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Phytochemical Properties and Health Benefits of *Hylocereusundatus*

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Review Article

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Abstract

Hylocereusundatus is typically the most cultivated vine cactus belonging to the family of Cactaceae, originating natively from Mexico and America. Commonly, it is well known under the name of "dragon fruit" or "pitaya". In Malaysia, it is also called 'buahnaga' which gives the meaning of dragon fruit. Besides its attractive coloration, the fruits of *Hylocereusundatus* are being prevailed globally because of its rich source of polyphenolic components and their antioxidant activity. A wide ranging of phytochemicals of betalains, polyphenolic compounds and carotenoids are discovered to possess chemo-protective properties against oxidant stress in the body as well as maintain optimum equilibrium between antioxidants and oxidants for the enhancement of human health. The findings of this review are important to deliver an overview of *Hylocereusundatus* and its functional phytochemicals, with relation to its potential health benefit in providing perspectives of research and application. It presented more environmental benign antioxidant and antibacterial agents that are significant in the fields of healthcare, food processing, nutraceutical and cosmeceutical. Therefore, there should be a collective work by scientists and researchers to maximize the value chain of this fruit to global cultivars in order to expand the global market of dragon fruit.

Keywords: Antioxidant; Betalains; Dragon Fruit; Pitaya; Polyphenolics; Nanoformulations

Introduction

The genus *Hylocereus* belongs to the vine cactus from the subfamily of Cactoideae within the family of Cactaceae (Table 1). It is a native fruit originating from Mexico and Central and South America [1], and has been cultivated in Vietnam for at least 100 years, following by the French [2]. From the report of Rural Industries Research and Development Corporation (RIRDC) in 2013, *Hylocereusundatus* is the most abundant crop of tropical exotic fruits documented with 34,150 sites out of 50,100planting sites or 62.2% of total plantings in Northern Territory [3], Australia. Based on the survey data, the farm gate value of the dragon fruit is $2.25 million from a production of 750tonnes [3].

Kingdom	: Plantae (Plants)
Sub kingdom	: Trachebionta (Vascular plants)
Super division	: Spermatophyta (Seed plants)
Division	: Magnoliophyta (Flowering plants)
Class	: Magnoliopsida (Dicotyledons)
Order	: Caryophyllales
Family	: Cactaceae (Cactus family)
Subfamily	: Cactoideae
Tribe	: Hylocereae
Genus	: *Hylocereus* (A. Berger) Britton & Rose
Species	: *Hylocereus undatus* (Haw.) Britton & Rose

Table 1: Nomenclature of *Hylocereusundatus* [4,5].

There are three cultivars of dragon fruit: *Hylocereusundatus,* red-coloured pericarp with white flesh; *Hylocereuspolyrhizus,* red skinned with red flesh and *Selinecereus megalanthus,* yellow-coloured with white flesh [6]. Typically, *Hylocereusundatus* is a cactus plant which possesses fruit as the Red Dragon Fruit or Red Pitaya Fruit, the most widely cultivated vine cactus. In addition, it knows as Red Pitaya or Strawberry Pear cactus fruit as well. In Malaysia, it is also called 'buahnaga' which gives the meaning of dragon fruit. Commonly, this fruit is named as pitaya because of the bracts or scales on the fruit skin and hence the name of pitaya meaning "the scaly fruit" [7]. Table 2 listed several common names of dragon fruit with respect to different countries and languages.

Country/ Language	Common / Vernacular Name
Chinese	huǒlóngguǒ (fire dragon fruit)
Colombia	Pitahaya roja/blanca, Flor de caliz, Pitajaya
English	Strawberry Pear, Dragon fruit, Red pitaya, Red Pitahaya, Night Blooming Cereus, Belle of the Night, Cinderella Plant, Queen of the Night, Jesus in the Cradle
Estonian	Maasik-metskaktus
French	Cierge-lézard, Pithaya rouge, Pitaya
German	Distelbirne, Echtestachelbrin, Drachenfrucht
Hawaii	Panini-o-ka-puna-hou, Papipipua
Indonesian	Buahnaga
Mexico	Junco, Flor de caliz, Pitajava, Pitahaya roja, Tasajo
Portuguese	Cato-barse, Cardo-ananaz
Puerto Rico	Flor de caliz, Pitajava, Junco, Junco tapatio, Reina de la Noche
Vietnam	Dragon fruit, Thanh long (green dragon)
Spanish	Flor de caliz, Junco tapatio, Pitahaya orejona, Pitajaya, Reina de la noche
Swedish	Dachenftskogskatus, Röd pitahaya, Echtestachelbrin

Table 2 : Common / Vernacular Name of Dragon Fruit [8-10].

With the unique properties of Crassulacean Acid Metabolism (CAM), members of family Cactaceae exhibit extraordinarily high water-use efficiency with low water requirements [11]. In addition, as a response to high carbon dioxide (CO_2) atmospheric concentration, CAM plants increase the production of their biomass [12]. The fruit consists of red peel covered with green tipped overlapping scales and white flesh dotted with numerous edible soft black seeds. In a year, the *Hylocereusundatus* cactus flowers a few times. It also classified as a night-blooming flower which only flowers at night, and blooming with huge fragrant blooms that typically last for one night only [13]. Over past decades, this fruit is cultivated commercially in Malaysia, Vietnam, Thailand, Taiwan, Nicaragua, Colombia, Australia and the USA [2,14].

Phytochemical Composition of *Hylocereusundatus*

In recent years, the fruits of *Hylocereus* cacti have greatly increased its popularity worldwide due to its attractive colours, sweet, juicy pleasant taste and have been considered the most beautiful in Cactaceae family. Besides its red-purple coloration, the fruits of *Hylocereus* cacti are being highlighted by global cultivators because of its rich source of polyphenolic components and their antioxidant activity [15].

Polyphenolic compounds are an excellent antioxidant and bio-active free radical scavengers, playing an important role in protecting humans [16]. Antioxidant refers to a compound that is capable of retarding the oxidation of lipids, nucleic acids and proteins by hindering the initiation and propagation of oxidative chain reactions, and hence preventing oxidative damage towards body's cells [17,18]. This can be achieved through the mechanisms of reduction, free radical-scavenging, potential complexing of pro-oxidant metals and quenching of singlet oxygen [19]. The antioxidant potential of polyphenolics depends on the number of hydroxyl groups in the compound. With the higher number of hydroxyl groups, the tendency of chain breaking antioxidant behaviour of the compound increases [20]. Phenolic is found in abundant in plants, which is the major secondary metabolites of plants, serving in plant defence mechanism for counteracting reactive oxygen species (ROS) [21,22].

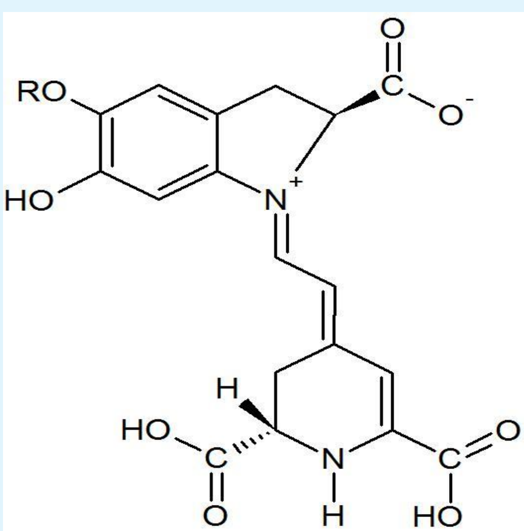

Figure 1: Chemical Structure of Betacyanin.

Jamilah (2011) reported that *Hylocereusundatus* consists of 150.46 ± 2.19mg of polyphenolic components such betalains, gallic acid and betacyanins per 100 g of dry weight [23]. In cacti, red-violet betacyanins and yellow betaxanthins are the most important fruit pigments, belonging to betalain pigments [24]. Betalain is a class of water soluble pigments that provide the colours in a wide- ranging of flowers and fruits [25]. Moreover, betacyanins (Figure 1) that are attached to N-heterocyclic compounds are a class of compounds that can also be employed as antioxidants, with radical scavenging activities [26].

Betanidin and isobetanidin are the simplest forms of betacyanins, which are the corresponding C-15 diastereoisomer. Nowadays, there are 30 structures of betacyanins are recognized and well archived [27]. In all plants, majority of the betacyanins are 5-*O*-glucosides (e.g. betanin), which are the primary red-violet pigment in red beet root (*Beta Vulgaris*), though 6-*O*-glucosides are also being discovered [7,28]. In the research of Wybraniec et al. (2001), hylocerenin (betanidin, 5-O-(6'-O-(3''-hydroxy-3''-methylglutaryl)-*β*-D-glucopyranoside)), a new species of betacyanin was revealed in newly cultivated species of *Hylocereus* cacti [29]. Gallic acid (3,4,5-trihydroxybenzoic acid) is an organic substance existing in plant materials either as a free acids, as esters, or as part of tannic acid molecule (Figure 2) [30]. This ubiquitous chemical is one of the most biologically-active phenolic compounds of plant origin. Gallic acid possesses wide range of biological activities, such as antioxidant, antibacterial, antiviral, and analgesic [31]. As antioxidant, gallic acid acts as an anti-apoptotic agent and helps to protect human cells against oxidative damage [32]. Several studies have clarified the antioxidant behaviours of gallic acid and its derivatives. From previous research, antibacterial properties of gallic acid were shown effective against human pathogens (*Staphylococcus aureus*, *Corynobacterium accolans*), a plant pathogen (*Erwinia carotovora*) and human pathogenic yeast (*Candida albicans*) [33,34]. Gallic acid isolated from *Oenothera biennis* roots was also revealed to have the ability of antifungal in the study of Shukla et al. (1999) [35]. Meanwhile, methyl gallate was also shown to exhibit effective bactericidal activity against numerous Gram-positive and Gram negative microbes [36].

Gallic acid is also capable of possessing cytotoxic effects against cancer cells, without harming normal cells [37]. For instance, the presence of gallic acid in Triphala, an Indian herbal drug is the primary attribution to its cytotoxic properties, which are effective in the treatment of prostate and breast cancer cells. Because of its several interesting properties and commercial applications, gallic acid is a compound of great interest to both pharmaceutical and chemical industries [31].

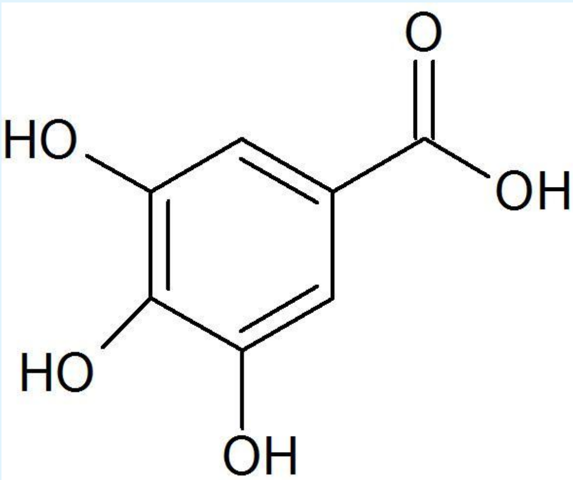

Figure 2: Chemical Structure of Gallic Acid.

However, the antioxidant activity of dragon fruit is mainly due to the content of ascorbic acid (Vitamin C). As shown in (Table 3), dragon fruit contains 20.5 mg of vitamin C per 100 g of raw fruit [38]. The chemical structure of ascorbic acid is shown in (Figure 3). In living organisms, ascorbic acid serves in many physiological functions, such as acts as reductant to prevent cellular components from oxidative damage [39]. This is because ascorbic acid has the capability of serving as a scavenger in the oxidation of free radicals and oxygen-derived species, *e.g.*, singlet oxygen, hydrogen peroxide and hydroxyl radicals [40]. Hence, ascorbic acid is found to be very useful in the treatment of photo-aging [41]. Instead, pro-oxidant properties of ascorbic acid also contribute to its antibacterial effects [42].

In the human body, the formation of free radicals is regulated by various enzymes and antioxidants in response to exogenous stimuli. In the case of extensive production of free radicals, it could lead to traumatic injury, inflammation and other chronic events, such as cancer and degenerative disease, due to the oxidant stress [45]. Over last few decades, few antioxidant vitamins which have the ability of limiting oxidative damage, have been introduced such as β-carotene, Vitamin C and Vitamin E, thus minimizing the threats of particular chronic diseases [46]. This can be observed from the closely association of heart disease and low plasma levels of β-carotene, tocopherol and L-ascorbic acid in epidemiological studies [47].

Nutrient	Amount per 100 g	% Daily Value
Water	87 g	NA
Protein	1.1 g	2.1 %
Fat	0.4 g	NA
Carbohydrates	11.0 g	3.4 %
Fibre	3 g	12 %
Vitamin B1 (Thiamine)	0.04 mg	2.7 %
Vitamin B2 (Riboflavin)	0.05 mg	2.9 %
Vitamin B3 (Niacin)	0.16 mg	0.8 %
Vitamin C (Ascorbic acid)	20.5 mg	34.2 %
Calcium (Ca)	8.5 mg	0.9 %
Iron (Fe)	1.9 mg	10.6 %
Phosphorus (P)	22.5 mg	2.3 %
Zinc	NA	NA

Table 3: Typical Nutritional Value per 100 g of *Hylocereusundatus* fruit [43,44].

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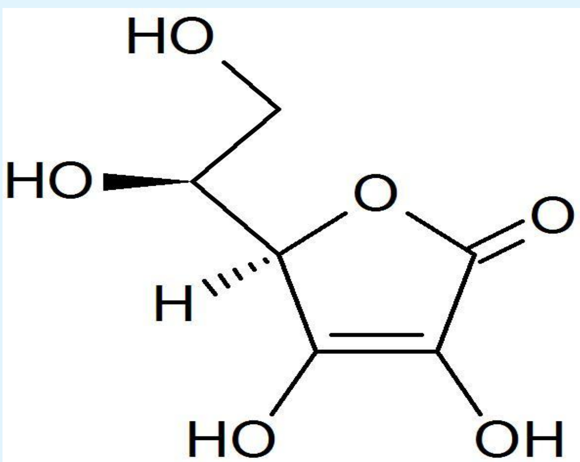
On the other hand, as the result of ascorbic acid can readily and reversibly be oxidized to dehydroascorbic acid, ascorbic acid can be utilized as a strong reductant in the interactions of ascorbic acid with numerous metal ions [48,49]. From previous studies, the presence of ascorbic acid, dehydroascorbic acid and its intermediate monodehydroascorbic acid free radical indicated their involvement in redox coupling reactions involving electron transport and membrane electrochemical potentiation [50]. In case of neurochemical reactions, ascorbic acid is found to be involved in the formation of neurotransmitters and hormones. Besides, ascorbic acid may also serve as a neuromodulator in the interactions of extracellular ascorbic acid with various membrane proteins [40].

Application of Phytochemicals of *Hylocereusundatus*

In recent years, there is an increasing effort in exploring the potential sources of natural food colorant due to the increased public concern about side effects of synthetic colorants [51]. Earlier investigations discovered that the constituent of betalains with two subgroups of red-violet betacyaninand yellow betaxanthins, with their excellent stability over a broad pH range (3.2 - 7.9), in both peels and flesh, can be potentially utilized as natural substitute for food colouring agents [25,52]. To date, due to their restricted occurrence, the betalains have comparatively less scientific implications contrary to other classes of natural pigments such as carotenoids, chlorophylls, and anthocyanins [24,53].

Figure 3: Chemical Structure of Ascorbic Acid.



Commercially, *Beta vulgaris* (beet) is the primary source of extraction of betalains, contain ingorganic compounds of pyrazines and geosm in which are responsible for the earthly flavour and aroma of the culture [54]. In contrast, the betalains extracted from pitaya can be applied directly as natural food colorant without addition of flavour, enhancing the visual appearance of wide-ranging of foods [55]. Hence, the extraction of colouring agents from both peel and flesh of pitaya provide healthy alternative for the industry of food, as well as minimize the environmental effect from discharging of the peel which has relatively low commercial values [56].

In order to overcome the risk of toxicity of artificial antioxidants in the application of food and pharmaceutical, extensive researches have been conducted to search for potential environmentally benign bio-antioxidants to replace the synthetic ones [57]. From the recent studies, a vast of antioxidant phytochemicals from natural resources demonstrated the significant potential of defending the human body against oxidative damage by ROS, comprising of free radicals such as peroxyl, hydroxyl, superoxide and alkoxyl, as well as non-radicals molecules, *e.g.*, hypochlorous and hydrogen peroxide [58,18]. Over the past few years, numerous studies also clarified the remarkable role of consumption of vegetables and fruits in diminishing risk of degenerative diseases such as cardiovascular disorders, cancer, inflammation, arthritis, brain dysfunction and accelerated aging disorders [59,60]. This is mainly attributed to their antioxidant constituents, exclusively vitamin B, C, E, tannins, carotenoids, flavonoids and phenolic, in scavenging free radicals and hindering peroxidation [61,62].

In the work of Perez et al. (2005), topical application of the fruit pulp of pitaya helped in healing the wound in diabetic rats. Meanwhile, it enhanced the tensile strength and collagen of the wound site and improved the synthesis of hexosamine, proteins and DNA with simultaneous reduction in oedema and period of epithelialisation [63]. On the other hand, fresh pitaya also exhibited significant role in reducing blood sugar level and total cholesterol level including LDL cholesterol but amplified the antioxidant function of serum in hypercholesterolemia rats [24,15]. Furthermore, both peel and flesh fractions of pitaya also exhibited effective antibacterial properties against several food-borne pathogens which were particularly owing to the in vitro antimicrobial properties of phenolic compounds [64]. Consequently, pitaya can be widely incorporated in the food industry, mainly formulations of dietary supplements, edible films and coatings [65].

Prebiotics are indigestible oligosaccharides that help in improving host health by promoting the growth and development of certain bacterial colony beneficially [66]. Apart from betalain and phenolic constituents of pitaya, *Hylocereusundatus* contains 86.2 g/kg of oligosaccharides [67], which are known to exhibit prebiotic properties that assist in improving human stomach resistance against acidic conditions and partial resistance to human salivary α-amylase, as well as stimulating the growth of bifidobacteria and lactobacilli [68]. Accordingly, pitaya can be employed as a potential source of prebiotics, for providing ingredient in functional food and nutraceutical products. Interestingly, an earlier investigation revealed the seed of dragon fruit contains a significantly high content of essential fatty acids (50%), that is, 48% linoleic acid (C18:2) and 1.5% linolenic acid (C18:3) [69]. The essential fatty acids were capable of nourishing hair, skin, and nails, eradicating illnesses of psoriasis, eczema, and dandruff. Besides, it can also modulate the skin's metabolism by regulating the movement of nourish collagen and oils beneath the skin [70,71].

Health Benefit of Dragon Fruit

In addition to being used as a food colouring agents, consumption of Dragon fruit mostly as fresh fruit as relieving thirst due to it contains high water level compared with other nutrient levels (see Table 3 for typical nutritional value per 100g of Dragon Fruit) [72].

Dragon fruit can also take the form of juice, jam, or preserves according to the taste needed. Regular consumption of Dragon fruit helps in fighting against cough and asthma; also it helps for healing wounds and cuts quickly due to it contains high amount of vitamin C (Table 3). However, the high level of vitamin C found in Dragon fruit plays an important role to enhance immune system and also to stimulate the activity of other antioxidant in the body [40,73].

Moreover, Dragon fruit is also rich in flavonoids that act against cardio related, also dragon fruit aids to treat bleeding problems of vaginal discharge. As shows in table 3 Dragon fruit rich in fibers, however it aids in digestion of food [74]. Dragon fruit is also packed with B vitamin group (B1, B2 and B3) which possess an important role in health benefit.

Vitamin B1 helps in increasing energy production and in carbohydrate metabolism, Vitamin B2 in Dragon Fruit acts as a multivitamin; however, it aids to improve and recover the loss of appetite. And Vitamin B3 present in dragon fruit plays an important role in lowering bad cholesterol levels; it provides smooth and moisturizes skin appearance. As well as it improves eyesight and prevent hypertension [62,75].

Dragon fruit is also helpful in reducing blood sugar levels in people suffering from type2 diabetes, studies suggest that the glucose found in Dragon fruit helps in controlling the blood sugar level for diabetes patients [76]. Dragon fruit contains high level of phosphorus and calcium (Table 3); it helps to reinforce bones and play an important role in tissue formation and forms healthy teeth [76].

Market Trend of Dragon Fruit

Presently, Vietnam is vital contributor for global dragon fruit market with an established planting area of 28,700 ha, that is, an 18-fold increases as compared to that during 2008 – 2009 [77,78]. In Vietnam, the provinces of BinhThuan, Tien Giang and Long are the primary dragon fruit production areas, up to 90 percent of total production(about 617,500 tonnes) in Vietnam [79]. According to the Department of Agriculture and Rural Development of BinhThuan Province, the province has dominated the nation's dragon fruit industry with the acreage of dragon fruit of 23,000ha and a yield of 550,000 tonnes per year [80].

Because of its high nutrient content, attractive shape and colour, there is a significant increasing demand in export markets from China, Thailand, Indonesia, Japan, South Korea, the United States, and New Zealand, particularly from the EU market [81]. In the first 5 months of 2013, export volume of dragon fruit reached 120,600tonnes with a value of 78.9 million USD, that is, a growth of 3.7 percent in volume and 24.1percent in value as contrary to the same period in 2012 [82]. To boost the quality of dragon fruit, EU launched three-year project (European Trade Policy and Investment Support Project, EU-MUTRAP) with the funding of 300,000 euros (US$325,000) in the summer of 2014 to support the cultivation of dragon fruit, striving to enlarge its plantation in Binh Thuan Province to 25,000ha by 2020, with an established yield of 700,000 - 750,000 tonnes per year [83].

Conclusion

It is interesting to note that the cultivation of *Hylocereusundatus* is expanding in recent years due to its health and economic importance. Therefore, this could lead to utilization of dragon fruit as a source of functional materials to provide phytochemicals with the powerful antioxidant capability of preventing nutrition-related illnesses and enhancing human defence system of consumer's. Apart from their attractive antioxidant properties, dragon fruit can also be in corporate as food preservatives owing to their effective antibacterial activity against some food-borne pathogens. The research and development of dragon fruit should be intensified and extended by emphasizing its value chain and production aspects for long-term perspective.

Authors' Contributions

NAE was responsible of manuscript approval and final approval. LKC, AA, AME, AAE, FDA and RM were responsible of manuscript drafting and writing. Authors read and approved the final manuscript.

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