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REVIEW ARTICLE

Health benefits and neutracuticle properties of palmyra palm - A forgotten treasure

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Abstract

Palmyra (*Borassus flabellifer* L.) a versatile tropical palm, has been extensively utilized across Asia and Africa for its economic, nutritional and medicinal value. Every part of the Palmyra tree from the fruit and sap to its leaves and roots, holds immense potential for human health and nutrition. Nutritionally, palmyra fruit and sap are rich sources of essential vitamins, minerals and antioxidants, including vitamin C, iron, calcium and phenolic compounds. The low glycaemic index of its sugar makes it a suitable alternative for diabetic patients, while the sap is traditionally consumed as a refreshing and nutrient-rich beverage. Pharmacologically, various extracts from the palmyra tree exhibit a wide range of bioactive properties. Studies have revealed that palmyra possesses anti-inflammatory, antioxidant, hepatoprotective and antimicrobial properties, potentially useful in preventing and managing chronic diseases like diabetes, liver disorders and cardiovascular ailments. The high content of flavonoids, polyphenols and other bioactive compounds in Palmyra has been linked to its role in reducing oxidative stress and promoting overall health. This paper aims to explore the comprehensive nutritional profile of palmyra and evaluate its pharmacological potential in modern therapeutic applications, thereby facilitating its broader use in food systems and as a natural remedy in traditional medicine.

Keywords: alkaloid; antioxidants; medicinal values; nutraceutical properties; palmyra

Introduction

The palmyra tree (*Borassus flabellifer* L.), also known as the toddy palm or sugar palm, is one of the oldest tree species in India (1). Native to the tropical regions of Africa and Asia, this multifunctional tree is highly valued for its versatility and adaptability to arid environments (2). Despite being underutilized, the palmyra palm holds significant potential for providing health and nutritional benefits, along with being a vital resource for local communities by offering food, shelter and raw materials (3). Palmyra has been deeply integrated into traditional practices, where various parts of the tree serve numerous utilitarian and medicinal purposes. Its leaves are widely used for thatching, weaving mats and making baskets, while its durable wood is prized for construction and furniture (4). Additionally, the fibers of the tree are utilized for ropemaking and its sap is a valuable resource for producing sugar, jaggery and alcohol (5).

From an ethnomedicinal perspective, the palmyra palm has been employed in traditional medicine systems for centuries. The sap, commonly referred to as "toddy," has been used for its purported health benefits, including antioxidant and antimicrobial properties (6). Other parts of the tree, such as the fruit, leaves, roots and bark, have been used to address various ailments due to their nutritional and medicinal values (7). For instance, the fruit is consumed to alleviate digestive disorders, while its dietary fiber supports gut health and prevents constipation (8). Traditional practices have highlighted the ability of the palmyra palm to support immune health, regulate blood pressure and maintain vision, owing to its richness in vitamins A and C, potassium and dietary fiber (9). These ethnobotanical applications underscore the tree's role in enhancing overall well-being in local communities. Recent research has unveiled the pharmacological properties of the palmyra palm, driven by laboratory-based investigations that reveal the presence of bioactive compounds. Extracts from various parts of the tree, such as the fruit, sap and leaves, have shown promising health benefits, including antioxidant, anti-inflammatory and antidiabetic effects (10, 11). These properties are attributed to the tree's rich phytochemical composition, including flavonoids, tannins and phenolic compounds (12).

Pharmacologically, the palmyra palm has demonstrated potential in addressing metabolic disorders, cardiovascular health and immune response modulation (13).

For example, its antioxidant properties protect cells from oxidative damage, which is crucial in preventing chronic diseases (14). Additionally, the antidiabetic effects of palmyra extracts have been linked to their ability to regulate blood glucose levels and improve insulin sensitivity. The sap has shown antimicrobial properties in lab-based studies, further validating its traditional uses. These pharmacological insights not only support traditional applications but also highlight the potential of the palmyra palm as a source of natural bioactive substances for developing functional foods and therapeutic agents (15). The connection between the ethnobotanical and pharmacological significance of the palmyra palm lies in its bioactive compounds. The vitamins, minerals and phytochemicals present in the tree's various parts form the basis for both its traditional usage and its pharmacological potential. While traditional applications reflect empirical knowledge passed down through generations, laboratory-based investigations provide scientific validation and deeper understanding of these benefits (16). Given the increasing global interest in sustainable crops and natural remedies, the palmyra palm stands out as a valuable resource with immense potential. By systematically exploring its ethnobotanical uses and pharmacological properties, we can promote its utilization in modern dietary and therapeutic applications. Future research should focus on further documenting and harnessing its health benefits, thus contributing to local economies and improved health outcomes. This review aims to explore the pharmacological properties of the palmyra palm and shed light on its potential as a valuable asset in modern dietary and therapeutic applications.

Nomenclature and morphological description of the plant

The scientific name for the palmyra palm is *Borassus flabellifer*. The term "Borassus" is derived from a Greek word meaning "leathery fruit," while "flabellifer" highlights the fan-shaped leaves of the tree. It belongs to the Arecaceae family, which encompasses a wide range of palm species found predominantly in tropical and subtropical regions (11). *Borassus flabellifer* is a dioecious plant, meaning male and female flowers grow on separate trees, making cross-pollination essential for fruit production. It is a monocotyledonous species with a chromosomal number of 2n = 36, indicating a simple genetic makeup adapted to diverse climatic conditions (17).

The palmyra palm can grow up to 30 meters in height, making it one of the tallest palms and it has a remarkable lifespan of approximately 150 years. The trunk is cylindrical and measures about 1.5 m in circumference at the base, with semi-circular scars left by fallen leaves creating a distinctive corrugated appearance. Young trees have black stems covered with dry, persistent leaf sheaths, while older trees develop smooth trunks with slender petiole leaves. The tree produces large, fan-shaped leaves that can reach up to 3 m in diameter, serving multiple purposes, including shelter and raw materials. Palmyra fruit is large and stringy, containing a nut-like shape with seeds inside (18). When young, these fruits are three-sided but gradually develop into a semi-spherical shape, enclosed with sepals. When the fruit becomes mature and ripens, its colour changes from dark brown to black. Its propagation is primarily through seeds, which are resilient and capable of withstanding harsh conditions, ensuring its survival and regeneration (19).

Geographical distribution and growth conditions

International distribution

The Palmyra tree is widely distributed across several continents. In Asia, it thrives in countries such as Bangladesh, Myanmar, India, Sri Lanka, Thailand and Malaysia. In the Americas, countries like Mexico, Cuba and parts of Brazil have reported populations of palmyra trees. As of 2021, approximately 140 million palmyra trees were projected worldwide (20).

Distribution in Asia

In Asia, palmyra trees are abundantly found in Bangladesh, Myanmar, India, Sri Lanka, Thailand and Malaysia. Sri Lanka is home to approximately 10 million palmyra trees, with two-thirds of these located in the Jaffna district. Central Myanmar is estimated to have about 2.5 million palmyra trees, while central Cambodia accounts for around 1.8 million trees (21).

Distribution in India

In India, there are around 70 million palmyra trees, with the majority found in Tamil Nadu, which houses two-thirds of the country’s palmyra population. The species is also commonly found in Andhra Pradesh, Kerala, Odisha and parts of Karnataka, where it plays a crucial role in rural livelihoods and ecological balance (22).

Growth condition

The palmyra palm is a perennial plant that starts yielding after 15 years in areas with ample water supply, whereas in arid regions, it takes around 25 years to begin producing fruits (23). Its growth rate is modest, averaging about 3 cm per year, reflecting its adaptation to slow but steady development (24). The tree thrives in well-drained, sandy to loamy soils with good aeration, although it can tolerate saline and drought-prone environments (25). Optimal growth is observed in regions with annual rainfall between 500 and 1500 mm and temperatures ranging from 25 °C to 35 °C. The flowering season varies with location, but typically, flowers bloom during the dry season, while fruits mature during the following wet season, ensuring synchronization with environmental resources (26).

Traditional uses

Ethnobotanical uses

Every part of the Palmyra tree, including root, leaves, fruit, inflorescence, shoot, kernel, embryo and sap, possesses unique pharmacological properties and numerous health benefits (Fig. 1). These parts are rich in bioactive components, are rich sources of vital macro and micro minerals and they contain various phenolic compounds known to hold antioxidant and other biological activities. In addition to antioxidant properties, the tree also demonstrates anti-inflammatory effects, antibacterial activity and antidiabetic potential. Furthermore, compounds in the sap and leaves offer hepatoprotective benefits, while the kernel and leaves show anti-cancer properties (27-29).

Roots: They contain phytochemicals such as flavonoids that show antioxidant properties. Additionally, the roots are a source of minerals, including iron (1.41 ppm), manganese and

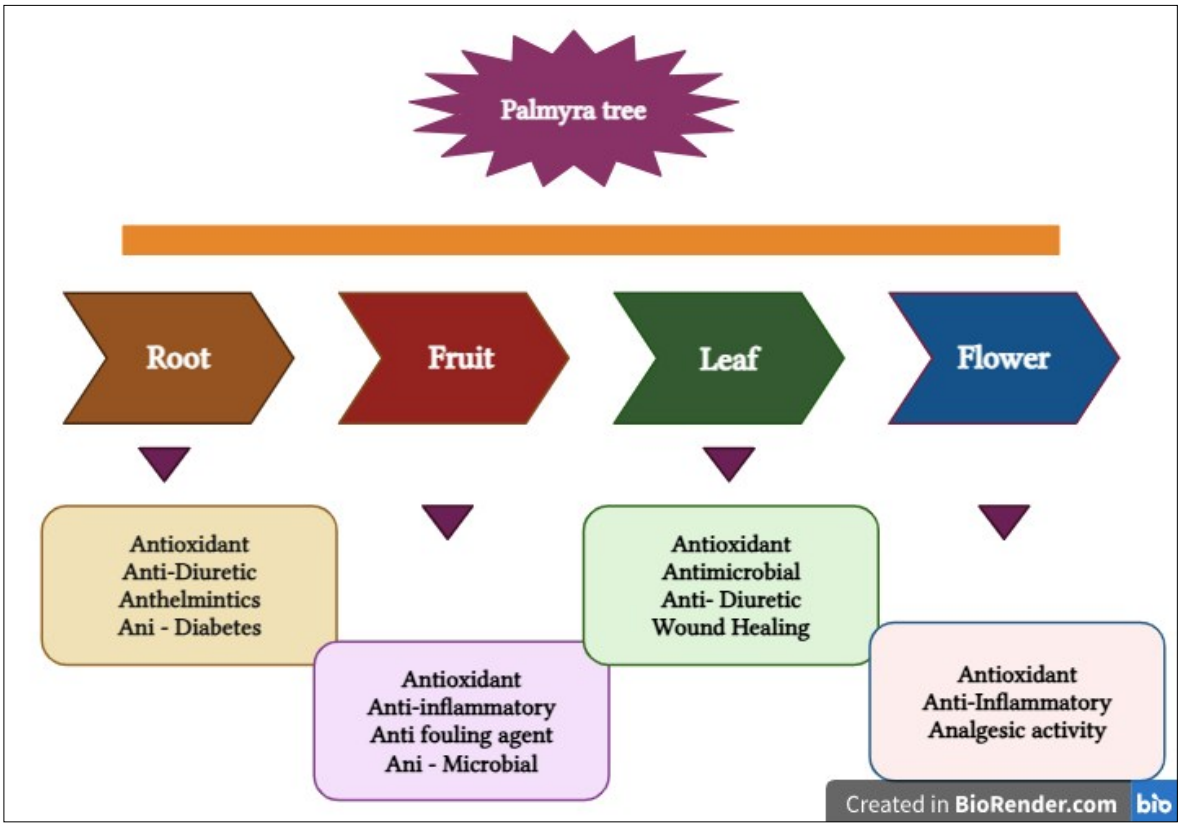

Fig. 1. Different parts of the palmyra tree exhibit different health benefits.

zinc. Secondary metabolites like alkanes, alkenes and as flavoring agents (30). Antioxidants taken from the roots and leaves of the palmyra tree are utilized to create natural antioxidants for the agro-based food and pharmaceutical industries. The immature root of the palmyra tree is known to act as a diuretic drug and has anti-parasitic properties. Additionally, the roots are used to cure various ailments, provide a cooling effect and have diuretic characteristics (31). A decoction made from the roots of the palmyra tree is used as a medicine for respiratory disorders and is also directed to individuals with gastric catarrh and hiccups. The root and its juice treat inflammatory reactions caused by harmful pathogens (32).

Buds: Palmyra buds, often regarded as one of the oldest traditional vegetables, have been utilized in ancient cuisines for centuries (28). These sprouts are the young tubers of the *Borassus flabellifer* plant, harvested once they begin to sprout. According to historical records, their use dates back to ancient times, with references to their consumption found in texts as early as 1000 BCE in South Asia (33). The palmyra buds are known by various names across India and other countries. In Tamil Nadu, they are called "Panam Kizhangu," while in Andhra Pradesh and Telangana, they are referred to as "Tadkula Kanda" or "Palmyra Root." In Kerala, they are known as "Thala Kizhangu," and in Karnataka, they are called "Panakol" or "Kole." In Odisha, they are termed "Tamala Kanda." Outside India, they are called "Palmyra Root" or "Thal Kiri" in Sri Lanka, "Tha Maung" in Myanmar, "Akar Palmyra" in Malaysia and "Akar Kelapa" in Indonesia. These regional names highlight the widespread use and cultural significance of palmyra buds. The sprouts are stem-like, slightly xanthous and become chewy when cooked, making them a unique culinary ingredient (34). These sprouts are a good source of Fibre, which aids in proper bowel movement and helps prevent impairment.

Stem / bark /shoot: The decoction prepared from the bark of the palmyra tree, when mixed with salt, is traditionally used as a mouthwash, while the charcoal made from the bark serves as a teeth cleaner. Additionally, the flour derived from the budding shoots of the palmyra contains flabelliferin, a compound with cytotoxic properties that shows mitogenic activity (35). The flour also exhibits neurotoxic effects, primarily due to the presence of saponins, which are spirostane tetraglycoside isomers. These saponins contain variations in their molecular structure, contributing to their neurotoxic activity (29).

Fruit: Palm fruit is a rich source of vitamin C, vitamin A, antioxidants, pectin and various kinds of minerals. The pulp part of the ripened fruit is recommended to cure dermatitis. The bitter compounds in palmyra fruit can be detached by giving them to the enzyme naringinase (36). During the summer, consuming palm fruit helps keep the body hydrated and replenishes essential nutrients. Additionally, the fruit displays anti-inflammatory and antioxidant activities due to its high content of crude flavonoids, saponins and phenolics (18, 25). Furthermore, it is recognized for its anti-asthmatic properties. The fruit of the palmyra palm also possesses anthelmintic properties, effectively destroying parasitic worms like roundworm and hookworm that cause stomach disorders. It is beneficial for treating dermatitis, vomiting and acts as a liver - curing syrup (37).

Furthermore, the liquid extract contains a variety of phytochemicals, including cardiac glycosides, quinones, phenols, coumarin and betacyanin. The sweet mesocarp of the palmyra fruit is higher in carotenoids, which turn xanthous orange at the time of ripening, making it suitable as a natural dye and known for its antioxidant characteristics.

Additionally, the extract of palm toddy can rapidly convert silver ions (Ag^+) from silver nitrate (38). The ability of palm toddy extract to rapidly convert silver ions (Ag^+) from silver nitrate is related to its pharmacological properties in the context of its reductive and antimicrobial activities. This process, known as reduction, suggests that the palm toddy contains bioactive compounds capable of reducing metal ions, which is an important feature in the synthesis of nanoparticles, particularly silver nanoparticles (39). These silver nanoparticles have known antimicrobial properties, which contribute to the pharmacological action of the extract. Thus, this reduction activity ties into the broader pharmacological benefits of palm toddy, especially its potential use in treating infections (40).

Leaves: The intake of the leaves of the palmyra tree supports proper health and helps prevent numerous diseases like cancer and tumor due to their presence of phytochemicals. The leaves demonstrate antimicrobial and antioxidant activities, making them a potential treatment for various infectious diseases (41). Consistent intake of 650 mg/kg body weight of leaf extract has been shown to improve cardioprotective HDL lipid levels (42).

Antioxidant effect of leaf: The phytochemicals found in the leaves of the palmyra tree exhibit antioxidant activity which is utilized in the production of natural antioxidants in the pharmaceutical industry (43) The antioxidant effect of the leaf was given in Fig. 2.

Spadix: The consumption of spadix ash from this tree is traditionally practised to alleviate conditions such as an enlarged spleen and liver and to relieve heartburn sensations (44). This suggests that the spadix ash may possess medicinal properties that can benefit digestive health and organ function (45).

Palmyra fiber pith: Palmyra fiber pith is a rich of dietary Fiber, essential minerals like magnesium and calcium and bioactive compounds supporting gut health and overall wellness The nutrient profile of palmyra pith is given in Fig. 3. Its medicinal benefits include potential applications in managing cholesterol and improving digestive health (46).

Flower: The sap derived from the male inflorescence of palmyra is valued for its medicinal properties. It acts as a laxative, stimulates the gastrointestinal tract and is a diuretic agent (34). Additionally, the sugar produced from the sap can help neutralize the toxic effects in the human body and is generally used to cure liver-related disorders. Extracts from inflorescence are also noted for their analgesic properties providing pain relief (47). The leaves of the palmyra tree contain compounds such as hexaproline, hexosamine and total proteins, which help cure arthritis. Ethanolic extracts of these leaves have demonstrated anti-inflammatory activity in mice at doses of 100 and 350 mg/kg. Additionally, the ash derived from well-burned inflorescence is utilized to alleviate conditions such as splenomegaly and bilious fever and is recognized for its properties as an antacid and antiperiodic (48).

Seed /kernel: The extract from the seed coat of palmyra has been shown to exhibit inhibitory effects against certain strains of bacteria. Additionally, the pellets derived from the palmyra tree are known to reduce and delay hypersensitivity reactions (49). The endosperm of the pulp comprises significant mucilage, which has demonstrated no skin inflammation and was well-accepted by guinea pigs (34). This is valuable in the pharmaceutical industry, where it can be utilized as an excipient in gel format (50).

Sap and toddy: The latex of the palmyra palm (*Borassus flabellifer*) is harvested through a traditional tapping process, with the sap collected in clay pots tied to the tree. This practice is widespread across India, where the sap is known by different names. In Andhra Pradesh and Telangana, it is called "Thaati Kallu", while in Tamil Nadu, it is referred to as "Pathaneer". In Kerala and Karnataka, it is known as "Kallu" or "Tati Kallu", respectively. In Odisha and West Bengal, it is

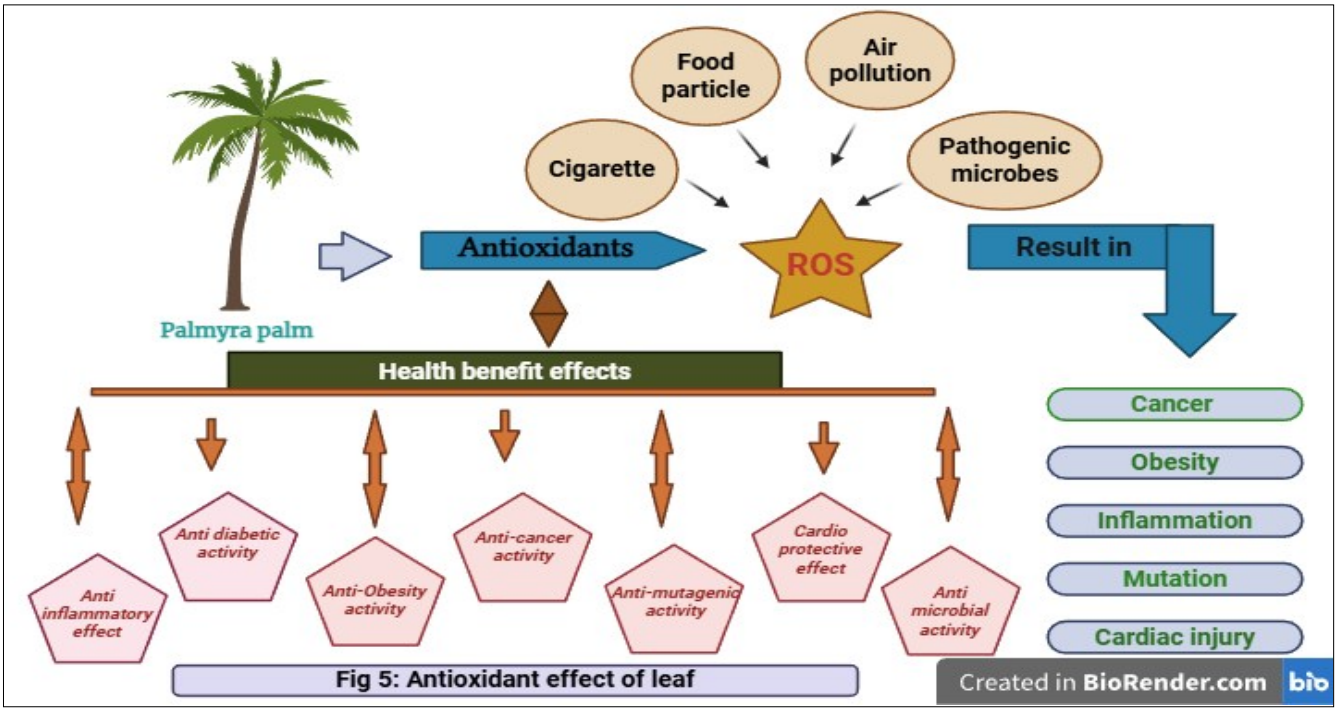

Fig. 2. Antioxidant effect of leaf.

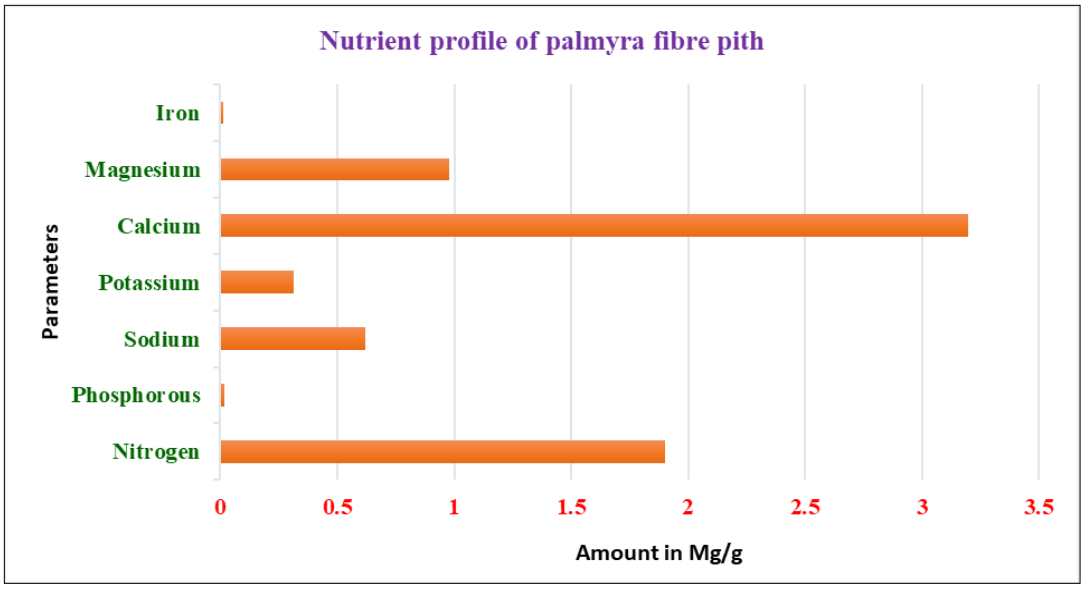

Fig. 3. Nutrient profile of palmyra fibre pith (58).

called "Tala Ras" or "Taal Ras" and in Maharashtra and Gujarat, it is termed "Taad Neera" or "Tad No Ras". In Manipur, it is known as "Kouna". Freshly collected sap, called "Neera", is sweet and non-alcoholic, while its fermented form, commonly referred to as "Toddy", holds significant cultural and economic value (8). The sap, especially when collected early in the morning is energizing and boasts numerous health benefits. Newly collected fluid is particularly rich in B vitamins. The sap from the palmyra tree is sweet and provides a cooling sensation when consumed (5). Processed products of palm sap include palm jaggery and palm syrup, which serve as natural substitutes sugarcane for sugar in most parts of India (51).

The jaggery prepared from palm, commonly referred to as "golden palm gur," is valued for its flavour and health benefits. Toddy is a sweet sap collected from the male and female inflorescences of the palmyra tree and it is allowed to ferment to produce an additional brew called "Arrack," which is popular in Tamil Nadu due to its organic production (52). Freshly made toddy can be heated to boost the fermentation process and is known for its medicinal properties, including the treatment of various types of ulcers. Additionally, the sap serves as a sweetener for diabetes and jaggery made from this sap may help reduce the risk of lung disease. The wine prepared from palmyra shows antibacterial properties. When fermented, the sap transforms into a wine rich in ethanol and is noted for its immunosuppressant effects (53).

Ethnomedicinal uses

Palmyra palm holds significant ethnomedicinal value across various regions, with different parts of the plant used in traditional medicine to address diverse health concerns. In Andhra Pradesh, the latex, known locally as *Thaati Kallu*, is prepared as a decoction and consumed as a cooling drink to alleviate heatstroke and promote hydration. In Tamil Nadu, the fresh sap, referred to as *Pathaneer*, is a popular cooling and refreshing beverage consumed to combat dehydration. Similarly, in Kerala, the latex, called *Kallu*, is fermented into a mild alcoholic beverage believed to offer digestive benefits. In Odisha, the root, known as *Tala Ras*, is prepared as a decoction to treat respiratory disorders and acts as a diuretic. In Gujarat, the fresh sap, locally termed *Tad No Ras*, is consumed to replenish lost minerals and aid digestion (7). Additionally, in Sri Lanka, the bark, referred to as *Panam Gal*, is made into a paste and applied topically to treat skin infections and wounds. These traditional practices highlight the palmyra palm's integral role in local healthcare systems and its diverse therapeutic applications. Various ethnomedicinal uses of palmyra are given in Table 1.

Phytochemical Constituents

The Palmyra palm is rich in various phytochemicals, contributing to its wide range of pharmacological properties. These include terpenes like flabelliferin, which is known for its antioxidant activity, protecting cells from oxidative stress. The plant also contains triterpenoids, which have been found in the bark and leaves and are recognized for their anti-inflammatory and anticancer effects (54). Polyphenols, such as phenolic acids and catechins, are present in the fruit and leaves and exhibit potent antioxidant properties, helping to neutralize free radicals. The saponins found in the roots, leaves and fruit of the plant show antimicrobial and anti-

Table 1. Ethnomedicinal uses of palmyra

S.No.	Place	Local Name	Plant Part use	Method of usage	Ethnomedicinal use	Reference
1.	Andhra Pradesh	Thaati Kallu	Latex	Decoction	Cooling drink, alleviates heatstroke and promotes hydration	(41)
2.	Tamil Nadu	Pathaneer	Latex	Fresh sap	Cooling and refreshing beverage, consumed for hydration	(42)
3.	Kerala	Kallu	Latex	Fermented sap	Mild alcoholic beverage, digestive benefits	(42)
4.	Odisha	Tala Ras	Root	Decoction	Treats respiratory disorders, acts as a diuretic	(43)
5.	Gujarat	Tad No Ras	Latex	Fresh sap	Replenishes lost minerals, aids digestion	(43)
6.	Sri Lanka	Panam Gal	Bark	Paste	Applied to treat skin infections and wounds	(44)

inflammatory effects (55), while flavonoids, such as quercetin, contribute to anti-inflammatory, anticancer and antioxidant activities. Additionally, certain alkaloids, like strychnine-like compounds, are present in the roots and seeds, which have neurotoxic properties but could also exhibit beneficial effects in controlled doses. These phytochemicals are primarily isolated using methods like solvent extraction followed by chromatographic techniques such as TLC and HPLC, enabling the identification and characterization of these bioactive compounds. Various Phytochemical constituents of palmyra were depicted in Table 2.

Pharmacological properties

Palmyra palm exhibits a variety of pharmacological properties due to the bioactive compounds found in its different parts. These properties have been investigated in both *in vitro* and *in vivo* studies (56). Table 3 depicts key pharmacological actions, including antimicrobial and antinematode activities.

Antimicrobial activities

The antimicrobial properties of the Palmyra palm have been extensively studied, particularly the activity of its extracts against various pathogenic microorganisms. Results demonstrated that both the fruit and bark extracts possess broad-spectrum antimicrobial activities, particularly against Gram-positive and Gram-negative bacteria like *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans*. The active compounds, including flavonoids and saponins, inhibit microbial growth by disrupting the cell membrane integrity and interfering with metabolic processes. Whereas, *in vitro* studies have shown the highest activity in the bark and fruit extracts, with the minimum inhibitory concentration (MIC) values ranging from 50 µg/mL to 100 µg/mL. The bark extract has been shown to inhibit the growth of both Staphylococcus aureus and Escherichia coli, making it a potential candidate for development into a natural antimicrobial agent (57).

Antinematode activities

The antinematode properties of the Palmyra palm have been investigated through both *in vitro* and *in vivo* experiments. It has been observed that extracts from the roots and seeds of the plant have significant effects on nematodes like Ascaris lumbricoides. The bioactive compounds, particularly alkaloids and saponins, have been linked to the paralysis and mortality of nematodes. *In vitro* studies using seed extracts at a concentration of 10 µg/mL have shown the nematode paralysis within 24 hr of exposure. The root extracts also exhibited similar activity and a dose-dependent reduction in nematode motility was observed, indicating the potential of these extracts as natural anthelmintic agents (58).

Use as food

The palmyra is not only valuable for its medicinal properties but also serves as a versatile food source. Various parts of the plant, including the sap, fruit, tuber and shoot, have been traditionally utilized in culinary practices across regions (59). The sap, often harvested as toddy, is rich in nutrients and can be transformed into value-added products such as palm sugar and palmyra vinegar, which are not only used for their unique flavors but also their health benefits (60), including supporting digestive health and managing blood sugar levels. The fruit of the palmyra is a great source of vitamins, minerals and antioxidants, making it an ideal choice for hydration and overall wellness. The tuber and shoots are processed into flours and other products, providing dietary fiber and contributing to gut health. These food products highlight the versatility and nutritional importance of the palmyra palm in traditional and modern diets (61).

Sap

Sap obtained from the palmyra is indeed a rich source of nutrients and minerals. However, its short shelf life poses a

Table 2. Phytochemical constituents of palmyra

S.No.	Name of the compound	Type of compound	Procedure of isolation/detection	Reference
1.	Flabelliferin	Terpenes	Solvent extraction(hexane/ethanol) + Chromatography	(28)
2.	Triterpenoids	Terpenes	Chromatography (TLC/HPLC)	(28)
3.	Phenolic Acids	Flabelliferin	Methanol/Ethanol extraction + HPLC	(29)
4.	Saponins	Flabelliferin	Solvent extraction + Chromatography	(29)
5.	Quercetin	Flavonoids	Ethanol extraction + HPLC	(29)
6.	Strychnine-like Compounds	Alkaloids	TLC + HPLC	(30)

Table 3. Pharmacological properties of palmyra

S.No.	Type of experiment	Name of the compound	Dose of application	Pharmacological actions	Reference
1.	***In-vitro***	Flabelliferin (Extract from leaves)	50 µg/mL	1. Antibacterial activity. 2. Inhibition of the growth of gram-positive and gram-negative bacteria.	(51)
2.	***In-vivo***	Triterpenoids (Bark extract)	200 mg/kg	1. Anti-inflammatory effects 2. Reduction in oedema and inflammation in the paw swelling model	(52)
3.	***In-vitro***	Saponins (Root extract)	100 µg/mL	1. Antifungal activity. 2. Inhibition of fungal growth.	(53)
4.	***In-vivo***	Polyphenols (Fruit extract)	150 mg/kg	1. Antioxidant effects. 2. Reduction of oxidative stress markers in liver tissues.	(54)
5.	***In-vitro***	Alkaloids (Seed extract)	10 µg/mL	1. Antinematode activity. 2. Paralysis of nematode worms within 24 hours.	(55)
6	***In-vivo***	Triterpenoids and Flavonoids (Whole plant extract)	10 µg/mL	1.Antidiabetic effects. 2. Reduction of blood glucose levels	(55)
7.	***In-vitro***	Flavonoids (Fruit extract)	25 µg/mL	1. Anticancer activity. 2. Inhibition of cell proliferation in breast cancer cell line.	(56)

challenge for preservation. To address this, developing value-added products can enhance their utility and extend thier market potential (62). Here are some potential value-added products derived from the sap of palmyra.

Palmyra vinegar

The fermentation of Palm sap through acetic acid produces palmyra vinegar, which has a distinctive flavor. This vinegar is a valuable source of vitamins and minerals. It is used to enhance reminiscence and used to cure conditions such as bladder infections, skin disorders, headaches and body aches. Additionally, palmyra vinegar can lower blood glucose levels while increasing serum insulin levels by up to 80 % (63). Due to its effectiveness as an antihyperglycemic agent, palmyra vinegar is suggested for individuals with type 1 diabetes. It is a rich source of essential minerals, including calcium (1.8 mg/kg), iron (0.04 mg/kg), phosphorus (16 mg/kg), potassium (35 mg/kg) and sodium (63.1 mg/kg) they are crucial for various biological functions in the body (64).

Palm sugar

The sap is ideal for sugar production, with a sugar content of 12 % and a purity of around 80 %. Palm sugar is an excellent alternative to cane sugar in various recipes and is known for its therapeutic properties against eye diseases (46). Compared to sugarcane sugar, this kind of palm sugar has minimal sweetness, it might be due to additional nutrients absent in cane sugar. Palm sugar has a lower glycemic index of 37, than cane sugar glycemic index of 78. This makes palm sugar a suitable addition to the daily diet, as it does not significantly elevate blood sugar levels and is therefore recommended for individuals with diabetes (65).

Fruit

Freshly harvested fruits of the palmyra palm are rich in essential nutrients and phytochemicals that make them an excellent choice for rehydration and replenishment during hot summer days (66). These fruits are a good source of vitamins such as vitamin B-complex (particularly thiamine and riboflavin) and vitamin C, as well as minerals like potassium, calcium, magnesium, phosphorus and iron. Additionally, they contain carbohydrates in the form of natural sugars, which provide a quick energy boost. The phytochemicals present include polyphenols, flavonoids and alkaloids, which exhibit antioxidant properties (67). The fruit also contains dietary fiber, aiding in digestion and small amounts of beta-carotene, which contributes to overall health and wellness. These compounds not only help in hydration but also provide protect against oxidative stress, making the fruit nutritionally and therapeutically valuable.

Palmyra yoghurt

Good quality pulps are sorted out for pulp extraction, which is then allowed to heat at about 50 °C for 5 min. Then the pulp is mixed with milk and boiled to 99 °C for 15 min. After cooling to approximately 42 °C, a prepared starter culture is added, resulting in palmyra yoghurt. Given that palmyra fruit is rich in B complex vitamins and minerals. Palmyra yoghurt offers a more balanced nutritional profile than regular milk yoghurt (68).

Shoot flour

Tender and soft seedlings were washed, peeled and made into small pieces. Then the pieces are allowed to dry at 85 °C and ground into a flour. Then the ground flour is stored in well - closed, airtight plastic containers for further use (69).

Palmyra tuber flour and rava

Developed tubers are chosen and the outer layer is removed. The tubers are then steamed and cut into chips. Various products such as rava, laddu, payasam and pakora can be made from palmyra tuber flour. The tuber of the palmyra palm, being rich in dietary fiber, exhibits pharmacological properties by aiding in the prevention of digestive issues such as constipation and promoting gut health (45). Additionally, its consumption has been associated with alleviating urinary problems, supporting the body's natural detoxification processes. The tuber flour also enhances satiety, potentially aiding in weight management and contributes to overall body strength and vitality, underscoring its therapeutic significance (59).

Nutritive values of different parts of palmyra

Different parts of the palm are abundant in various nutrients and phytochemicals that are indispensable for regular activities (70). The roots are particularly high in protein (8.83 %) and fibre, while the fruit pulp is greater in magnesium and calcium, both are vital micronutrients required by the body. The powder obtained from the palmyra tuber is a valuable source of iron and calcium, which are essential for red blood cell formation and eliminating poisons from the body (71). The nutrient composition of diverse palmyra products is given in Table 4.

Economy of the plant

The Palmyra originated in the hottest regions of Sri Lanka, India and Burma and as well as in many of the humid countries. The economic potential of a single Palmyra palm tree per year can be assessed through its diverse range of products described in Table 5. From the Neera (juice) extract, approximately 150 L can be processed to produce 20 kg of Gur (jaggery), which holds an approximate market value of ₹4000. Additionally, 20-25 kg of Karuppatti (a form of jaggery) can also be derived from the tree. Palm candy, a high-value product, can be obtained in a yield of 16 kg. The mature leaves of the palm, around 10 kg or 8 leaves annually, can be woven into six mats worth ₹100. The Thumbu (coir) extracted amounts to 11 kg, offering the potential for further processing. Similarly, the leaf ribs (Eeark or Ekil), weighing 2.25 kg, can be transformed into 12 brushes valued at

Table 4. Nutrient composition of various products of palmyra

Source	CHO	Protein	Fat	Fibre	Ash	Ca	P	K	Na	Mg	Reference
Fruit	18.2	0.8	0.2	7.8	0.7	108	567	-	-	21	(25)
Seed	71.5	12.5	1.9	4.3	2.2	48	-	6	52	23	(28)
Sprouts	23.5	8.5	0.6	7.3	4.9	-	-	-	-	-	(29)
Neera	10.9	0.35	-	-	0.5	-	0.1	-	-	-	(30)
Haustorium	70	5.4	21	-	5	26	290	-	-	-	(34)
Tuber	77.5	6.78	-	4.49	0.02	-	21.4	-	-	-	(36)

Table 5. Economy of single palm per year

Raw material	Quantity	Finished product	Approximate value (in Rs.)	Reference
Neera / Juice	150 liters	Gur (20kg)	4000	(42)
Karuppatti / Jaggery / Gur	20-25 kg	-	-	(42)
Palm candy	16 kg	-	-	(43)
Matured leaves	10 kg / 8 Nos.	Mat 6 Number	100	(44)
Thumbu / Coir	11 kg	-	-	(45)
Eeark / Ekil (Leaf ribs)	2.25 kg	Brush 12 Number	70	(46)
Naar / Fiber	16-20 kg	Basket 1 Number	70	(47)
Viragu / Fire wood	10 kg	-	-	(48)

₹70. Moreover, the fiber (Naar) produced, approximately 16-20 kg, can be utilized to craft a basket worth ₹70. Lastly, the tree contributes 10 kg of firewood annually, adding further utility(64). This comprehensive utilization highlights the Palmyra palm's significant economic contribution, offering multiple revenue streams from a single tree (72).

Toxicity studies

Toxicity studies conducted on Palmyra have revealed both beneficial and potentially harmful effects, depending on the part of the plant used and the method of preparation. The fruit, one of the most commonly consumed parts, is generally considered non-toxic and safe for human consumption, providing a rich source of nutrients and bioactive compounds. (73) However, some parts of the plant, particularly the young shoots and the tuber, have shown evidence of neurotoxic effects, possibly due to the presence of saponins and other bioactive compounds that may cause adverse effects if consumed in large quantities. For instance, the sap obtained from the palmyra is used in various traditional medicinal applications and as a food source, but it must be consumed fresh due to its short shelf life. The storage of sap over extended periods or under inappropriate conditions can lead to the growth of harmful microorganisms, which could pose a health risk (74). Additionally, the latex from the tree, while used for medicinal purposes in some cultures, requires careful handling, as its composition can vary and may cause skin irritation in sensitive individuals**.**

Future Thrust

Nutritional profiling and value-added products

There is a need for comprehensive nutritional profiling of different parts of the palmyra palm to establish its potential in addressing malnutrition and food security. Future research should focus on developing value-added food products like Palmyra-based energy drinks, snacks and nutraceuticals to tap into the growing demand for health-conscious foods.

Exploring medicinal and pharmacological compounds

More in-depth studies are required to isolate and characterize bioactive compounds present in the palmyra palm. Research should focus on identifying specific phytochemicals responsible for their medicinal properties, especially in the treatment of diseases like diabetes, cancer and cardiovascular conditions. Developing standardized extracts and formulations for therapeutic use would enhance its integration into modern medicine.

Pharmaceutical applications and clinical trials

Future thrusts should include preclinical and clinical trials to validate the medicinal claims of the palmyra palm, particularly its anti-diabetic, anti-inflammatory and antioxidant effects. This would help in gaining regulatory approvals for its use in pharmaceutical products. Collaborative efforts between traditional healers and the pharmaceutical industry could accelerate the development of palmyra-based medications.

Economic and community development

Strengthening the palmyra palm industry can benefit rural communities significantly. Future initiatives should empower local farmers and artisans through training in palmyra product development, creating cooperatives and establishing fair trade networks to ensure sustainable income generation.

Conclusion

In conclusion, though the palmyra palm is underexploited it holds significant nutritional, medicinal and pharmacological potential, making it a highly valuable tree for both traditional and modern uses. Nutritionally, its fruits, sap and other edible parts are rich in essential nutrients like carbohydrates, vitamins and minerals, which provide energy and nutritional support to communities, especially in tropical regions. Medicinally, various parts of the palmyra palm have long been used in traditional medicine to treat ailments such as diabetes, digestive disorders and respiratory issues. Its antioxidant, anti-inflammatory, antimicrobial and anti-diabetic properties, which are backed by scientific studies, showcase its therapeutic potential. The sap is particularly noted for its ability to regulate blood sugar levels and boost the immune system. Pharmacologically, bioactive compounds extracted from the palmyra palm, including polyphenols, flavonoids and tannins, have shown promise in developing drugs to manage chronic conditions like diabetes and inflammation. The plant's potential as an anti-cancer, anti-viral and liver-protective agent also opens new avenues for pharmaceutical research. Therefore, the palmyra palm presents a multifaceted resource that contributes to food security and holds promise for future medical and pharmacological applications. Expanding its use through sustainable cultivation and further research into its medicinal properties could greatly benefit health, nutrition and economic development.

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Authors' contributions

VK conceptualized the work, curated the data and wrote the original draft. RT conceptualized the work, supervised the project, acquired funding and contributed to writing, review and editing. GA contributed to the original draft, developed the methodology and performed validation. PJ contributed to writing the original draft and performed editing. AB provided resources and contributed to visualization. RS contributed to the methodology and to writing, review and editing. SS contributed to writing, review and editing. DSK contributed to writing, review and editing. BMB contributed to the methodology and editing.

Compliance with ethical standards

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References

1. Immanuel RR, Rao GB. Production potential of groundnut under palmyra (*Borassus flabellifer*) based agroforestry system in coastal red soils of Tamil Nadu. Crop Res. 2021;56(3-4):105–10. https://doi.org/10.31830/2454-1761.2021.017
2. Prasad AB, Arunkumar A, Vignesh S, Chidanand DV, Baskaran N. Exploring the nutritional profiling and health benefits of palmyra palm haustorium. South African J Bot. 2022;151:228–37. https://doi.org/10.1016/j.sajb.2022.01.027
3. Sarma C, Mummaleti G, Sivanandham V, Kalakandan S, Rawson A, Anandharaj A. Anthology of palm sap: the global status, nutritional composition, health benefits and value-added products. Trends Food Sci Technol. 2022;119:530–49. https://doi.org/10.1016/j.tifs.2021.12.002
4. Krishnaveni TRS, Arunachalam R, Chandrakumar M, Parthasarathi RN. Potential review on palmyra (*Borassus flabellifer* L.). Adv Res. 2020;21(9):29–40. https://doi.org/10.9734/AIR/2020/v21i930229
5. Jeshwanth T, Johar V, Singh V. Health benefits of palm tree. J Adv Edu Sci. 2024;4(2):21–27.
6. Jana H, Jana S. Palmyra palm: Importance in Indian agriculture. Rash Krishi. 2017;35–40.
7. Vengaiah PC, Murthy, Sattiraju M, Maheswarappa HP. Value-added food products from palmyrah palm (*Borassus flabellifer* L). J Nutr Health Sci. 2017;4(1):1–3. https://doi.org/10.15744/2393-9060.4.105
8. Olotu PN, Olotu IA, Datok T, Famojuro TI. A study on 74 varieties of palm trees used around the world as food and ornaments. J Pharmaco Phytochem. 2024;13(1):102–19. https://doi.org/10.22271/phyto.2024.v13.i1b.14819
9. Rajeshwari ER, Sathanya PS, Vignesh S, Baskaran N. Palmyra and coconut haustorium: a comprehensive review on nutritional composition, bioactive potential, value-added products and its health benefits. Food Chem Adv. 2024:100836. https://doi.org/10.1016/j.focha.2024.100836
10. Gummadi VP, Battu GR, Keerthana DMS, Manda K. A review on palmyra palm (*Borassus flabellifer).* Int J Curr Pharm Res. 2016;8:17–20. https://doi.org/10.22159/ijcpr.2016v8i2.13647
11. Mohan CK, Soundarya V, Kumar RV, Kumar LK, Sharathnath KV, Narender B. *In-vitro* anti-inflammatory activity of dried leaves of *Borassus flabellifer*. Indo Am J Pharm Sci. 2016;3:809–13.
12. Jerry A. A comprehensive review on the medicinal properties of *Borassus flabellifer*. J Acad Ind Res. 2022;7:93–97.
13. Kiriti AS, Arun KE, Vignesh S, Chidanand DV, Baskaran N. Evaluating the effects of different processing methods on the nutritional quality of bovine milk. Food Hum. 2023;1:128–36. https://doi.org/10.1016/j.foohum.2023.05.005
14. Allwin SI, Lititia S, Cherian SA, Shelton BD, Jebitta SR. A review on nutritive, medicinal and commercial aspects of Asian palmyra palm fruit. Songklanakarin J Sci Technol. 2024;46(1).
15. Jamkhande PG, Suryawanshi VA, Kaylankar TM, Patwekar SL. Biological activities of leaves of ethnomedicinal plant, *Borassus flabellifer* Linn. (palmyra palm): Evaluation. Bull Fac Pharm Cairo Univ. 2016;54(1):59–66. https://doi.org/10.1016/j.bfopcu.2016.01.002
16. Pammi N, Bhukya KK, Lunavath RK, Bhukya B. Bioprospecting of palmyra palm (*Borassus flabellifer*) nectar: unveiling the probiotic and therapeutic potential of the traditional rural drink. Front Microbiol. 2021;12:683996. https://doi.org/10.3389/fmicb.2021.683996
17. Sayanhika S, Selvakumar PM. An insight into the cosmetic and dermatologic applications of the molecules of palmyra palm. Cosmetics. 2024;11(6):196. https://doi.org/10.3390/cosmetics11060196
18. Narayanankutty A, Job JT, Kuttithodi AM, Sasidharan A, Benil PB, Ramesh V, et al. Proximate composition, antioxidant, anti-inflammatory and anti-diabetic properties of the haustorium from coconut (*Cocos nucifera* L.) and palmyra palm (*Borassus flabellifer* L.). J King Saud Univ Sci. 2023;35(1):102404. https://doi.org/10.1016/j.jksus.2022.102404
19. Rayappa MK. Palmyra palm (*Borassus flabellifer*) non-centrifugal sugar-Current production practices as a natural sugar and a promising functional food/additive. J Agric Food Res. 2023:100829. https://doi.org/10.1016/j.jafr.2023.100829
20. Basava PAR, Vignesh S, Chidanand DV, Arunkumar, Anandraj, Baskaran N. Evaluation of physiochemical, antioxidant and antimicrobial potential of palmyra palm haustorium. Pharma Innov J. 2021;10(10):1665–70. https://doi.org/10.22271/tpi.2021.v10.i10.1665
21. Mariselvam R, Ignacimuthu S, Ranjitsingh AJA, Mosae SP. An insight into leaf secretions of Asian palmyra palm: A wound healing material from nature. Mater Today Proc. 2020. https://doi.org/10.1016/j.matpr.2020.05.393
22. Ramya S. Review on traditional and phyto-pharmacological aspects of *Borassus flabellifer* (palmyra tree). Int J Pharm Sci Rev Res. 2018;1:6–13.
23. Jerry A. A comprehensive review on the medicinal properties of *Borassus flabellifer*. J Acad Ind Res. 2018;7(7):93–97.
24. Selvakumar PM, Thanapaul RJ. An insight into the polymeric structures in Asian palmyra palm (*Borassus flabellifer* Linn). Org Polym Mater Res. 2020;2(2):16–21. https://doi.org/10.30564/opmr.v2i2.2639
25. Upadhyaya A, Sonawane SK. Palmyra palm and its products (neera, jaggery and candy)-a review on chemistry and technology. Appl Food Res. 2023;3(1):100256. https://doi.org/10.1016/j.afres.2022.100256
26. Yamagishi SI, Matsui T. Protective role of sulforaphane against vascular complications in diabetes. Pharm Biol. 2016;54:2329–39. https://doi.org/10.3109/13880209.2016.1138314
27. Jeshwanth T, Johar V, Singh V. Health benefits of palm tree. J Adv

Edu Sci. 2024;4(2):21–27.

28. Sarma C, Mummaleti G, Sivanandham V, Kalakandan S, Rawson A, Anandharaj A. Anthology of palm sap: the global status, nutritional composition, health benefits and value-added products. Trends Food Sci Technol. 2022;119:530–49. https://doi.org/10.1016/j.tifs.2021.12.002

29. Sangeetha S, Thuraisingam S, Jayawardane JA, Srivijeindran S. A novel approach to the formulation of an encapsulated bioactive powder from palmyra (*Borassus flabellifer* L) fruit pulp for nutraceutical applications. Food Chem Adv. 2023;3:100405. https://doi.org/10.1016/j.focha.2023.100405

30. Da Silveira, Agostini-Costa T. Bioactive compounds and health benefits of some palm species traditionally used in Africa and the Americas-a review. J Ethnopharmacol. 2018;224:202–29. https://doi.org/10.1016/j.jep.2018.05.035

31. Thakur NS. Pharmacological and phytochemical potential of wild fruits. Ann Phytomed. 2023;12(1):1–4. https://doi.org/10.54085/ap.2023.12.1.95

32. Singh H, Chellammal J. Fruits that heal: Biomolecules and novel therapeutic agents. Ann Phytomed. 2022;11(1):7–14. http://doi.org/10.54085/ap.2022.11.1.2

33. Pramod HJ, Yadav AV, Raje VN, Mohite M, Wadkar G. ioxidant activity of *Borassus flabellifer* (Linn.) fruits. Asian J Pharm Technol Innov. 2013:16–19.

34. Pavithra S, Vethamoni I, Pazhanivelan S, Venkatesan K, Anand M. Phytochemical profiling of dried palmyra haustorium powder through GC-MS analysis: unveiling novel bioactive compounds. Int J Plant Soil Sci. 2023;35(19):1235–43. https://doi.org/10.9734/ijpss/2023/v35i193662

35. Onyeukwu OB, Diakparomre O, Njideaka OT, Dibie DC, Nwaiku F. Palm wine: a review on its composition, preservation, health benefits and market value. Int J Basic Sci Technol. 2024;10(1):71–80.

36. Sangeeta S, Chandola G, Ramachandran P, Yadav P, Rai S. Fruits that heal: A natural boon to cure colon diseases. Ann Phytomed. 2023;12(1):5–14. http://dx.doi.org/10.54085/ap.2023.12.1.64

37. Rani VP, Mirabel LM, Priya KS, Nancy AA, Kumari GM. Phytochemical, antioxidant and antibacterial activity of aqueous extract of *Borassus flabellifer* (L.). Int J Sci Res Sci Technol. 2018;4(2):405–10.

38. Mohaideen NS, Srinivasan H. *Borassus flabellifer:* A multipurpose tree with potential applications. Curr Pharmacol Rep. 2024;10:414–21. https://doi.org/10.1007/s40495-024-00365-z

39. Ambrose DC. Effect of packaging on the shelf life of tender palmyra (*Borassus flabellifer*) fruit endosperm. J Appl Nat Sci. 2018;10(2):705–09. https://doi.org/10.31018/jans.v10i2.1770

40. Chitturi KL, Garimella S, Marapaka AK, Kudle KR, Merugu R. Single pot green synthesis, characterization, antitumor antibacterial, antioxidant activity of bimetallic silver and copper nanoparticles using fruit pulp of palmyra fruit. J Bionanosci. 2018;12(1-6):1–6. https://doi.org/10.1166/jbns.2018.1520

41. Rodiah MH, Jamilah B, Sharifah KSM, Russly AR. Physico-chemical and antioxidant properties of mesocarp and exocarp from *Borassus flabellifer.* Int Food Res J. 2019;26 (5):1469–76.

42. Chauhan L, Prakash KS, Srivastav PP, Bashir K. Physicochemical and thermal properties of candy crystals prepared from palmyra-palm jaggery. J Food Process Eng. 2017;40(1):12337. https://doi.org/10.1111/jfpe.12337

43. Viju N, Punitha SMJ, Satheesh S. Antifouling potential of palmyra palm (*Borassus flabellifer*) fruit husk extract. Proc Nat Acad Sci India B Biol Sci. 2020. https://doi.org/10.1007/s40011-020-01171-5

44. Natarajan K, Sangeetha R. Inhibition of carbohydrate-degrading enzymes by the root of *Borassus flabellifer* – An *in vitro* evaluation. Int J Res Pharm Sci. 2019;11(1):135–39. https://doi.org/10.26452/ijrps.v11i1.1797

45. Sarma C, Kalakandan SK, Mummaleti G, Thamburaj S. Changes in physico-chemical attributes and reaction kinetics of palmyra (*Borassus flabellifer*) sap stored under ambient and refrigerated temperature during fermentation. J Food Process Preserv. 2022;46(12):17277. https://doi.org/10.1111/jfpp.17277

46. Aparnna VP, Kumar CA, Singh S. Palm-based beverages around the world: a review. Curr Nutr Food Sci. 2024;20(1):16–27. https://doi.org/10.2174/1573401319666230417083106

47. Rupasena LP, Chandrasiri A. Marketing of palmyra based product (research study no. 93). Sri Lanka: Hector Kobbekaduwa Agrar Res Train Institute; 1995

48. Talluri MR, Gummadi VP, Battu GR. Antioxidant activity of *Borassus flabellifer*. Int Res J Pharm. 2017;8(3):18–22. https://doi.org/10.7897/2230-8407.080329

49. Sadila AY, Zubaidah U, Puspitasari W. Identification of diuretic chemical compound in palmyra palm (*Borassus flabellifer*) to cure kidney stone disease which commonly happen in Tuban. In: Proceedings of the 7th Asian Academic Society International Conference; 2019. p. 321–28.

50. Aheeshan B, Maathumai S, Subajini M, Wijesinghe WAJP, Sriwijendran S. Antioxidant activity and physicochemical analysis of coconut, kithul and palmyra palm treacle. J Sci. 2022;13(1):23–30. https://doi.org/10.4038/jsc.v13i1.40

51. Baird JA, Kamash Z, Raja R. Knowing palmyra: mandatory production of archaeological knowledge. J Soc Archaeol. 2023;23(1):76–98. https://doi.org/10.1177/14696053221144013

52. Singh SKCM, Senthil K, Kathirvel K, Murugan R, Ponnappan S, Mani S, et al. Enhancement of gut microbiota health using prebiotics from *Borassus flabellifer*. Acta Biomed. 2023;94(2):642–57.

53. Athinarayanan J, Periasamy VS, Alatiah KA, Alshatwi AA. Synthesis and cytocompatibility analysis of carbon nanodots derived from palmyra palm leaf for multicolor imaging applications. Sustain Chem Pharm. 2020;18:100334. https://doi.org/10.1016/j.scp.2020.100334

54. Kurian A, Thiripuranathar G, Paranagama PA. Determination of total phenolic content and antioxidant activity of *Borassus flabellifer* Linn. fruit pulp collected from several parts of Sri Lanka. Int J Pharm Sci Res. 2017;8(6):2701–05.

55. Shirisha G, Shaik RA, Sowjanya JN. *Borassus flabellifer* fruit versatile pharmaceutical application: an overview. Int J Adv Res Med Pharm Sci. 2018;3(4):12–16.

56. Sewwandi SM, Liyanage R, Bangamuwage R, Rathnayake I, Deen A, Jayawardana B, Liyanage R. Morphological, physicochemical and functional properties of 15 different dietary carbohydrate sources in Sri Lanka. JSFA Rep. 2023;3(10):463–72. https://doi.org/10.1002/jsf2.153

57. Das S, Tamang JP. Microbiology and health benefits of fermented palm drink of the world. In: Tamang JP, editor. Microbiology and Health Benefits of Traditional Alcoholic Beverages. Academic Press; 2025. p. 311–35 https://doi.org/10.1016/B978-0-443-13322-0.00009-5

58. Garmon C, Kmitch L. Hospital mergers and antitrust immunity: the acquisition of Palmyra Medical Center by Phoebe Putney Health. J Compet Law Econ. 2018;14(3):433–66. https://doi.org/10.1093/joclec/nhy015

59. Saputro AD, Van de WD, Dewettinck K. Palm sap sugar: a review. Sugar Tech. 2019;21(6):862–67. https://doi.org/10.1007/s12355-019-00743-8

60. Banu SM, Vigasini N, Surenderan S. Phytochemical screening, *in vitro* antioxidant and anti-inflammatory activity of freeze-dried *Borassus flabellifer* L. seed powder. Asian J Biol Life Sci. 2021;10(1):203. https://doi.org/10.5530/ajbls.2021.10.29

61. Sivaji M, Aheeshan B. Antioxidant activity and nutritional properties of freshly tapped palmyra (*Borassus flabellifer*) sap. Adv Technol.

2021;1:300–06. https://doi.org/10.31357/ait.v1i2.4880

62. Sathiyanarayanan G, Saibaba G, Kiran GS, Selvin J. Process optimization and production of polyhydroxybutyrate using palm jaggery as economical carbon source by marine sponge-associated *Bacillus licheniformis* MSBN12. Bioprocess Biosyst Eng. 2013;36:1817–27. https://doi.org/10.1007/s00449-013-0956-9

63. Mahilrajan S, Thuraisingam S, Prabagar J. Exploring the nutritional health and economic potential of palmyra fruit pulp. Food Chem Adv. 2024;3:100880. https://doi.org/10.1016/j.focha.2024.100880

64. Somasekharan S, Rajam N, Neenthamadathil K. Spice-infused palmyra palm syrup improved cell-mediated immunity in Wistar Albino rats. J Food Biochem. 2020:1–9. https://doi.org/10.1111/jfbc.13466

65. Reddy TPK, Kondle R, Challa PK, Wani AW. A review on nutritional, phytochemical and medicinal properties of underexploited fruit crops. Ann Phytomed. 2023;12(1):132–47. https://doi.org/10.54085/ap.2023.12.1.61

66. Samad A, Bincy. Civilizational memory: the transformation of palmyra as a cultural patrimony of the West [PhD dissertation]. St. Louis (MO): Washington University in St. Louis; 2020

67. Sayanhika S, Selvakumar PM. An insight into the cosmetic and dermatologic applications of the molecules of palmyra palm. Cosmetics. 2024;11(6):196. https://doi.org/10.3390/cosmetics11060196

68. Devi T, Sharmila P. Development and standardization of palmyra (*Borassus flabellifer*) tuber powder incorporated food. EPRA Int J Res Dev. 2019;4(3):2455–7838. https://doi.org/10.1108/eb039583

69. Behera S, Nayak B. Phytochemical constituents and nutritional potential of palmyra palm: a review. Rev Contemp Sci Acad Stud. 2022;(12):18. https://doi.org/10.55454/rcsas.2.12.2022.003

70. Basava PAR, Vignesh S, Elumalai A, Anandharaj A, Chidanand DV, Baskaran N. Nutritional and pharmacological properties of palmyra palm. Food Hum. 2023;1:817–25. https://doi.org/10.1016/j.foohum.2023.07.030

71. Sarma C, Mummaleti G, Sivanandham V, Kalakandan S, Rawson A, Anandharaj A. Anthology of palm sap: the global status, nutritional composition, health benefits and value-added products. Trends Food Sci Technol. 2022;119:530–49. https://doi.org/10.1016/j.tifs.2021.12.002

72. Basava PAR, Arunkumar, Anandharaj, Vignesh S, Chidanand DV, Baskaran N. Exploring the nutritional profiling and health benefits of palmyra palm haustorium. S Afr J Bot. 2022;151(Pt B):228–37. https://doi.org/10.1016/j.sajb.2022.01.027

73. Franco FM, Samuel G, Francis T. Mutualism between humans and palms: the curious case of the palmyra palm (*Borassus flabellifer* L.) and its tapper. Gadong (BN): Institute of Asian Studies, Universiti Brunei Darussalam; 2020 (Working Paper No. 59)

74. Peprah M, Apprey C, Larbie C, Asamoah-Boakye O. Phytochemical constituents of flour and composite bread from African palmyra (*Borassus aethiopum*) fruit from Ghana. Eur J Med Plants. 2018;23(1):1–7. https://doi.org/10.9734/EJMP/2018/40502

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