Phytochemical composition, biological activities and nutritional aspects of H.undatus: a review

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Abstract

The most commonly cultivated vine cactus in the Cactaceae family is normally *Hylocereus undatus*, which would be native to Mexico and America. It is commonly referred to as "dragon fruit" or "pitaya." Additionally, it goes by the name "buahnaga," which means "dragon fruit." In addition to their attractive color, *Hylocereus undatus* fruits are popular around the world due to their abundance of polyphenolic components and their antioxidant activity. Due to the characteristics, degree of production, and financial benefits of the pitahaya fruit, a member of the *Hylocereus* genus, more land has been planted in agriculture during the past two decades. Stalks, fruits, and flowers from the plant are used in food and film.

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Introduction

Over 100 years ago, the French introduced dragon fruit to Vietnam. It is known as "Thanh Long" (Green Dragon), having epidermis green foliaceous bracts or scales of a dragon.[1] Several *Hylocereus* and *Selenicereus* species, popularly known as strawberry pears, give medium to large-sized fruit that the local community has long consumed.[2] One of the tropical fruits belonging to the cactus family, Cactaceae is the dragon fruit or pitaya. Three major species of dragon fruit, particularly *Hylocereus undatus* (white flesh with pink skin), *Hylocereus polyrhizus* (red flesh with pink skin), and *Selenicereus megalanthus* (white flesh with yellow skin), are available for commercial cultivation. Because of the white flesh, *Hylocereus undatus* is often known as white pitaya. *Hylocerereus undatus* was first observed in southern Mexico, and has since moved to northern Australia, Taiwan, Malaysia, and other Asian nations. Pitaya raw flesh is tasty, and has little black seeds that are scattered throughout the white flesh.[3] The most common method of propagating *H. undatus* is by cuttings, which are generated by detaching foot-long lateral branches at a stem segment.[4] Fruits are a rich source of vital vitamins and minerals, such alpha-carotene, vitamin E, vitamin C, lycopene, phosphorus, and calcium. Fatty acids are significantly important in industry and wellness. Dragon fruits are popular, affordable, and have a large market demand as a result. Therefore, they are recognized as the fruit of the future. Dragon fruit cultivation and introduction in India are recent developments, and dragon fruit is still now being adopted in different regions.[5]

Due to the dragon fruit's low water and tillage demands, farmers in Karnataka and Maharashtra are currently studying more about how to cultivate it. As an outcome, the area under cultivation will likely grow in the future.[6] High levels of polysaccharides in the stem of *Hylocereus undatus* bind to the DNA, making it viscous and glutinous during the precipitation step during extraction.[7] It has been established that this species uses water effectively.[8] Dragon fruit plants produce hermaphroditic flowers, however, it is crucial that they are mated during blossoming, which typically occurs at night. Some cultivars are incompatible with one another.[9] Conventional derivatization methods were previously used for the preparation of reaction solutions as a component of amino acid analysis. Latency typically occurs in the pH range of 8.5-10.

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Matherials and Methods

Several search engines and online databases, including SciFinder Scopus, PubMed, Google Scholar, Web of Science and Science Direct, were used to perform an extensive literature survey from this review. The key words used were Antioxidant activity, Antibacterial toxicity, Phytochemical content, wound healing, pitaya. Table 1 describes the taxonomical classification of dragon fruit, while Table 2 illustrates the different varieties of dragon fruit and countries in which they are grown. On the subject of the review, both review papers and original research projects were included, with a focus on reports released during the last ten years. Papers which were merely abstracts, unpublished manuscripts, conference proceedings, and publications in languages other than English were not taken into consideration. This is how the review is laid out: the bioactive phytochemicals of the plant *Hylocereus undatus* are first exhibited in the leaves, fruits, roots, and seeds of the plant.

Morphology

The stems of dragon fruit have a habit of rising, spreading, and sprawling. They have lots of branching, too. There may be 4-7 fruits, each of which may measure up to 10 meters in length and 10-12 centimeters in diameter. Areoles are approximately 2-5 cm apart. Adult branches have spines that are 1-4 mm long and are almost conical to acicular. Color ranges from blue-green to greyish-brown. They produce fruits oval to oblong in shape. It is 3-8 cm thick and 4-10 cm long. It has a wide, deep red frame and bracteoles. These fruits have a white pulp with several little, black seeds dispersed throughout it that can be consumed. Pitaya florescence should last about 5 days for one turn.[10] Fruit dimensions and shapes vary widely amongst breeds, ranging from nearly spherical to rectangular, and weighing between 70 and 680 g each. Dragon fruit plants produce hermaphroditic flowers, however, it is crucial that they are pollinated during blossoming, which typically occurs at night.[9] Medium fruit size was decided based on parameters such as weight and physical appearance.[11] The floral and fruiting phases each take 21-26 and 46-59 days.[12] Red pulped cuttings considerably exceeded white pulped cuttings in terms of number of roots (8.62), maximum percentage of rooted cuttings (78.77%), maximum root length (21.61 cm), maximum root fresh weight (1.30 g), and maximum root dry weight (0.46 g).[13] The different aerial parts of the dragon fruit plant are seen in the Figure 1. Also, the fruit of the *Hylocereus undatus* is shown in Figure 2 and the flower is shown in Figure 3.

Growing area

Hylocereus undatus was introduced into Vietnam by the French around 100 years ago, where it was grown exclusively for the king. Later, it became popular among some of the wealthy families all over the country. It has recently been established as a backyard and orchard plant actually providing fruit to local and export markets in Southeast Asia and Europe. The plants can grow inher-

Figure 1. *Hylocereus undatus.*

Table 1. Taxonomical classification of dragon fruit.

Domain	Eukaryota
Kingdom	Plantae (Haeckel 1866)
Subkingdom	Tracheobionta
Superdivision	Spermatophyta (seed plant) (Wilkomm 1854)
Division	Magnoliophyta (flowering plant) (Cronquist *et al.* 1966)
Class	Magnoliopsida (Dicotyledons) (Cronquist *et al.* 1966)
Subclass	Caryophyllidae (Takhtajan 1966)
Order	Caryophyllales (Jussieu 1789 ex Berchtold and Presl 1820)
Family	Cactaceae (Cactus family) (Jussieu 1789)
Subfamily	Cereoideae (Schumman 1898 published in Schumman 1899)
Tribe	Hylocereae (Buxbaum 1958)
Genus	H. (A. Berger) (Britton and Rose 1909)

Table 2. Different species of dragon fruit with their country of origin.

Species	Country	Reference
H.undatus	Southern Mexico, since moved to northern Australia, Taiwan, Malaysia, other Asian nations, cultivated in the Indian states like Tamilnadu, Andhra Pradesh, Karnataka, Maharshtra, Panjab	(Hitendraprasad & Hegde, 2020)
H.megalanthus	United States, Canary Islands, Australia, Thailand, Vietnam, Southest Asia	(Hitendraprasad & Hegde, 2020)
H.polyrhizus	Vietnam, United States, Israel, China, Malaysia, Indonesia	(Jaafar Sidek & Md Zemi, 2019)

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ently in Mexico, Central and South America, and they are also grown in gardens. Orchards are now being cultivated to provide the fruit to local and international markets in North America and Europe.[14] *Hylocereus* species are still only found in North America.[15] From May to October, several pitahaya bloom flows take place in the northern hemisphere, and the daily floral opening period varies by region. Since a significant portion of Vietnam's population and economic assets are concentrated in coastal lowlands, deltas, and rural areas, the country has been identified as one of the five most susceptible to climate change.[1,16]

Climate requirements

As an epiphyte or hemi-epiphyte, *Hylocereus* has the ability to infect its hosts from the air or introduce roots into the cambium or root pith, killing the host in the process. Pitahaya (*Hylocereus undatus*) is a tropical climate cactus that can survive mean temperatures of 21-29°C and is resistant to water stress according to Barbeau (1990). Especially in Mexico and Central America *H.undatus* is available in areas with more than 2000 mm of annual rainfall, extreme temperature ranges of 11-40°C, and elevations of up to 1840 m above sea level. Lots of rain makes flowers degrade, affecting leaves. Despite the improvement in our knowledge of how higher tropospheric CO_2 concentrations influence the net uptake of CO_2 by *Hylocereus undatus,* climate change indicates a rise in mean air temperature as a result of rising greenhouse gas concentrations.[15] As mentioned by the Koppen classification, the area's altitude is 33.0 m, and its climate is Aw, with concentrated rainfall between November and March, an annual average temperature of 23.9°C, and an average annual rain over 1213 mm.[17] The possibility for fruit farming in Brazil is even larger thanks to the country's wide landmass and favorable temperature, which encourage the technique of tropical, subtropical, and temperate climate species, as well as unique circumstances that permit year-round production. For regions where it is impossible to grow other fruits and where irrigation and a better environment are required.[16] Figure 4 shows the maps of Vietnam's dragon fruit cultivation, while Figure 5 shows the different dragon fruit varieties.

Chemical characterization

Both soluble and insoluble fibers, as well as reducing and non-reducing carbohydrates, were investigated, according to the criteria advised by the Association of Official Analytical Chemists. This investigation was conducted in triplicate.[18]

Compared to the 2012 harvest (2.62 g/100 g), pitaya peel from the 2011 harvest had fewer reducing sugars (0.70 g/100 g-1). The proliferation of bacteria resistant to antibiotics has effectively done the improvements made in antibiotic research over the past fifty years.[19] Due to low global temperatures and a moderate loss of vapor pressure at night the rainy season offers *Hylocereus undatus* the perfect circumstances for photosynthesis.[20] Preparation operations such as peeling, cutting and washing also have an impact on the microbiological quality of minimally processed foods. Washing aids in the reduction of quality deterioration triggered by microorganisms and the leaching of cellular nutrients, as well as the dramatic drop of fungicide and insecticide content.[21] Betalains, which are water-soluble nitrogenous pigments, are extensively used as synthetic dyes.[22]

Pitahaya species

Yellow pitahaya (*H.triangularis*) and red pitahaya are the two most widely produced and consumed are the types of pitahaya (*H.ocamponis)*. The cultivation techniques only refer to red and

Figure 2. Fruit.

Figure 3. Flower.

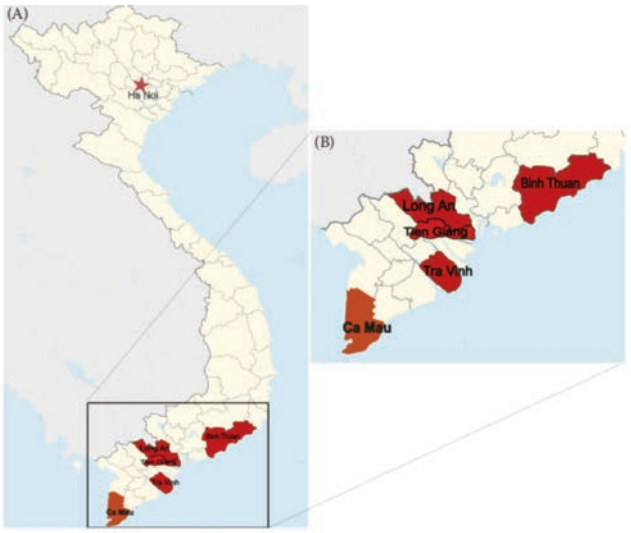

Figure 4. Maps of Vietnam's dragon fruit cultivation is concentrated in the black rectangle. **A**) with a star pointing to Ha Noi, the country's capital; the magnified map, **B**) shows the largest growing areas with the highest pitaya production, *i.e*. the southeast and the Mekong River Delta; Ca Mau province, in the country's south, has mangroves areas where dragon fruit has been successfully grown.

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yellow pitahaya. Red pitahaya is a climbing plant that grows highly tasty fruits on branches with a triangular section.[23] Pitahaya has been planted on a small scale. This plant has been established as well and its fruit has been exported from Mexico to global markets.[24] The red pitahaya fruits were discovered to include soluble solids that are demandable.[25] Cactaceae cytology research is focused on chromosome numbers but not structural chromosome aberrations.[26] Attempts have been made to evaluate the chemistry of betalains in *H.polyrhizus*.[26] Pitaya pulp is delicate, succulent, and filled with many 3 mm-diameter dark edible seeds. This fruit is recognized as being extremely nutrient-dense due to its high water content, carbohydrates, minerals, antioxidants, and low caloric intake.[16]

Botanical characteristics of pitahaya

Identical to cactus, the pitahaya's leaf system undergoes the characteristic metamorphosis in which the leaves grow thorns, serving as a significant barrier against water loss through stomata. The mechanism of chlorophyll photosynthesis by the stem and the branches, which are fleshy and green because of the chloroplasts they are gifted with. This, through a protracted but moderate evolutionary process brought on by the desert environment conversion, has actually occurred, in which cacti have survived with very little humidity. Pitahaya mimics the prickly pear tree in regards to its structure it is composed of spine branches with a triangular section, but they are unique morphologically with a form that would seem bigger. The axillary buds are where the branches arise.[23] In *Hylocereus Undatus,* separation of young flower buds caused blossoming and late cropping but had no effect on overall flower productivity.[27] The effectiveness of cladode or stem of maturity dates can be investigated, multiplication can be tested during various times of the year, rooting media can be regulated and in addition to IBA, other growth investigators can be evaluated for the growth of dragon fruit.[28] More than 90% of the 25 kinds of plant pathogens causing different diseases in dragon fruits are fungi.[29]

The burgeoning Israeli climbing cacti industry's primary markets are the contemporary European (fresh) fruit markets. These markets have specific requirements with regard to the desired fruit mass and consistent product delivery throughout the season.[26] The fruit is the most demanded product; the entire plant can be used for food and medicine.[30] Cuttings from some species root without the addition of auxin.[31] The concentrations of DNA were calculated using a fluorometer and the quality of the DNA and PCR products was illustrated on an agarose gel.[32] Because betacyanins are prevalent in the peel, it could also be used to recover colored pigments.[32]

Development of agriculture, yellow pitahaya

The genus *Hylocereus* includes many species, however, very few are cultivated due to their commercial and nutritional benefits, particularly *Hylocereus*. *H.costaricensis, H.undatus,* and *H.polyrhizus* are three species of *H.*[1] According to nutritional analysis, an average pitaya has a moisture content of 84-86 g/100 g, a protein content of 0.93-1.33g/100 g, a fat content of 0.40-1.01 g/100 g, vitamin C content of 1.0-6.3 mg/100 g, vitamin A content of 0.0066-0.186 mg/100 g, a crude fiber content of 0.88-1.84 g/100 g, glucose content of 4.6-6.39 g Iron (1.9-7.4 mg/100 g), potassium (181.0-321.0 mg/100 g), niacin (2.3-3.5 mg/100 g), calcium (7.6-15.6 mg/100 g), magnesium (29.5-44.3 mg/100 g), phosphorus (22.8-31.8 mg/100 g), sodium (5.0-13.5mg/100g), and zinc (0.26-0.42 mg/100 g) are among the other minerals present in pitaya.[33] Ninety-two point eighty-wo percent of the active ingredients in the *H.polyrhizus* extract were detected, of which 23.39% were triterpenoids, and 19.32% were steroids. The chemical elements present in these plants have anti-HIV and anti-cancer properties, argue the authors.[16] There are various nutrition parameters of dragon fruit, and their average values are shown in Table 3.

Depending on the species and origin, 100 g of fresh dragon fruit pulp contains over 80% moisture, 0.4 to 2.2 g of protein, 8.5 to 13.0 g of carbs, and 6.0 g of total sugar. This data is derived from the nutrient content of juice derived from various species and crops of dragon fruit. The nutrient values are quite unstable. Another component is the young stem of pitaya, which is very nutritious.[1] Furthermore, pitaya can be used in the pharmaceutical and cosmetic industry due to its nutritional significance and culinary applications.[16] According to reports in several species, especially sequoia, that exogenous auxin administration is necessary to encourage root development in cuttings.[34] The juice with the highest betacyanin content was developed by pasteurizing white dragon fruit juice at 65 °C for 30 minutes with 0.25% (w/w) ascorbic acid. (Article, 2014). White pitaya richer yogurt included more lactic acid and a faster rate of fermentation than red pitaya yogurt. Because the former's ability to store water increased the amount of whey in the yogurt[35] palmitic (C16:0), oleic (C18:1), and linoleic (C18:2) acids were the saturated fatty acid components in both pitaya seed oils (*Supplementary Figure 1*).[36] High-Performance Liquid Chromatography (HPLC) was used to distinguish three anthocyanins in the extracts.[11] Increased peel concentration in jam formulations led to higher levels of polyphenols, antioxidants, and B complex vitamins such as B1, B5, and B6.and B6.[10] The high number of nutritional compounds in pitaya fruit has attracted the attention of the food industry in their use as economically feasible, environmentally friendly, plantbased and clean-label.[12] As a dry fruit, the pitahaya fruit has a large export market due to its physical and chemical properties.[12]

Phytochemical properties

Botanical compounds are bioactive plant compounds that are not nutritious. These chemicals, which are secondary plant metabolites, are connected to beneficial properties. There has been an increase in interest in not even just not only in the discovery of the phytochemical substances found in dragon fruit but also in the exploration of their possible therapeutic benefits. Flavonoids,

Table 3. Nutritional content and their values.

Nutritional content	Values
Moisture	84-86 g/100 g
Protein	0.93-1.33 g/100 g
Fat	0.40-1.01 g/100 g
Vitamin C	1.0-6.3 mg/100 g
Vitamin A	0.0066-0.186 mg/100 g
Crude fiber	0.88-1.84 g/100 g
Glucose	4.6-6.39 g/100 g
Iron	1.9-7.4 mg/100 g
Potassium	181.0-321.0 mg/100 g
Niacin	2.3-3.5 mg/100 g
Calcium	7.6-15.6 mg/100 g
Magnesium	29.5-44.3 mg/100 g
Crude fiber	0.88-1.84 g/100 g
Phosporous	22.8-31.8 mg/100 g
Zinc	0.26-0.42 mg/100 g
Sodium	5.0-13.5 mg/100 g

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polyphenols, terpenoids, steroids, saponins, alkaloids, tannins, and carotenoids are examples of bioactive substances. Substances can be extracted from every component of the pitaya, not just the edible components of the dragon's fruit. The overall antioxidant activity is significantly influenced by the phenolic chemicals. These phenolic compounds possess the capacity to neutralize Reactive Oxygen Species (ROS), also known as free radical species by preventing free radical initiation, blocking chain reactions, and preventing the formation of free radicals such as superoxide ion, hydroxyl radical, singlet oxygen, and hydrogen peroxide.[19] Pitahaya is also known for its tolerance to hybridization. It is easily propagated by cuttings, producing it a popular and frequently traded plant among backyard growers in the United States.[37]

The following phytotechnical variables were investigated in dragon fruit cuttings: number of shoots, length of the largest shoot, fresh and dry masses of the shoot, and roots. The physical, chemical, and attributes of millicompost accelerated the establishment of the dragon fruit, whose levels of nutrients and physical characteristics were able to provide seedlings of higher quality and size compared to seedlings from the other two substrates tested.[17] A large pitahaya collection was identified and characterized using Amplified Fragment Length Polymorphism (AFLP) to see if there was any redundancy among the commonly named varieties and to assess the collection's overall diversity.[38]

H.undatus's phytochemical composition

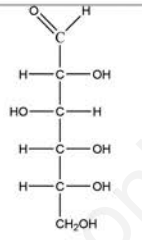
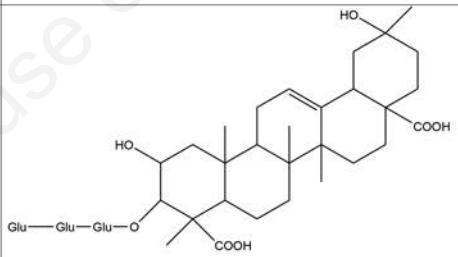
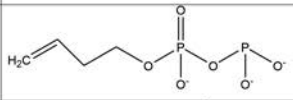
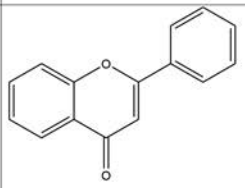
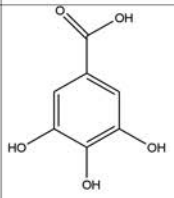
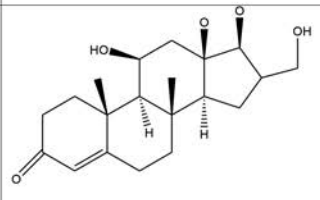
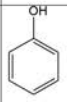
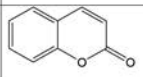
The body benefits from the nutrition and phytochemicals discovered in dragon fruit. Several studies have found that dragon fruit having the capacity to prevent human illness.[33] The fruits of the *Hylocereus* cactus have risen in value recently. Its tremendously increasing global popularity is a result of its pretty colors, sweet, juicy taste, and being considered as the Cactaceae family's most gorgeous. Cacti are being highlighted by global producers due to their abundant supply of polyphenolic components and their antioxidant activity.[39] Carbohydrates, proteins, saponin phenolic compounds, terpenoids, oils, flavonoids, tannins, phenols, coumarin, and steroids are among the phytochemicals detected in dragon fruit or pitaya. The fruit includes all the nutrients needed for a balanced diet, including vitamins, fat, crude fiber, and minerals, according to nutritional analyses.[33] Alzheimer's disease can be treated with cholinesterase inhibitor alkaloids such as donepezil, tacrine, rivastigmine, and velnacrine. Like phenylpropanoids, which are also included in both extracts, coumarins have anti-bacterial, anti-tubercular, anti-fungal, antiviral, and anti-inflammatory characteristics. Lupane glycine, betulinic acid, and oleanolic acid are examples of saponins that can be utilised to treat type 2 diabetes as well as chronic kidney diseas.[33] The Total Phenolic Content (TPC), Total Flavonoid Content (TFC), Ferric Reducing Antioxidant Power (FRAP), and 2,20-azino-bis (3-ethylbenzothizoline-6-sulfonic acid (ABTS) activities were all optimised using a five-level central composite design. Extraction interval (30-60 min), extraction temperature (40-80 °C), and ethanol concentration (60-80%) were the independent variables.[40]

Without seeds, juice yield is much lower, accounting for only 55% in some pitahaya varieties.[37] The antioxidant properties were examined using the total polyphenol assay, which expresses gallic acid as equivalent, and there were 86.10 mg of the total polyphenolic compound in 0.50 g of dried dragon fruit extract.[41] The various phytochemical parameters and their different structure are shown in Table 4. Various structures of phytochemical parameters are shown in Figure 6.

Toxicity of pitahaya

Since they assist in the identification of potential adverse effects, the definition of the exposure conditions necessary to cause these effects is key in the evaluation of dose-response relationships for adverse effects, including the definition of doses that do not produce such effects and the interpretation of experimental data for risk assessment, such as information on the mode of expo-

Table 4. Phytochemical constituents present in H.undatus fruit.

Composition of phytochemical	Structure
Carbohydrate	
Saponins	
Terpenoid	
Flavonoids	
Tannins	
Steroid	
Phenols	
Coumarin	

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sure. Toxicological studies are particularly relevant to help prove the safety of foods and ingredients.[16]

Application of the phytochemicals of the *H.undatus*

Extensive research has been transferred out to reduce the toxicity risk of artificial antioxidants used in pharmaceutical and food applications. carried out to look for potential environmentally beneficial bioantioxidants to replace synthetic antioxidants.[39] Pitaya fruit pulp externally applied to diabetic rats' injuries helped in its healing. In the meantime it is boosted tensile strength and collagen of the damaged site which increased the synthesis as well of proteins, DNA and hexosamine simultaneous oedema reduction and endurance of epithelialization.[39] The fruit, shoot, root and flower of this plant, which has been occasionally coupled with other plants had hypoglycemic, diuretic and medicinal properties that were known to the Mayas.[15] Genomic DNA can be recycled and reused from germination of seeds, and the appropriately here can give a high yield (975 mg/g) of DNA from leaf material.[7] When plain yogurt was compared to yogurt with added fruit, the total phenolic content increased. White dragon fruit enriched yogurts showed a greater increase in total phenolic content than red dragon fruit enriched yogurts. It was also discovered that the amount of phenolics in fruit-enriched yogurt and plain yogurt differs noticeably and that the presence of dragon fruit may alter the proportion of phenolics in yoghurt.[42] One hectare can sustain between 1000 and 1200 dragon fruit plants which is this crop's biggest advantage. Once planted these plants will continue to develop for approximately 20 years. The reality that it produces in the second year after planting and reaches max capacity in five years is even more remarkable. The use of various pant growth regulators has a significant possibilities for stimulating shooting in dragon fruit stem cuttings.[43]

Medicinal uses

Fruits from the genus *H.* and *Selenicereus* are very nourishing and significant in calcium, phosphorus, potassium, vitamins A and C, and vitamin C. In 26% of Mayan home orchards, *H.undatus* was conventionally produced for food and medication.[44] The effects of water-based extracts of the shoot, fruit peel, pulp, and flowers of *H. undatus* on the healing of wounds of streptozotocin diabetic rats were examined by Pérez et al. (2005). It is well known that the disease slows the healing procedure of wounds.[44] Pitaya fruits were used by Mayas as a diuretic, hypoglycemic, anti-heart disease, wound disinfectant, tumor dissolver, and dysentery medication.[33]

White dragon fruit (*Hyolecerus undatus*) is used in the medical community to aid in wound healing. Topical treatments containing white dragon fruit leaves and floral water extract are extremely beneficial for wound healing.[33] All plant components including cladodes, flowers and fruits are edible and contain large amounts of useful chemicals with proven medical benefits, such as the capacity for lower blood pressure. This has prompted the pharmaceutical industry's interest in extracting these compounds.[16]

Topical applications of the *H.* significantly accelerated the healing process in diabetic rats. The group that was given an aqueous extract (0.5%) of *H. undatus* showed significant improvement in wound healing, with 90% healing in the excision wound test and 81% healing in the incision wound test. The injection of the leaf extract increased cicatrizing by 73% and 66%, respectively, in the excision wound test (incision wound test).[45]

Because restrictions on the consumption of synthetic flavouring agents have led to an increase in the use of anthocyanins and flavonoids as food colourants, as well as pharmaceuticals and cosmetics, the skin of the dragon fruit can be a valuable source of natural dyestuff.[20] Food antioxidant compounds are vital in preventive medicine.[42] Bioactive compounds found naturally in food may play a critical role in the prevention of obesity development.[46]

Dragon fruit can also aid in the reduction of blood sugar levels in people with type 2 diabetes.[39]

Vitamin B1 in dragon fruit acts as a multivitamin, but it also helps to improve and recover from appetite loss. Vitamin B2 in dragon fruit acts as a multivitamin, but it also helps to improve and recover from appetite loss and the vitamin B3 discovered in dragon fruit helps to lower bad cholesterol levels while also providing a smooth and hydrated skin appearance. It also improves eyesight.[39]

H. species fruits have high bacterial resistance to antibiotics in *E. coli*. Opuntia ficus-indica peel and pulp decoction extracts from some of these fruits could potentially be used in pharmacology and the food industry to combat *E. coli, Salmonella typhi, Candida albicans, Bacillus subtilis*, and *Staphylococcus aureus*.[15]

Effective antagonistic bacteria have been discovered the exterior of dragon fruit twigs.[41] The complete nucleotide sequence of a strain of Cactus Virus X (CVX) isolated from *H. undatus* (Cactaceae) has indeed been defined (Table 5).[41]

The delightful flesh can also be aggregated with milk or sugar and used to produce marmalades, jellies, ice cream, and soft drinks.[14] The consumption of dragon fruit as a fresh produce on a regular basis greatly reduces asthma, cough, and other illnesses, cholesterol, and blood pressure; it aids in stomach disorders, it is good for heart health, useful in chemoprevention and in the prevention of congenital glaucoma, it boosts immune power, it diminishes arthritis pain, it is good for pregnant women, it aids in bone health, it repairs body cells, it aids in improving appetite, eye and brain health. Its flowers are used in aromatherapy.[10] Pitaya peel, in addition to being used as a natural dye in food, can improve the nutritional value and texture of products (Table 6).[47]

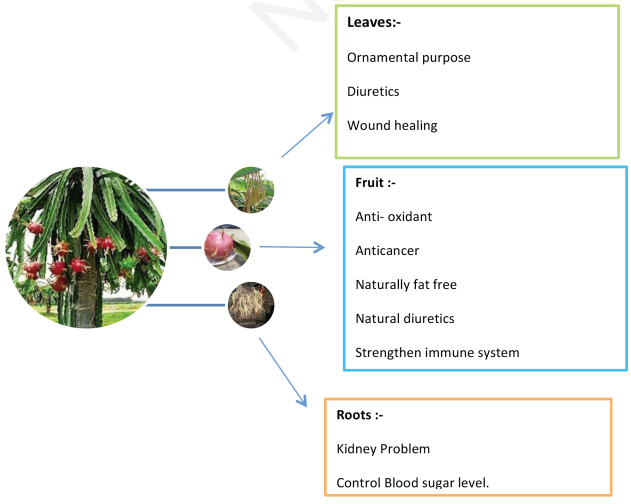

Figure 6. *H. undatus* plant part uses and its associated food matrices.

Industrial uses

Dragon fruit juice, sherbets, jam, syrup, yogurt, jelly, preserve, candy, and pastries are just a few of the industrial products that can be produced using it. Pulp is now and then mixed into pizzas. Dragon fruit wine industry is a relatively prosperous industry in Malaysia. As a raw material for the food coloring industry, the red and pink pulp of dragon fruit can be used as a food coloring agent.

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Table 5. Pharmacological action of the different activities of *H.undatus*.

Type of activity	Pharmacological action	Reference
Anticancer activity	The polyphenols, dibetanin and flavonoids have an anticancer influence. This fruit may be suppress oestrogen and progesterone receptors in ER responsive breast cancer cells by targeting multiple tumorigenic pathways that lead to cell cycle arrest and apoptosis.	(Guimarães *et al.*, 2017) (Prisa, 2022)
Anti-inflammatory activity	Dragon fruit has antioxidant and anti-inflammatory properties due to its composition which consists compounds such as betalains and squalene. Betalains are unstable and sensitive to degradative factors such as temperature, pH, oxygen, or light. The anti-inflammatory activity betalains derived from the *H.polyrhizus* peel may be attributed to their high antioxidant activity. Free radicals may be the primary pro-inflammatory mediators, thus reducing the mediators decrease the inflammatory response.	(Luu *et al.*, 2021)
Antioxidant activity	The availability of electrons to neutralise free radicals is the essential point of in vitro antioxidant activity. Several studies were carried out on both the red and white pitaya samples, including antioxidant activity tests (DPPH, ABTS) . The total antioxidant content of *H.undatus* seeds water extract was determined to be 0.08 mg/ml . Total antioxidant power is synonyms with total reducing power.	(Luo *et al.*, 2014) (Safira *et al.*, 2021).
Antimicrobial activity	Using the well diffusion method, four pathogenic bacteria (*Escherichia coli, Klebsiella sp, Staphylococcus epidermidis,* and *Staphylococcus aureus*) were tested for the selectivity to different solvents of *H.undatus*.	(Mahdi *et al.*, 2018) (Safira *et al.*, 2021)
Antidiabetic activity	The functional properties of different concentrations of fruit samples differ significantly (p=0.01). The antidiabetic activity of dragon fruit extracts ranged from 1.033 to 32.436 percent at various concentrations. Consuming 600 g of pitaya fruit everyday decreased blood glucose levels in type 2 diabetics. One of the most frequent systemic diseases in the world, diabetes mellitus is produced by an inability of the pancreas to produce enough insulin or by the insufficient sensitivity of cells to the effects of insulin.	(Sudha *et al.*, 2017)
Hypolipidemic activity	The hypolipidemic activity of dragon fruit flesh extract was tested in rats. The extract of dragon fruit flesh could reduce TG, total cholesterol, LDL, and total cholesterol ratio over HDL cholesterol, as well as body weight and the Lee index of obesity, while also dramatically increasing serum HDL cholesterol, total faecal cholesterol, and fat. This study found that dragon fruit flesh extract had antiobesity and hypolipidemic biological activities, which could help prevent atherosclerosis.	(Safira *et al.*, 2021).
Hepatoprotective activity	In a recent study, Parmar *et al.* (2019) examined whether a methanolic extract of dragon fruit may protect rats' livers from damage brought on by acetaminophen. The animals were given different doses of methanolic extracts of pitaya (300 and 500 mg kg-1, p.o.) and silymarin (200 mg kg-1, p.o.), a standardised extract derived from seeds of Silybum marianum widely used in the treatment of liver, for three days, 30 minutes prior to acetaminophen ingestion (3 g kg-1 day-1, p.o.). For comparative purposes, silymarin (200 mg kg-1, p.o.), a standardised extract made from the seeds of Silybum marianum, is widely used in the treatment of liver illnesses of different sources. The rats were killed for histological research after the final course of treatment, and blood was collected and analyzed for several serum enzymes. The findings by Parmar *et al.* (2019), both at the enzymatic and histological levels, indicated the antioxidant and hepatoprotective potential of pitaya:	(Luu *et al.*, 2021)
Antiviral activity	Secondary metabolites that plants synthesised during a microbial infection are associated to the physiological and biochemical basis of a plant's resistance to attacks by various pathogens (such as viruses, fungi, or bacteria). The physiological and biochemical basis of a plant's resistance to attacks by diverse diseases is connected to secondary metabolites that plants synthesised during a microbial infection (such as viruses, fungi, or bacteria). Different bioactive compounds, including secondary metabolites with greater antimicrobial properties, such as terpenoids (sesquiterpene lactones, diterpenes, triterpenes, and polyterpenes), steroids, phenolic acids (hydroxybenzoic and hydroxycinnamic acids), stilbenes, lignans, quinones, and tannin, are linked to the benefits of plant consumption against a variety of pathogenic microorganisms	(Luu *et al.*, 2021) (Sudha *et al.*, 2017)
Wound healing activity	The process of healing a wound is a multiple stage 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. Clinical pathology has the daily task of managing wounds, which frequently fails in the absence of sufficient physiological, endocrine, and nutritional support. the healing abilities of Hylocereus undatus leaves, rind, pulp, and flowers in injured streptozotocin-diabetic rat wounds. Each rat suffered an excision or an incision wound on the back, and over the duration of seven days, different aqueous extract concentrations (0.05%, 0.1%, 0.2%, 0.4%, and 0.5%) were given topically twice daily.	(Luu *et al.*, 2021)
Antihyperlipidemic activity	Dyslipidaemia is a complicated condition that increases the risk of adverse cardiovascular events because it is recognized to induce atherosclerosis. Due to the advantages connected with its composition, adding pitaya peel powder to diets would help avoid hyperlipidemia.	(Luu *et al.*, 2021)
Antianaemia activity	Pitaya includes vital nutrients such iron (Fe), vitamins C, E, B12, thiamine, and riboflavin, which are precursors needed for erythropoiesis. An investigation of the benefits of dragon fruit on postpartum moms, who are thought to be sensitive to anaemia. The high vitamin C concentration of dragon fruit is what provides it its anti-anaemia properties since it makes non-heme iron and iron essential for blood formation easier to consume.	

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Table 6. Nutritive properties of different part of plants.

Parts of plants	Nutritive properties	Reference
Leaves	Used as diuretics	(Safira *et al.*, 2021) (Tenore *et al.*, 2012)
Fruits	Nourishing and significant in calcium, phosphorous, potassium, vitamin a and c, anti-heart disease, wound disinfectant, dysentery medication.	(Tenore *et al.*, 2012) (Safira *et al.*, 2021
Fruits peel and pulp	Used as natural dye in food; can improve the nutritional value and texture of product	(De Mello *et al.*, 2014) (Safira *et al.*, 2021)
Flower	Used in soups and salads, eaten as a vegetable. Tea is sometimes made with flower.	(Gunasena *et al.*, 2006) (Safira *et al.*, 2021

Dragon fruit flower buds are used in soups and salads, and they can be consumed as vegetables. Tea is sometimes made with flowers.[48]

Conclusions

The ethanolic extract of *Selenicereus undatus* was found to have anti-diabetic qualities, suggesting it may be beneficial in the treatment of diabetes. The results demonstrate that the dragon was an excellent source of antioxidant activity. Furthermore, it had the capacity to heal wounds when applied with an extract cream, which shown an incredible capacity to do so and had a greater activity than the water extract alone. This could have a variety of applications in the pharmaceutical and biomedical industries as well as in industrial equipment. All plant components, including the cladodes, flowers, and fruits, which contain significant amounts of bioactive chemicals and have been shown to have therapeutic effects, can be consumed. The pharmaceutical industry's interest in differentiating these chemicals, including hypertension control. The phenolic compounds, antioxidants, unsaturated fatty acids, terpenes, several trace elements, and other nutrients found in the dragon fruit were abundant.

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Online supplementary material:

Figure S1. Composition of fatty acids in H.undatus (Luu et al., 2021).