International Journal of Herbal Medicine
Available online at www.florajournal.com

E-ISSN: 2321-2187
P-ISSN: 2394-0514
www.florajournal.com
IJHM 2025; 13(3): 19-24
Received: 16-02-2025
Accepted: 20-03-2025

Sakshi A Kokare
Shri Swami Samarth Institute of Pharmacy, At Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Vaishnavi S Kalamb
Shri Swami Samarth Institute of Pharmacy, At Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Ravindra L Bakal
Department of Quality Assurance, Shri Swami Samarth Institute of Pharmacy, At Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Pooja R Hatwar
Department of Pharmaceutical Chemistry, Shri Swami Samarth Institute of Pharmacy, At Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Kajal S Jumde
Department of Pharmaceutics, Shri Swami Samarth Institute of Pharmacy, At. Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Corresponding Author:
Sakshi A Kokare
Shri Swami Samarth Institute of Pharmacy, At Parsodi, Dhamangaon Rly, District Amravati, Maharashtra, India

Unlocking the secrets of dragon fruits

Sakshi A Kokare, Vaishnavi S Kalamb, Ravindra L Bakal, Pooja R Hatwar and Kajal S Jumde

DOI: https://www.doi.org/10.22271/flora.2025.v13.i3a.983

Abstract
Dragon fruit, a tropical and subtropical fruit belonging to the Cactaceae family, has gained popularity worldwide due to its rich nutritional profile and potential health benefits. This review aims to provide a comprehensive overview of the taxonomy, morphology, cultivation, nutritional value, health benefits, and utilization of dragon fruit. The fruit is rich in antioxidants, vitamins, and minerals, and contains bioactive compounds with potential anti-cancer, immunomodulatory, hepatoprotective, antibacterial, and anti-diabetic properties. Dragon fruit has been explored for its potential uses in food products, including natural colouring and prebiotic enrichment. Its peels and seeds, often discarded, have been found to possess valuable nutrients and bioactive compounds. With its adaptability to various climates and increasing demand, dragon fruit presents opportunities for farmers and industries. This review highlights the potential of dragon fruit as a valuable crop for improving health and nutrition.

Keywords: Dragon fruit, pitaya, *Hylocereus* nutrition, antioxidants, health benefits, phytoconstituents

1. Introduction
The pitaya fruit, also known as dragon fruit, is a popular member of the *Cactaceae* family and is grown extensively in tropical and subtropical regions. White-pulp pitaya (*Hylocereus undatus*), red-pulp pitaya (*Hylocereus polyrhizus*), and white-pulp pitaya (*Hylocereus megulanthu*) are the three types of pitaya fruit that are categorised according to the colour of their pulp and peel [1]. Because of the skin layer that has "scales", this fruit is also known as dragon fruit. The term "moon flower or mistress of the night" refers to the fact that dragon fruit blooms only grow at night, which is special in addition to the skin surface that has "scales". Bats are responsible for nighttime pollination. Dragon fruit is a fruit that belongs to the *Cactaceae* family and is susceptible to extremes in temperature and works best in arid regions where the temperature doesn't rise above 45 °C [2]. Dragon fruit has a rather pleasant taste and is also known in Malaysia as "*bush naga*" or "*buah mata naga*" [3]. Dragon fruit is high in antioxidants, vitamins, and minerals and low in calories. Iron, magnesium, and vitamin C are all abundant in it. A trellis or other strong structure is necessary for the climbing cactus plant to develop. The colour, shape, and size of dragon fruit vary across the several types that are available [4]. In several nations, dragon fruit is growing in popularity. It can be eaten raw or added to cocktails, sweets, and jellies. Also, the pigments can be utilised as colouring agents in the food and pharmaceutical sectors [5]. The pulp is white contains many edible black seeds, which is juicy and tender and can be eaten raw or in the form of liquids, ice cream, and jelly [6]. Fruit and vegetable-rich diets are frequently advised due to their potential to improve health [7]. Red dragon fruit peel (RDFP) is one of the plants that have the potential to be extracted as a crude extract that can subsequently be processed into herbal medicines [8]. Phytoconstituents from various plants in the form of crude extract need to be further identified and screened so that it is standardised with the aim of healing management. Dragon fruit is a great way to get nutrients, including calcium, phosphorus, and vitamin C. Higher therapeutic benefits include lowering blood pressure, lowering cholesterol, balancing blood sugar, preventing colon cancer, enhancing kidney and bone function, enhancing brain function, improving vision, and even being used as a cosmetic element. The iron-rich, red-fleshed dragon fruit raises haemoglobin and erythrocyte levels. The pulp reduces aortic stiffness, effectively manages oxidative damage, and provides diabetic patients with dietary fibre. The essential fatty acids linoleic and linolenic acid, which are needed as substrates in human metabolism and cannot be produced *in vivo*, are abundant in dragon fruit seeds. Rich in polysaccharides and mixed oligosaccharides, dragon fruit flesh is a natural probiotic [9]

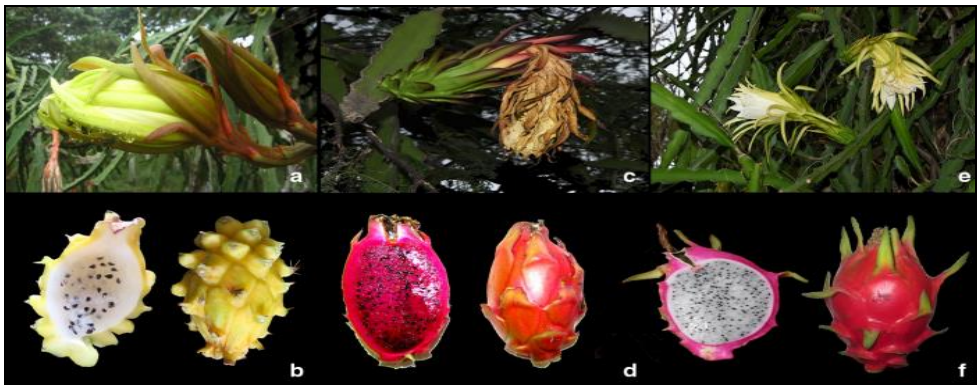

Fig 1: Flowers and fruits of selected species of Selenicereus. **A&b**-Selenicereus megalanthus in Boyacá, Chitaraque, Colombia. **c&d**-S. ocamponis in Oaxaca, San Martín Toxpalán, Mexico. **e&f**-S. undatus in Puebla, San Antonio Texcala, Mexico. Photo [10].

2. Taxonomy

- Kingdom: Plantae
- Division: Spermatophyta
- Class: Dicotyledonae
- Ordo: Cactales
- Family: Cactaceae
- Genus: Hylocereus
- Species: *Hylocereus polyrhizus*, *Hylocereus undatus*, *Hylocereus megalanthus* [2].

3. Morphology

Among the dragon fruit kinds, white, red, and yellow are the most widely cultivated. The oblong shape and white pulp colour of white and yellow dragon fruit are characteristics of these fruits, but the rounded shape and red-violet pulp colour of red dragon fruit are more common. However, the yellow dragon fruit has yellow skin, and the red dragon fruit and white dragon fruit have red peels [11].

The dragon fruit plant (*Hylocereus* spp.) is a rapidly growing evergreen cactus with thin, leafless vine-like branches that can grow up to 1.5 to 2.5 meters in height. It is an epiphytic or terrestrial cactus with green, succulent branches that have three wings [12].

The flowers of these two species appear under the areoles; they are large (more or less 30 cm), in the shape of a funnel, and nocturnal. The ovary is located at the base of a long tube carrying the foliaceous scales to the exterior. There are numerous stamens on a slender anther stalk. The unusually large, tubular style is 20 cm in length and 0.5 cm in diameter; the stigmas have 24 slender lobes, creamy green in colour [13]

Fig 2: Dragon fruits plant with flower and fruit [12]

Fig 3: Inner part of dragon fruit [14]

4. Cultivation

A semi-epiphytic plant, dragon fruit thrives in a dry tropical or subtropical climate with average temperatures between 21 and 29 °C. However, it can tolerate temperatures as high as 38 to 40 °C and even below freezing for brief periods of time. With alternating wet and dry seasons, this crop needs 600-1300 mm of rainfall and sunshine [12]. In contrast to the control samples, which were kept fresh for just 14 days, dragon fruit was harvested after 28 to 30 days of blooming and successfully stored for 35 days at 10 °C under modified atmosphere (MA) in a PE bag (O_2 transmission rate 4000 ml/m²/day) [15].

From a small 12-hectare farm in the early 1990s, the area planted with dragon fruit has grown to nearly 600 hectares with a volume of production of more than 1800 Mt in 2020 [16]. In particular, climbing cacti with edible fruits have been proposed as new dry land fruit crops due to their high degree of water-use efficiency [17]. The plants are anchored by aerial roots that grow from the underside of the stems, allowing them to climb on walls, rocks, or trees [18]. Beginning with the fruit's flesh creation and continuing for 21 days following anthesis, the fruit was harvested every 7 days until its abscission, which took place 70 days after anthesis [6]. The tropical and subtropical dragon fruit (*Hylocereus undatus*) passes through several ripening cycles all year long [19]. Fruit's maturity level during harvest has an impact on post-harvest growth and ultimately determines its quality. While overripe fruit is likely to exhibit senescence, resulting in both quantitative and qualitative losses, prematurely picked fruit is vulnerable to physiological problems brought on by cellular disarray and cell wall rupture [20].

The fruit of *Selenicereus* is very important to the business. The peel and pulp can be used to make natural dyes, and the seeds, which contain unsaturated fatty acids, may be used in food, cosmetics, or medicine [21]. Dragon fruit is a new and promising crop that presents both potential and problems, and farmers across the world are enthusiastic about its growth [22].

5. Nutritive Value

Several minerals and nutrients can be found in red dragon fruit, such as vitamin B3, B1, and B2, fats, carbohydrates, protein, betacyanin, phytoalbumin, carotene, cobalamin, ascorbic acid (vitamin C) [23]. The B vitamin group (B1, B2, and B3), which is abundant in dragon fruit, plays a significant role in health benefits. While vitamin B2 in dragon fruit functions as a multivitamin, it also helps to restore and enhance appetite loss. Vitamin B1 aids in boosting energy production and in the metabolism of carbohydrates. Additionally, vitamin B3, which is found in dragon fruit, helps to reduce bad cholesterol and gives skin a smooth, hydrated appearance. Additionally, it prevents hypertension and enhances vision [24]. Pectin is a polysaccharide present in almost all plants to maintain the integrity of the cell structure [25].

Dragon fruit has enormous nutritious content in all its parts, including the pulp, peel, seeds, flower buds, and dried flowers. The red dragon fruit is one naturally occurring source that is well known to have antioxidant potential [26]. Red beetroot roots (Beta vulgaris) and the dragon fruits from *Hylocereus cacti*, primarily *Hylocereus polyrhizus*, are two of the Caryophyllales plants (Hempel & Bohm, 1997) notable dietary sources of betaxanthins and betacyanins [27].

Table 1: Nutritional value per 100 g FW of different species of pitaya (*Hylocereus* spp.) [28]

Nutritional Compositions	H. undatus	H. polyrhizus	H. megalanthus
Total phenolic content	28.65 mg GAE	24.22 mg GAE	22.90 mg GAE
Carbohydrates	6.26 g	5.97 g	13.07 g
Dietary Fiber	0.83 g	1.01 g	1.27 g
Total sugar	6.06 g	5.60 g	5.93 g
Protein	0.94 g	0.89 g	0.40 g
Fat	0.57 g	0.57 g	0.10 g
Iron	0.87 mg	0.78 mg	21.07 mg
Zinc	0.34 mg	0.29 mg	4.35 mg
Sodium	4.50 mg	14.30 mg	1.43 mg
Niacin	0.43 mg	2.80 mg	0.20 mg
Potassium	193.0 mg	158.29 mg	98.41 mg
Phosphorus	29.9 mg	29.2 mg	18.0 mg
Calcium	45.7 mg	31.2 mg	11.7 mg
Magnesium	45.9 mg	33.2 mg	16.1 mg
Glucose	1.58 mg	1.33 g	0.99 g

6. Geographical Distribution

A potential tropical fruit, dragon fruit (*Hylocereus* spp.) may be grown in a variety of tropical and subtropical regions of the world, including Southeast Asia, Central America, and South America [29]. Extensively grown in Southern China, Vietnam, Malaysia, Taiwan, China, Okinawa, and Israel [30].

Many nations, including Australia, Cambodia, China, Colombia, Ecuador, Guatemala, Hawaii, Indonesia, Israel, Malaysia, New Zealand, Peru, the Philippines, Taiwan, Thailand, Spain, Sri Lanka, and Vietnam, have successfully adopted dragon fruit production. This fruit crop was just recently introduced in India, and only a small number of producers have begun to cultivate it in regions such as Maharashtra, Karnataka, Gujarat, West Bengal, etc. [31]. The primary traditional fruit and most popular local fruit in their native area are the fruits of *Hylocereus* spp. [13].

7. Health Benefits

Due to its nutritional and medicinal qualities, the dragon fruit has many positive effects on human health, namely in the area of managing and controlling oxidative stress. Many people in the community have been using this fruit as a blood-boosting medication and as a treatment to improve endurance [32]. The dietary and therapeutic benefits of dragon fruit are well documented [33].

The flesh leaves, and fruit skin of red dragon fruit are all parts that can be used for health. Consequently, it is anticipated that this fruit will be able to be utilised as an alternative medication to treat anaemia [32]. Red dragon fruit peel (RDFP) is one of the plants that have the potential to be extracted as a crude extract that can subsequently be processed into herbal medicines. Phytoconstituents from various plants in the form of crude extract need to be further identified and screened so that it is standardised with the aim of healing management [8].

7.1 Anticancer activity

One of the major causes of death in the world that requires attention is cancer. Natural components with anticancer properties can be very helpful in the treatment of cancer. The cytotoxic impact of dragon fruit phytoconstituents has been demonstrated in numerous investigations [33].

Dragon fruit's high antioxidants, including polyphenol,

anthocyanin, betalains, steroids, and triterpenoids, are linked to its antiproliferative properties. Fruits with high polyphenol content have exceptional antioxidant properties and may reduce the risk of cancer. The ant proliferative effects of dragon fruit methanol extract on HepG-2 cells may also be due to the antioxidant activities of the fruit's phenols, betalains, and other antioxidant compounds [34].

7.2 Immunomodulatory activity

A chemical that influences the immune system is called an immunomodulator. Both the innate and adaptive immune systems, which have extremely intricate biochemical mechanisms, make up immunity. Polysaccharides, terpenoids, saponins, alkaloids, iso-flavonoids, glucosides, tannins, fatty acids, steroids, triterpenes, and flavonoids are a few substances that have the ability to modulate the immune system. The purpose of this study was to separate and identify the active ingredients in *H. polyrhizus* peels that can strengthen the body's immune system [35].

7.3 Hepatoprotective activity

Tri-terpenoids glycosides, tannins, saponins and flavonoids are the bioactive compounds present in fruit which possess hepatoprotective activity. These phytoconstituents provide shield to the liver against fat peroxidation followed by progression in Serum Glutamic-Pyruvic Transaminase (SGPT) & Serum Glutamic-Oxaloacetic Transaminase (SGOT). Hylocereus polyrhizus species protect the liver from damage caused due to the carbon tetrachloride [23].

7.4 Antibacterial

The White Pitaya (*Hylocereus undatus*) Peel Flavonoid Extract exhibits antibacterial activity against Escherichia coli, according to antibacterial testing. It is ineffective against *Staphylococcus aureus* at all concentrations, although it is moderately active against E. coli at 100% concentration. Both *S. aureus* and *E. coli* cannot be killed by the White Pitaya Flesh Flavonoid Extract [36].

7.5 Anti-diabetic Action

One of the leading causes of death worldwide is diabetes, commonly known as diabetes mellitus, a metabolic disease. Research on natural or herbal remedies for diabetes is growing quickly. Due to its cAMP phosphodiesterase inhibitory effect, Undatus is thought to maintain insulin for a longer amount of time. The phytoconstituents included in white dragon fruit are quite effective at reducing blood sugar levels. Three distinct mechanisms, including increasing insulin retention, blocking phosphodiesterase, and reducing oxidative stress through antioxidant action, are how flavonoid concentration mediates hypoglycaemic function [33]. Red dragon fruit peel boiled into water offers anti-diabetic properties [37].

7.6 Inflammation-reducing effects

Dragon fruit's composition, which contains compounds like betalains and squalene, offers it anti-inflammatory and antioxidant properties. Rodriguez *et al.* (2016) discovered that betalains from the peel extract of H. polyrhizus, both encapsulated and non-encapsulated, had anti-inflammatory qualities. Although encapsulation can increase the bioactivity of betalains, they are unstable and susceptible to degradation-causing factors such light, oxygen, pH, and temperature [33].

8. Storage

The rate of respiration and PLW have an impact on the postharvest storage life. Yellow pitaya (*Selenicereus megalanthus*) should be stored at 6 °C, while dragon fruit (*Hylocereus undatus* and *Hylocereus polyrhizus*) should be stored at 10 °C [15].

9. Utilisation in Food Products

A staple in numerous foods, such as bread, cookies, pasta, and noodles, is wheat. Due to the existence of two gluten protein components, gliadin and glutenin, wheat flour can be combined with water to produce elastic dough [38]. Mostly waste products that are typically thrown away after being processed by the dragon fruit juice business [39]. Because of its abundance of minerals and comparatively low-calorie content, dragon fruit is regarded as one of the "superfoods"[40].

Dragon fruit's profusion of antioxidants and pigments, such as polyphenols, hydroxycinnamates, flavonoids, betacyanin, and betalains, are used by the food processing industry for prebiotic enrichment and natural colouring [20].

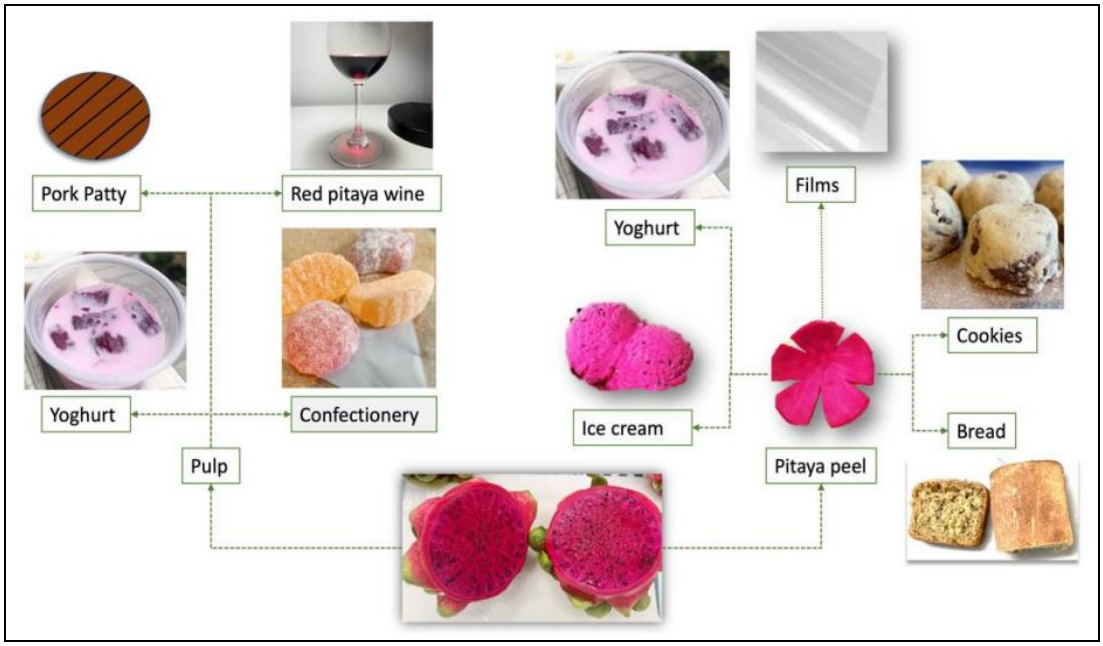

Fig 4: Utilisation of red pitaya in food products [1]

10. Conclusion

Dragon fruit appears to have many commercial selling factors, according to the article above. Growers from all over India are drawn to them because of their appealing shape and colour as well as their excellent nutraceutical qualities. The two primary organic food dyes, betacyanin and betaxanthin, which give the outer layer of the peel its red and yellow hues, respectively, cause the pulp and peel of different pitaya species to differ in colour. Pectin from dragon fruit peels can be extracted using HCL solution, producing an 11% pectin yield. According to the findings of various studies, dragon fruit can help prevent a number of human ailments. Accordingly, dragon fruit can be categorised as a fruit that falls within the category of medicinal plants, which can be used as a substitute for pharmaceuticals based on chemicals. Dragon fruit is use as anti-inflammatory, antioxidant, and anti-diabetic, high blood pressure, and many other conditions.

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