



Dragon Fruit (*Hylocereus* spp.): A Comprehensive Review on It's Nutritional, Phytochemical, and Pharmacological Properties with Health-Promoting Applications

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ABSTRACT

Dragon fruit (*Hylocereus* spp.), commonly known as pitaya, has gained global recognition as an exotic fruit with exceptional nutritional and therapeutic value. This review provides a comprehensive overview of its nutritional composition, phytochemical constituents, and pharmacological potential. Dragon fruit is rich in vitamins, minerals, dietary fiber, and natural pigments such as betalains, which contribute to its strong antioxidant capacity. Phytochemicals including flavonoids, phenolic acids, and polyunsaturated fatty acids have been associated with diverse bioactivities. Emerging evidence highlights its pharmacological properties, including antioxidant, anti-inflammatory, antidiabetic, hypolipidemic, anticancer, and antimicrobial effects, which support its role as a functional food and nutraceutical. Furthermore, dragon fruit shows promise in promoting gut health, managing metabolic disorders, and preventing chronic diseases. This review emphasizes the therapeutic applications and future prospects of *Hylocereus* spp., underscoring its potential as a health-promoting food resource and candidate for nutraceutical development.

Keywords: Dragon fruit, *Hylocereus* spp., Pitaya, Nutritional value, Phytochemicals, Pharmacological properties, Functional food, Health benefits.

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1. Introduction

The genus *Hylocereus* of the family Cactaceae comprises the dragon fruit, widely known as pitaya. Owing to its vibrant red skin and overlapping green bracts, it is popularly referred to as "dragon fruit." It is also known by several other names, including strawberry pear, pitahaya, dragon pearl fruit, night-blooming cereus, and Cinderella plant. Dragon fruit is believed to have originated in Central America and was later introduced to Asia, particularly

Vietnam, by the French in the early 19th century. In Mexico, it is referred to as pitahaya, while in Central and northern South America it is commonly called Pitaya Roja^[1-3]. The fruit exhibits remarkable genetic diversity, with species differing in shape, thorniness, skin color, and pulp color. Studies have shown that pitaya pulp contains relatively low concentrations of anthocyanins, such as cyanidin 3-glucoside, delphinidin 3-glucoside, and

pelargonidin 3-glucoside, whereas the seeds and peel are richer in polyphenols, betacyanins, and amino acids^[4-6]. The levels of betacyanins, phenolics, and flavonoids increase progressively during fruit maturation, with pigmentation appearing initially in the pulp before the peel. In recent years, dragon fruit has gained attention for its medicinal potential. Traditionally used as a natural coloring agent, it is now recognized for multiple therapeutic applications, including antioxidant, antibacterial, antidiabetic, anticancer, and nutraceutical properties^[7].

The bioactive composition of dragon fruit, including essential minerals such as potassium and compounds like betacyanin, p-coumaric acid, vanillic acid, and gallic acid, has been linked to potential benefits in managing diabetes, dyslipidemia, metabolic syndrome, cardiovascular diseases, and cancer^[8]. These health-promoting attributes have contributed to the rising global popularity of dragon fruit, which is consumed fresh or incorporated into beverages, jellies, and chocolates. Its pigments also serve as natural colorants in both the food and pharmaceutical industries. Among the commonly cultivated species, *H. megalanthus* bears yellow skin with white pulp, *H. polyrhizus* has red skin with red pulp, and *H. undatus* is characterized by red skin with white pulp. The fruit typically has an oval shape, sweet-sour pulp, and numerous small, dark seeds^[9,10].

2. Phytochemistry

Dragon fruit is a nutrient-dense fruit and a valuable source of vitamins, antioxidants, dietary fiber, carotenoids, phenolic compounds, minerals, fatty acids, phytosterols, betacyanins, and hylocerinin, among others. Incorporating dragon fruit into a balanced diet may provide multiple health benefits, including antioxidant defense, digestive health support, and overall well-being^[11]. Beyond its exotic taste and striking appearance, dragon fruit offers an impressive phytochemical profile that enhances its nutritional and therapeutic potential. This review provides an in-depth analysis of the phytochemistry of dragon fruit and its associated health-promoting properties.

Nutritionally, dragon fruit contains appreciable levels of calcium, phosphorus, magnesium, and vitamin C, making it a functional food for bone health, muscle function, and electrolyte balance. Vitamin C (ascorbic acid), in particular, plays a vital role as a water-soluble antioxidant, supporting immune defense, collagen synthesis, and cellular protection against oxidative stress. Additionally, dragon fruit contributes to carbohydrate metabolism, cardiovascular function, and blood sugar regulation, thereby aiding in the prevention of hypertension and diabetes. The fruit also supplies iron, pectin, dietary fiber, and organic acids such as citric and malic acid, which not only influence flavor and pH balance but also participate in metabolic pathways^[12-15].

The vivid coloration of dragon fruit is attributed to betalains, a group of water-soluble pigments with strong antioxidant capacity. Betacyanins, responsible for the bright red and pink hues, have been studied for their antioxidant and anti-inflammatory properties, which may help

neutralize free radicals, lower the risk of chronic diseases, and contribute to overall health maintenance^[16,17].

Dietary Fiber

Dragon fruit is a rich source of both soluble and insoluble dietary fiber. Fiber plays a crucial role in supporting digestive health by promoting regular bowel movements, preventing constipation, and contributing to weight management by inducing satiety^[18].

Carotenoids

Among the carotenoids identified in dragon fruit, beta-carotene serves as a precursor of vitamin A, which is essential for maintaining vision, immune defense, and healthy skin. In addition to carotenoids, dragon fruit contains various amino acids, carbohydrates, and simple sugars. Both white- and red-fleshed varieties have been shown to contain amino acids such as leucine, threonine, valine, histidine, lysine, alanine, serine, aspartic acid, glycine, and proline. The relative concentrations of these amino acids vary depending on the cultivar and growth conditions. Although dragon fruit is not primarily consumed for its protein content, these amino acids contribute to its nutritional profile^[19]. The fruit also contains carbohydrates in the form of glucose, fructose, and sucrose. Glucose serves as the primary fuel for cellular activities, while fructose provides sweetness and quick energy. Sucrose, a disaccharide of glucose and fructose, functions as a transport sugar in plants, facilitating energy transfer from photosynthetic tissues to developing fruits^[20].

Polyphenols

Dragon fruit is abundant in flavonoids and other polyphenols, which contribute to its antioxidant potential. These compounds are associated with anti-inflammatory, cardioprotective, and neuroprotective effects. They also play a protective role in plants by mitigating damage caused by UV radiation, pathogens, and environmental stress^[20].

Phenolic Compounds

Key phenolic constituents of dragon fruit include flavonols and hydroxycinnamic acids, which exhibit anti-inflammatory and antioxidant activities. Specific phenolic acids isolated from the fruit include gallic, vanillic, syringic, protocatechuic, p-coumaric, and caffeic acids^[21].

- **Quercetin:** A flavonoid with strong antioxidant activity, helping protect cells from oxidative stress.
- **Kaempferol:** Exhibits both antioxidant and anti-inflammatory effects.
- **Catechins:** Found in tea and dragon fruit, catechins may support cardiovascular health and exhibit anticancer activity.
- **Epicatechin:** Known for its cardioprotective benefits and potential to improve blood flow.
- **Proanthocyanidins:** Potent antioxidants that may further enhance the fruit's health-promoting effects.

The composition and concentration of these flavonoids vary with the cultivar, maturity stage, and environmental conditions.

Fatty Acids: Dragon fruit contains small but significant amounts of healthy fatty acids, particularly linoleic acid, which supports membrane integrity and cellular function. Pitaya seed oil is especially rich in lipids, sterols, phenols,

and tocopherols, making it a valuable source of essential fatty acids such as linoleic, oleic, and palmitic acids. Additionally, phytoconstituents such as n-hexadecanoic acid, 1-hexadecyne, 2-chloroethyl linoleate, octacosane, and trichloroacetic acid hexadecyl ester have been identified in the peel of *H. undatus* and *H. polyrhizus*^[22].

Phytosterols

Dragon fruit also provides phytosterols, plant-derived compounds structurally similar to cholesterol. These bioactive molecules are linked to cholesterol-lowering properties and may contribute to improved cardiovascular health^[22].

Hylocerenin

Hylocerenin, a unique phytochemical identified in certain species such as *H. costaricensis*, exhibits notable antioxidant properties. Although its full pharmacological profile is not yet well characterized, ongoing research suggests it may have promising therapeutic applications^[22].

Health Benefits

Dragon fruit is associated with multiple health-promoting properties, including the enhancement of appetite, vision, and memory. It exhibits anti-aging effects cancer-preventive potential and positive impacts on the immune system, metabolism, digestion, oxidative stress, diabetes, and cardiovascular health. Species of *Hylocereus* have long been valued in traditional medicine, particularly in Latin America, where the leaves and flowers have been used for their hypoglycemic, diuretic, and wound-healing activities. Regular consumption of red pitahaya is considered beneficial for cardiovascular health, as its natural antioxidants including vitamin C, vitamin B3, and flavonoids may reduce cholesterol and hypertension, thus lowering the risk of heart disease^[23-25]. Dragon fruit is also regarded as a suitable fruit for diabetic patients due to its low sugar content and the presence of glucose, which aids in blood sugar regulation. Consistent intake has been traditionally reported to relieve conditions such as cough, asthma, and skin sores. Owing to its richness in calcium and phosphorus, dragon fruit supports bone and dental development, while also contributing to improved eyesight and skin health through its anti-aging properties^[26-28].

4. Nutritional Value of Dragon Fruit

Dragon fruit contains a diverse range of phytochemicals, including polyphenols, flavonoids, and vitamin C, which contribute to its strong antioxidant capacity. Flavonoids such as kaempferol, quercetin, and isorhamnetin have been identified in both flowers and fruits, while the pulp of purple varieties is particularly rich in anthocyanins natural pigments that provide antioxidant activity and protect against capillary fragility. The red peel is a nutrient-dense source of vitamins B1, B2, B3, and C, as well as minerals. Compared to many subtropical fruits, dragon fruit demonstrates relatively high antioxidant activity^[29-31].

Nutritionally, dragon fruit is low in carbohydrates and fat-free, yet high in dietary fiber, essential minerals (Ca, Fe, P), and vitamins B1, B2, B3, and C. Its seeds, which make up around 50% of the fruit's fatty acid content, provide important polyunsaturated fatty acids such as linoleic and linolenic acid. Edible black seeds are rich in vitamins, minerals, soluble carbohydrates, proteins, calcium, and

magnesium, further enhancing the fruit's nutritional value. Vitamin C (ascorbic acid), present in significant amounts, is a key water-soluble antioxidant that supports physiological function and facilitates iron absorption. Experimental studies have shown that red-pulp dragon fruit, rich in betacyanins, protects against diet-induced obesity and related metabolic disturbances. Moreover, clinical evidence indicates that regular dragon fruit consumption can elevate HDL cholesterol levels while reducing total cholesterol, triglycerides, and LDL cholesterol in patients with type 2 diabetes^[32].

3. Medicinal Value of Dragon Fruit

Dragon fruit (*Hylocereus* spp.), although primarily consumed as food, also possesses notable medicinal applications. It has been explored for its role in managing prediabetes, hypertension, obesity, diabetes, hyperlipidemia, and related metabolic disorders. The red variety, being a natural source of iron, has the potential to elevate erythrocyte and hemoglobin levels, suggesting its use in addressing anemia. Additionally, the presence of phytoalbumin confers chemopreventive properties, while its rich phytochemical profile may contribute to reducing disease incidence. Essential nutrients and bioactive compounds in dragon fruit include vitamins (B1, B2, B3, C, carotene, cobalamin), minerals (iron, phosphorus, calcium), proteins, polyphenols, phenols, flavonoids, carbohydrates, glucose, lipids, and betalains (betacyanin and betaxanthins)^[36]. Traditionally, pitahaya has been utilized to relieve asthma, cough, and digestive disorders, regulate blood sugar, lower blood pressure, and eliminate toxins, including heavy metals, from the body. It has also been linked to the prevention of colon cancer. Interestingly, even the stem exhibits therapeutic potential; premature stems contain higher levels of ascorbic acid than the pulp and may reduce certain disease risk factors. Leaves and flower extracts of *H. undatus* have been reported to promote wound healing in traditional tropical medicine^[36].

Key medicinal properties of dragon fruit include:

- Antioxidant properties: Dragon fruit is a rich source of natural antioxidants that protect against cellular damage caused by free radicals, which are implicated in aging, cancer, and cardiovascular diseases. Phenolic compounds, flavonoids, tannins, alkaloids, vitamin C, anthocyanins, and betalains (especially from the peel) contribute to its potent radical-scavenging activity^[37].
- Antidiabetic properties: Diabetes mellitus results from impaired insulin secretion or sensitivity. Dragon fruit has shown potential in reducing blood glucose levels by mechanisms such as inhibition of α -glucosidase, enhancement of insulin sensitivity, stimulation of insulin secretion, and suppression of hepatic gluconeogenesis. Animal and preliminary human studies suggest that high doses of red and white pitaya significantly reduce blood glucose, although more clinical trials are needed to confirm these effects [46].
- Antimicrobial properties: Secondary metabolites of dragon fruit exhibit defensive roles against microbial invasion. Extracts of both red and white varieties demonstrated antibacterial activity against a range of

pathogenic microorganisms, indicating their potential in infection management.

Anticancer activity:

Owing to its high content of antioxidants (polyphenols, anthocyanins, betalains, triterpenoids, and steroids), dragon fruit shows promise in cancer prevention. Betalains in particular display both antimicrobial and anticancer effects by inhibiting cyclooxygenase enzymes (COX-1 and COX-2), reducing lipid peroxidation, and suppressing tumor cell growth. Extracts of *H. polyrhizus* and *H. undatus* have shown cytotoxic activity against prostate (PC3), breast (Bcap-37), and gastric (MGC-803) cancer cell lines, with pitaya peel extracts obtained through supercritical CO₂ extraction exhibiting especially strong effects^[37,38].

Wound-Healing Activity:

Wound repair is a multistage biological process involving the extracellular matrix, multiple cell types, and soluble mediators such as growth factors and cytokines. Its ultimate goal is to restore tissue integrity following injury. Extracts from the stem and flowers of dragon fruit have been shown to promote fibroblast migration, a key event in wound healing, while also demonstrating significant DNA protective activity. The peel of red dragon fruit (*Hylocereus polyrhizus*) contains bioactive compounds such as flavonoids, niacin, cobalamin, terpenoids, carotene, phytoalbumin, betalains, tannins, and saponins. Flavonoids inhibit lipid peroxidation, thereby accelerating tissue repair, while tannins and saponins play a direct role in tissue regeneration^[39].

Anti-Hyperlipidemic and Anti-Obesity Properties:

Dyslipidemia is a complex metabolic disorder and a major risk factor for atherosclerosis and cardiovascular diseases. Extracts of pitaya peel, rich in crude fiber (69.30% total

dietary fiber, comprising 56.50% insoluble and 14.82% soluble fiber), have been reported to reduce hyperlipidemia by lowering caloric intake. These fibers bind bile acids and cholesterol in the intestine, promoting their excretion and improving insulin sensitivity. In addition, phenolics, polyphenols, and flavonoids present in dragon fruit extracts contribute to lowering serum lipid levels by inhibiting intestinal cholesterol absorption and enhancing its fecal elimination^[39].

Hepatoprotective property:

The hepatoprotective potential of pitaya is attributed to its abundance of antioxidants, including triterpenes, flavonoids, glycosides, tannins, saponins, and alkaloids, which safeguard liver tissues against oxidative stress and damage^[39].

Anti-Inflammatory Property:

Dragon fruit exhibits anti-inflammatory effects owing to its phytochemical composition, notably betalains and squalene. Betalains extracted from the peel of *H. polyrhizus* possess potent antioxidant activity, reducing inflammatory responses by neutralizing free radicals, which are key mediators of inflammation^[40].

Anti-Anemia Property: Dragon fruit provides several nutrients vital for erythropoiesis, including iron, vitamin C, vitamin E, vitamin B12, thiamine, and riboflavin. Its high vitamin C content enhances the absorption of non-heme iron, thereby supporting hemoglobin synthesis and improving anemia management. In recent years, dragon fruit has attracted significant attention due to its rich profile of phytochemicals, many of which are found not only in the edible pulp but also in waste components such as the peel. These bioactive compounds underscore the potential of dragon fruit as a functional food and a source of natural therapeutic agents^[40].

Table 1: Functions of some of the main antioxidant compounds and minerals contained in Dragon fruit^[33-35]

Components	Property	Functions	Amount
Betanin	Antioxidant	High free radical scavenging activity and oxidative stress inhibition are two characteristics of betanin.	2.0 g sample with 20 mL of 80% methanol in a 250 mL Erlenmeyer flask
Betalains	Antioxidant, cardioprotection, antiobesity	Betalains possess the ability to reduce cancer cell growth and combat oxidative stress, making them beneficial in supporting overall health. Additionally, they can aid in weight loss and improve digestion, while also helping to reduce LDL cholesterol levels in the blood and strengthen the immune system.	42.71 ± 2.48 mg/100 g fresh pulp
Linoleic acid and linolenic acid	Antiobesity, cardioprotection	Dragon fruit seeds are rich in omega-3 and omega-6 fatty acids, which have been shown to lower triglyceride levels and decrease the likelihood developing cardiovascular diseases.	Linoleic acid and linolenic acid
Flavonoids	Neuroprotection	Flavonoids work on blood vessels and brain cells to lower the risk of heart disease. It decreases heart disease and keeps blood pressure stable.	White-fleshed 26.71 ± 4.46 mg RE/100 g FW and Red fleshed 46.29 ± 2.47 mg RE/100gFW
Hydroxycinnamates	Anticancerous	It prevents cancer because of hydroxycinnamates.	Minor amounts of hydroxycinnamic acids

Carotenoids (Beta- carotene)	Anticancerous, cardioprotection	decreased risk of heart disease and cancer	1.41 mg/100 g
Lycopene	Anticancerous	Lycopene reduces the proliferation of several human cancer cell lines.	3.39 mg/100 g
Iron	Better visual functions	Red dragon fruit has a lot of iron, which causes pregnant women's levels of haemoglobin and erythrocytes to rise.	1.90 mg/100g
Phosphorus (P) and calcium:(Ca)	Body strengthening	Dragon fruit contains significant amounts of phosphorus and calcium, which play a crucial role in promoting the development of robust bones, healthy teeth, and tissues.	P 22.49 mg/100g and Ca 8.5 mg/100g

Table 2: Pharmacological effect and activities^[36-38]

S.no.	Pharmacological effect	Pharmacological activity
1	Antioxidant properties	There has been an increase in the utilization of natural antioxidant substrates found in medicinal plants that have protective effects against cellular damage brought on by free radicals, which are linked to many disorders like cancer. Thus, the antioxidant (radical-scavenging) qualities of many plants' constituent phenolic chemicals (such as phenolic acids, lignans, flavonoids, stilbenes, and tannins), vitamin C and alkaloids could be responsible for their popularity in disease prevention. An abundant source of antioxidants, dragon fruit peel extract contains betacyanin and anthocyanin and has a strong enough activity against free radicals.
2	Antidiabetic properties	Diabetes mellitus, a widespread systemic condition, occurs due to either the pancreas' incapacity to produce adequate insulin or the cells' reduced responsiveness to insulin's effects.
3	Antimicrobial properties	Secondary metabolites that plant life synthesized following microbial contamination are linked to the physiological and biochemical basis of a plant's resistance to attacks by specific diseases (such as viruses, fungi, or bacteria).
4	Anticancer activity	As a result of its high concentration of potent antioxidants such polyphenol, anthocyanin, betalains, steroids, and triterpenoids, dragon fruit has the potential to inhibit the growth of cancer cells. In addition to having antibacterial qualities, betalains have the ability to prevent the growth of human tumour cells, lipid peroxidation, and the cyclooxygenase (COX-1 and COX-2) enzymes.
5	Wound healing activity	The process of healing a wound is a multistage process that involves many different cell populations, the extracellular matrix, and the action of soluble mediators like growth factors and cytokines. It is designed to restore the integrity of damaged tissues. Extracts from the dragon fruit's stem and bloom encourage fibroblast migration, which is essential for the healing of wounds.
6	Anti- hyperlipidemic and anti-obesity properties	Due to its propensity to accelerate atherosclerosis, dyslipidemia is a complicated condition and a significant risk factor for unfavorable cardiovascular events. Pitaya peel extracts helped to reduce hyperlipidemia because of its high crude fiber content (69.30% total dietary fiber, broken down into 56.50% insoluble food fiber and 14.82% soluble food fiber), which lowers caloric consumption.
7	Hepatoprotective property	Pitaya's potent antioxidant content, which includes triterpenes, flavonoids, glycosides, tannins, saponin, and alkaloids, may contribute to its hepatoprotective properties.
8	Anti-inflammatory property	Due to the presence of substances like squalene and betalains in it

Table 3: The phytochemicals present in different parts of the plant^[39-40]

Aerial Parts	Phytochemical compounds	Method
Pulp and peel	Betacyanin, phenolics, flavonoids	Color test followed by UV-Vis
Pulp	Carbohydrates, proteins, amino acids, alkaloids, terpenoids, steroids, glycosides, saponins	NA
Fruit	Glycosides, alkaloids, phenols, tannins, steroids	Color tests
Peel	Quinic acid, cinnamic acid, 3-O-rutinoside, jasmonic acid, octadecanoic acid	UHPLC-ESI-QTRAP-MSMS
Pulp and stem	Phenolics	Color test followed by UV-Vis

4. Conclusion

Dragon fruit (*Hylocereus* spp.), commonly known as pitaya, stands out as a nutrient-rich exotic fruit with remarkable nutritional, phytochemical, and pharmacological potential. Its diverse composition-including vitamins, minerals, dietary fiber, essential fatty acids, polyphenols, flavonoids, carotenoids, betalains, and unique compounds such as hylocerenin-contributes to its wide range of biological activities. Evidence from traditional uses and contemporary research highlights its antioxidant, anti-inflammatory, antidiabetic, anticancer, antimicrobial, hepatoprotective, anti-obesity, wound-healing, and anti-anemia properties. Beyond its medicinal significance, dragon fruit is gaining global popularity as a functional food due to its ability to support digestive health, regulate blood sugar, lower cholesterol, strengthen bones, and improve cardiovascular well-being. Importantly, both edible and non-edible parts of the fruit, including the peel and seeds, possess valuable phytochemicals, making them potential candidates for nutraceutical and pharmaceutical applications. Despite growing evidence of its health-promoting benefits, further clinical investigations and mechanistic studies are necessary to validate its pharmacological efficacy and establish standardized formulations. Overall, dragon fruit holds immense promise not only as a dietary component but also as a natural therapeutic agent, offering exciting opportunities for future research and development in functional foods and modern medicine.

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