relationship between biochemical changes in the fruit rather than just changes in morphology (Image created using Biorender.com).

3. Date palm (*Phoenix dactylifera* L.) for nutrition and health

3.1 Traditional and ethnomedicinal uses

Humans depend on plants for their livelihood, both for nutrition and health. In the Middle East, the recorded use of plants for human health dates back to the earliest civilizations, with more than 300 plant species documented for their medicinal value. Among these, the date palm is widely used.^[50] Traditionally, date fruits are consumed alone or in combination with other herbs.^[51]

Date fruits have been used to treat intestinal problems, colds and sore throats, cystitis, fever, oedema, and abdominal discomfort, while pastes made from dates are applied to the forehead and eyes to relieve headaches.^[50] The pollen of the date palm is traditionally used to address male and female infertility and sexual dysfunction. Experimentally, date palm pollen (DPP) pretreatment effectively protected male mice against 50 Hz electromagnetic-field (EMF)-induced reproductive damage by improving sperm count, motility, viability, morphology, and testosterone levels, demonstrating its potential to mitigate EMF-related adverse effects.^[14] Dates are also a major food and income source for local populations in the Middle East and North Africa and play important economic, social, and environmental roles in these regions. The exudate of dates is used to treat diarrhoea, while the roots of the plants are used to relieve toothache.^[4] The bark and sap of date palm trees are employed in traditional remedies for diarrhoea, genitourinary infections, and bronchitis.^[52] Date fruit juice fermented with red natron has been used as a

remedy for swollen and aching legs, applied as a bandage.^[53] Dried date fruits boiled in milk are administered to children as a remedy for measles.^[54] Decoctions prepared from date fruits, filtered to remove fibrous material and mixed with table salt, have been used to treat dehydration following diarrhoea and vomiting.^[4] The Qur'an and hadith mention olive oil, dates, black seeds, honey, and vinegar as medicinal treatments. In Middle Eastern countries, date palm pollen is also mixed with water to treat fertility problems. In Egypt, crushed date seeds are consumed daily to relieve gout pain, hepatic and renal problems.^[52] In some Middle Eastern practices, warmed date kernel paste mixed with margarine is used as an analgesic and local antipyretic for abscesses.^[41] Burnt and powdered date seeds added to kohl are traditionally applied to improve ophthalmia and stimulate eyelash growth.^[52,55] Traditional medicinal practices have utilized multiple anatomical parts of date palm to manage a wide range of health conditions. These ethnomedicinal applications, spanning digestive, reproductive, inflammatory, and systemic disorders, are summarized in Fig. 2.

3.2 Nutritional composition and functional potential

Dates (*Phoenix dactylifera* L.) are nutritionally rich, with 100 g of flesh providing about 314 kcal, high levels of fructose and glucose, essential minerals such as selenium, copper, potassium, and magnesium (each contributing over 15% of the Recommended Dietary Allowance, RDA), along with 8.0 g/100 g of dietary fibre—mainly insoluble fibre—and notable antioxidants including carotenoids and phenolics. Date seeds

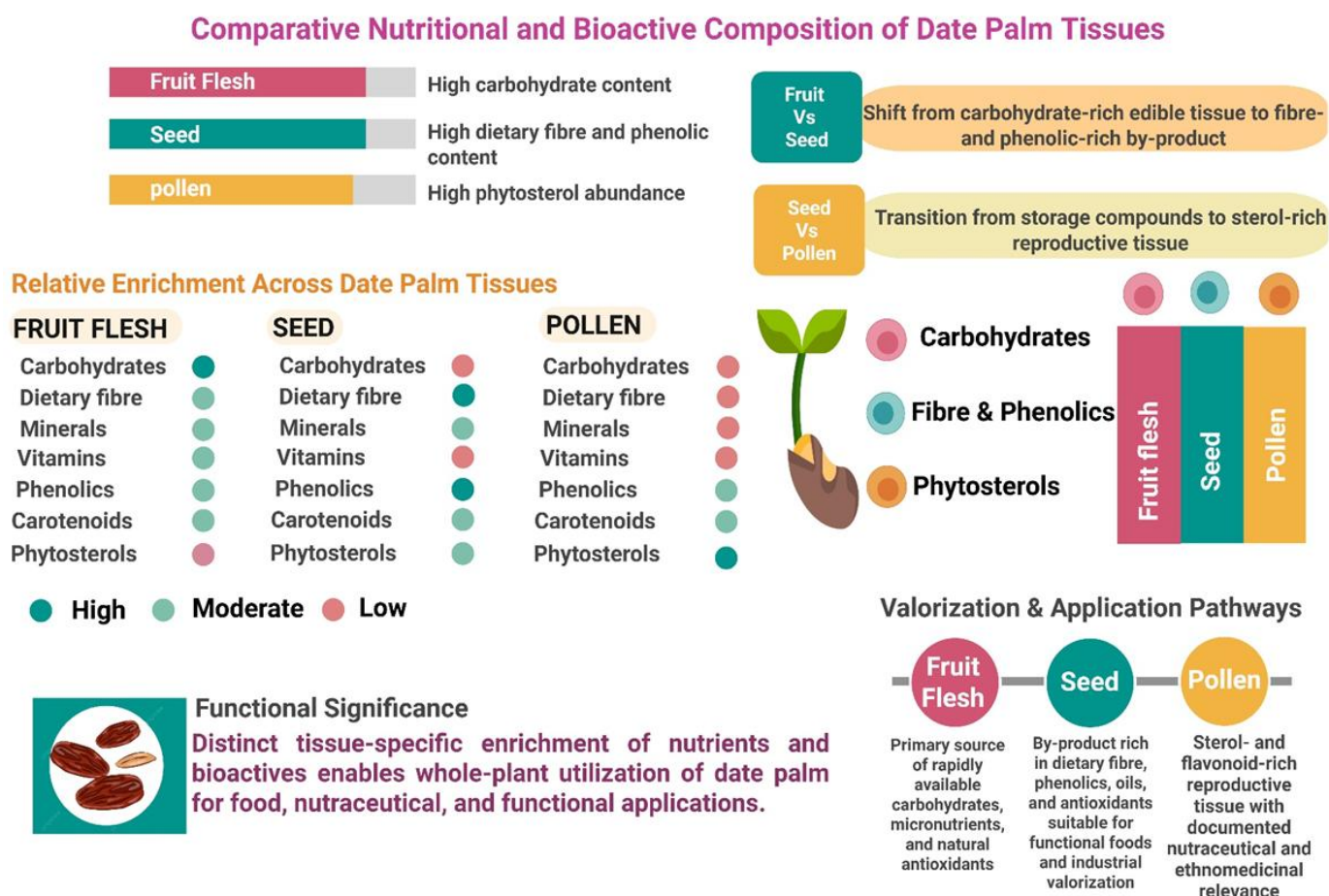


Fig. 2: Traditional and ethnomedicinal uses of date palm (*Phoenix dactylifera* L.) across major health domains. Different plant parts, including fruit, seed, pollen, sap, and bark, have been traditionally employed for digestive, inflammatory, reproductive, infectious, ophthalmic, and musculoskeletal conditions, highlighting the whole-plant therapeutic relevance of date palm (Image created using Biorender.com).

contain 5.1 g/100 g protein, 9.0 g/100 g fat, 73.1 g/100 g dietary fibre, 3942 mg/100 g phenolics, and 80,400 µmol/100 g antioxidant activity, underscoring their strong potential as functional food ingredients.^[41,56,57] Dates are very rich in vitamins, especially β-carotene (vitamin A), thiamine (B1), riboflavin (B2), niacin, ascorbic acid (C), and folic acid (folacin).^[58-60] They contain at least 15 essential minerals, including phosphorus, potassium, sodium, zinc, manganese, magnesium, copper, iron, fluorine and selenium, and are known for their richness in non-starch polysaccharides and lignin.^[32,55] Date fruits are particularly rich in flavonoids and polyphenols, contributing to their health-promoting effects, and their favorable organoleptic properties make them popular among consumers seeking nutritious options.^[61]

The flavonoid content in Sukkari dates exhibits a wide range, with concentrations varying significantly across studies. Higher concentrations were reported at 56.79 mg QE g⁻¹^[62] and at 61.03 mg QE g⁻¹,^[30] highlighting the potential for significant bioactive compound extraction from Sukkari dates. This variability may be due to differences in extraction methods, environmental conditions, and cultivar-specific characteristics. The IC50 values for Safawy, Ajwah, and

Sukkari were 104, 125, and 177 µg/mL, respectively, all demonstrating good scavenging activity compared to ascorbic acid (IC50 12.09 µg/mL).^[62] The antioxidant properties of date palms can contribute to health benefits by mitigating oxidative stress, which is linked to various diseases.^[63] Natural antioxidants from plant sources, like date palms, are increasingly preferred over synthetic alternatives due to their safety and efficacy.^[64] In a study measuring 17 date cultivars, antioxidant activity ranged from 2.46 to 9.80 µmol Trolox g⁻¹ FW using the DPPH method and from 5.90 to 17.78 µmol Trolox g⁻¹ FW with the FRAP method; cultivars such as Nabtat Ali exhibited the highest antioxidant values, while Osilah showed the lowest.^[65] Higher phenolic concentrations generally lead to increased antioxidant capacity, and genetic factors significantly influence antioxidant profiles, resulting in diverse activities among cultivars.^[66] Environmental factors and ripening stages can also affect antioxidant values, so observed differences are not solely attributable to genetics.^[20] Ferulic acid, a phenolic compound with significant antioxidant properties, is present in Sukkari dates in concentrations ranging from 2.01 to 2.28 mg/100 g dry weight (DW).^[67] Its presence contributes to the nutritional and medicinal value of

dates, enhancing their role as a staple food in many cultures.^[48] Protocatechuic acid (PCA) has also been detected in Sukkari dates at 0.893 mg/100 g DW,^[67] further underscoring the importance of these fruits as dietary sources of phenolic compounds.^[68] The catechin content in Sukkari dates ranges from 0.386 to 7.50 mg/100 g DW, highlighting their potential as a source of catechins with well-known health benefits.^[47,67] Phenolic acids are among the primary polyphenolic compounds identified in both the fruit and seed of the date palm. Liquid Chromatography–Mass Spectrometry (LC MS) analysis detected several phenolic acids such as caffeic acid (seed), ferulic acid (pulp), p-coumaric acid (pulp and seed), gallic acid (seed), and protocatechuic acids (seed) in date palm seed and pulp. Lignans, which are diphenolic compounds commonly found in plant-based foods, have also been documented in dates. A concentration of 323.6 µg/100 g of lignans was reported in fresh date fruit.^[69] Schisandrin and schisandrol B were also reported in various cultivars of date seeds.^[70]

Dates are therefore a significant source of bioactive compounds, particularly phenolics, in both pulp and pit. The high phenolic content of date pits, which are typically treated as waste, suggests potential for their use as functional additives in baked goods (e.g., muffins and bread) and as functional ingredients in coffee and oil industries.^[71] A total of 21 flavonoids were identified in Medjool date fruits and pits via LC-ESI-QTOF-MS/MS analysis, making flavonoids one of the largest identifiable polyphenolic groups.^[72] In their study using 8 cultivars of date pits across 3 ripening stages, flavonoid content in pits increased with ripening, rising from 0.28–1.15 mg QE/g in immature pits to 2.04–5.03 mg QE/g in mature pits. Thus, waste generated after the production of mature dates represents a valuable source for flavonoid extraction. Tannin content in date pits followed an opposite trend, aligning with the divergent physiological roles of pulp and seed: as the fruit ripens, the pulp develops traits to attract dispersal agents, whereas the seed continues to accumulate tannins to defend against insects and pathogens.^[72,73] Despite a relatively low protein content (1.7–12.5 g/100 g), dates contain essential amino acids such as arginine and histidine, important for physiological and metabolic functions.^[74]

Date seeds have been found to contain a significantly higher proportion of insoluble fibre. Insoluble fiber accounts for approximately 75% of the total fiber content in date seeds.^[75] Variations in insoluble fiber content across studies highlight the need for standardized analytical methods, especially during maturation from Kimri to Tamar, when changes are most evident. As dates mature, insoluble fiber content decreases, which may influence their digestive health benefits.^[76] The physical state of pit flour, particularly particle size, significantly impacts the quantification of mineral content; different fragment sizes yielded varying results, indicating that processing methods can influence the nutritional profile of date pits.^[77] Date pits can be used as raw materials for producing date seed oil, extracting high-value

compounds, and even in water desalination technologies.^[78] In parts of the Middle East, roasted and ground date pits are used as a caffeine-free coffee-like beverage.^[79] Date seed powder holds great potential as a low-cost natural supplement in processed foods, especially baked products. The partial substitution of wheat flour with date seed powder in bread resulted in increased dietary fiber and phenolic content, along with inhibited microbial growth, thereby extending storage stability.^[80] Microwave-assisted extraction has emerged as a rapid, eco-friendly technique capable of efficiently recovering polyphenolic compounds from date pits within 5 minutes.^[81]

One of the research studies incorporated date pit anthocyanin-rich extracts into carboxymethyl cellulose-based intelligent indicator films. The developed films exhibited improved physical and mechanical properties, along with higher antioxidants and antimicrobial activity against foodborne pathogens.^[82] A study found that six Iraqi date cultivars had seeds containing 7.77–9.25% oil, rich in oleic acid (40.5–46.3%) and antioxidants (42.95–206.89 µg/g phenolics; 178.1–424.3 mg/L tocopherols).^[83] Cultivar-specific variations in fatty acid profiles and antioxidant activities confirm date pit oil as a nutritionally valuable byproduct. The oil can be used in cooking, frying, seasoning, and as a substitute for palm olein in many food products.^[84] Additionally, date pit oil has been employed in margarine production due to its high thermal stability and longer shelf life, as an alternative to vegetable oils like corn and sunflower oil in mayonnaise.^[85] Its ability to reduce cellular and oxidative rancidity, to protect human skin from UV irradiation makes it valuable for skincare and cosmetic products.^[86] An inexpensive adsorbent using date pits was developed to reduce lead and cadmium levels in milk.^[87] Comparing bentonite, date pits, and chitosan nanoparticles, they found that date pits achieved the best average adsorption capacity (84% and 88%, 97% and 93%, 82% and 98%, respectively) without affecting the nutritional content of milk. These findings suggest that date pits may serve as a natural adsorbent for heavy metal mitigation in food systems. A novel encapsulation technique utilizing date pit powder has also been investigated as a protective delivery system for probiotics. The encapsulated probiotics demonstrated improved survival and controlled release under simulated gastrointestinal conditions compared to those without date pit powder, indicating that date pit powder may be a promising, low-cost biomaterial for enhancing probiotic delivery in functional foods.^[88]

4. Health benefits of phytochemicals in date palm

Numerous phytochemical studies have revealed the presence of various beneficial compounds in date palm, including anthocyanins, phenolics, sterols, carotenoids, procyanidins, and flavonoids. These compounds are known for their beneficial properties.^[13,89–91] Accordingly, several studies have explored the biological activities of different date palm parts, particularly the seeds, to validate their functional and antimicrobial potential. The date seed extract showed strong

Table 1: Combined phytochemical composition of *phoenix dactylifera* and their associated health benefits.

Phytochemical / Group	Source	Health Benefits	References
Lutein, neoxanthin, β -carotene, violaxanthin, antheraxanthin	Fruit	Antioxidant; supports eye health	[23,98]
Phytosterols & phytoestrogens	Fruit	Anticancer; anti-inflammatory; hormonal modulation	[99-101]
Benzoic/cinnamic acid derivatives	Fruit	Antioxidant; anti-inflammatory	[23]
p-coumaric acid, ferulic acid, sinapic acid <i>etc.</i>	Algerian fruit varieties	Antioxidant; antimicrobial	[21]
Phenolic acids (protocatechuic, caffeic, ferulic, <i>etc.</i>)	Fruit extract	Antioxidant; hepatoprotective	[102]
Gallic, p-coumaric, ferulic derivatives	Saudi date fruit	Antioxidant; anti-inflammatory	[67]
Caffeic acid derivatives	Amari date	Anticarcinogenic	[103,104]
Salicylic acid	Hallawi fruit	Anti-inflammatory	[104]
Protocatechuic, gallic, syringic acids	Tunisian fruit	Antioxidant	[105]
Flavonoid glycosides (apigenin, luteolin, quercetin, <i>etc.</i>)	Deglet Noor fruit	Antioxidant; anti-inflammatory	[106]
Diosmetin & glycosides	Fruit	Antihypertensive	[107,108]
Apigenin, luteolin, quercetin, isoquercetrin, rutin	Saudi varieties	Antioxidant; antimicrobial; anticancer	[109,110]
Kaempferol	Amari & Hallawi fruits	Neuroprotective; anti-inflammatory	[104,111]
KPF			
Pelargonin	Fruit	Antioxidant; anti-inflammatory	[102]
Catechin	Date pits	Antioxidant; lipid peroxidation inhibition	[109,112]
Alkaloids, phenolics, flavonoids, tannins	Bark	Antimicrobial; antioxidant	[9]
β -carotene, phenolics, tannins	Leaves	Antioxidant; anti-inflammatory	[11,10]
Phenolics, flavonoids, phytoestersols, saponins	Pollen	Reproductive enhancement; antioxidant	[14,15]
Phenolics, bioflavonoids	Sap	Antioxidant; antimicrobial	[97]
Phenolic acids, flavonoids, pyrogallol	Seeds	Antioxidant; potential anticancer	[17-19]
Chlorogenic acid CGA	Fruit	Neuroprotection; antioxidant; anti-tumor	[113]
Formononetin	Fruit	Cytotoxic against cancer lines	[101]
Genistein	Fruit	Anti-inflammatory	[114]
Isoquercetin	Fruit	Antiviral incl. SARS-CoV-2; antioxidant	[115]
Lariciresinol	Fruit	Antibacterial	[116]
Luteolin	Fruit	Antioxidant; neuroprotective	[117]
Quercetin	Fruit	Cardioprotective; anti-inflammatory	[118]
Rutin	Fruit	Neuroprotective; antimicrobial; anticancer	[119]
Secoisolariciresinol	Fruit	Anti-inflammatory	[120]
Sinapic acid	Fruit	Antioxidant; anti-inflammatory; antidiabetic	[121]
Syringic acid	Fruit	Neuroprotective; antioxidant	[122]

antibacterial activity against several microbes. The date seeds were collected, rinsed, roasted, burned, and powdered. The powder was kept in saline for 24h at room temperature and tested for antibacterial activity against the four pathogenic bacteria. Four concentrations of extract were used: 200, 100, 50, 25 mg/ml. Seed extracts at 200 mg/mL and 100 mg/mL were more effective in inhibiting the growth of *Escherichia coli*, *Proteus vulgaris*, and *Pseudomonas aeruginosa* than trimethoprim, gentamycin, and rifampin. No antibacterial activity was observed against *Klebsiella pneumoniae*.^[92] Essential oils extracted from the spathes of female date plants showed antibacterial activity against Gram-positive *Listeria monocytogenes* and *Staphylococcus aureus*, as well as Gram-negative *Escherichia coli* and *Salmonella enterica*.^[93]

Date seeds were isolated, soaked in water, washed and dried at 50 °C for 24h. The Date Seed Extract (DSE) were dried into a fine powder, centrifuged and filtered. The aqueous extract was tested for its antioxidant activity using ORAC, DPPH, FRAP, ABTS and superoxide radical scavenging assays. DSE effectively scavenged superoxide radicals produced by the xanthine/xanthine oxidase system, in a dose-dependent manner. It inhibited tyrosinase activity in the range of 4-1000µg/ml and α – glucosidase activity from 2-25µg/ml. DSE exhibited increased inhibition of α -glucosidase compared to acarbose with IC₅₀ values of 13.54µg/ml. Mild antiproliferative activity of DSE was observed when the extract was tested against 3T3-L1 cells.^[94]

Date fruits collected at the tamer stage were pitted and blended with water. The puree was then lyophilized to obtain dry powder. The dry powder was eluted with hexane, ethyl acetate, and methanol. Flavonoid glycosides found in date fruit demonstrated the highest inhibitory effect on COX-1, while triterpenoids 2 and 3 showed moderate inhibition, indicating anti-inflammatory activity.^[95] Four date varieties, Berhi, Khalase, Khenizi, and Reziz, showed cardioprotective activity. Methanolic extracts of the date fruits induced changes in cardiac tissue, reduced necrosis, restored cardiomyocytes, preserved cardiac muscle fiber morphology, mobilized progenitor cells towards the site of injury and improved the state of myocardial infarction.^[96] Date palm leaf powders of variety Deglet Nour, Ghars and Hamraya were dissolved in 70% ethanol for 3 days at 37 °C. The extract was then filtered, evaporated and dissolved in distilled water. The addition of hydroalcoholic extract of *P. dactylifera* leaves (HEPdL) at various concentrations resulted in a 50% reduction in residual α -amylase activity, demonstrating anti-diabetic properties.^[12] Fresh sap of the Besar date palm was collected and stored at 4° C to avoid fermentation. When sap is treated with wounded tissue, granulation tissue is rich in blood capillaries, fibroblasts and collagen with no inflammatory cells, which exhibit wound healing properties.^[97] A comparative overview of these phytochemicals across different plant organs is presented in Table 1, highlighting the diverse bioactive constituents that contribute to the nutritional, medicinal, and functional value of the species.

5. Conclusion and future perspectives

The date palm (*Phoenix dactylifera* L.) holds rich historical and cultural significance in the Arabian Peninsula and surrounding regions; however, further global research is required to fully explore its potential applications. Although the traditional uses of date fruits and other parts of the plant are well documented, detailed guidance on their health benefits remains limited. In addition, the phytochemical composition of date palm fruits varies considerably across different ripening stages, emphasizing the need for further studies to optimize cultivation and harvesting practices for maximum health benefits. While preparation methods for date fruits—such as juices, fermented beverages, and decoctions—have been sufficiently described, information regarding the use of other plant parts is scarce. This lack of knowledge makes it difficult to determine how and when these components can be utilized effectively. Furthermore, unfamiliarity with such traditional practices in certain cultures may contribute to the underutilization of date palm resources in various regions of the world.

Numerous *in vitro*, *in vivo*, and clinical studies have investigated the health benefits of phytochemical compounds present in date palm fruits. However, research focusing on date pollen, seeds, and other plant parts remains limited. Phytochemical analyses of date palm leaves have revealed the presence of bioactive compounds, particularly alkaloids and saponins, which show potential for the treatment of chronic diseases. In contrast, scientific investigations into the health benefits of date palm flowers and bark are still scarce. Date fruits are widely recognized for their high nutritional value, yet further research is needed to explore the incorporation of date palm extracts into polyherbal formulations to enhance their therapeutic effects. Date seed oil, which is rich in polyunsaturated fatty acids, has demonstrated promising health benefits, though comprehensive studies are required to confirm these findings. Overall, various components of the date palm are abundant in essential nutrients, including vitamins, minerals, dietary fiber, and beneficial fatty acids.

Several studies have reported the use of date seed oil, pollen, and pits in the food industry to improve sensory qualities and extend the shelf life of food products. These applications can help reduce or prevent food spoilage while enhancing nutritional value, highlighting the date palm as a valuable resource for food manufacturing and processing industries. The diverse components of the date palm also hold significant potential for the development of functional foods rich in secondary metabolites that may help reduce the risk of chronic diseases. This review provides comprehensive insights into the phytochemical composition and nutritional significance of *Phoenix dactylifera* in human health. Various parts of the date palm—including fruits, seeds, bark, flowers, sap, and leaves—are rich in beneficial compounds such as sterols, phenolics, carotenoids, flavonoids, carbohydrates, vitamins, and minerals. The reported health benefits of these phytochemicals underscore the value of the date palm as a

multifunctional plant. Overall, this review serves as a valuable resource for researchers interested in the phytochemical richness, nutritional value, health benefits of the date palm and its components. It also highlights opportunities for the pharmaceutical, nutraceutical, and food industries to develop innovative, bioactive, and functional products using date palm as a sustainable raw material.

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Data Availability Statement

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

Supporting Information

Not applicable.

CRedit Statement

Ramya Manoharan: Data curation, Writing - Original draft preparation. **Chythra Somanathan Nai:** Methodology, Data curation. **Radhakrishnan Subramanian, Drishya Nishanth:** Writing - Original draft preparation. **Mohamed Sheteiwy:** Correction and Validation. **Abdul Jaleel:** Conceptualization, Validation, Supervision.

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