

Nutritional composition, phytochemical profile, and health benefits of *Hylocereus Undatus* (pitaya): A comprehensive review

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Abstract

Hylocereus undatus, occasionally referred to as the dragon fruit or white-fleshed pitaya, is a rich in nutrients fruit appreciated because of its colorful look and health benefits. It is inexpensive in calories but packed with minerals like iron, magnesium, and calcium in addition to essential nutrients like vitamin C and B vitamins. Similarly rich in dietary fiber, particularly promotes gut wellness and improves digestion, is pitaya. It additionally contains antioxidants, such as phenolic compounds, flavonoids, and betalains, which help with scavenging free radicals and reducing the detrimental effects of oxidative stress on the human body. The substantial amount of betalains in *Hylocereus undatus* phytochemical composition is notable because it contributes to the plant's anti-inflammatory and antioxidant properties. There has been an association among these phytochemicals and a decreased likelihood of contracting long-term conditions such as diabetes, cancer, and cardiovascular disease. Omega-3 fatty acids and omega-6 fatty acids, in particular, that reduce cholesterol levels while improving blood circulation, are plentiful in the fruit's seeds and are beneficial to heart wellness. The objective of this review is to highlight the nutritional profile, phytochemical and health benefits of *Hylocereus undatus* in detail.

KEYWORDS

bioactive profile, health maladies, nutritional, pharmacological, pitaya, value addition

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1 | INTRODUCTION

Natural antioxidants found in fruits and vegetables help to fight against chronic illnesses (Sharifi-Rad et al., 2020). Polyphenolic chemicals, as well as fiber, vitamins, and minerals, were shown to be the most abundant antioxidants in tropical fruits (Muscolo et al., 2024). The phytochemical and antioxidant activities of plants appear to vary depending on their geographical location (Nurul & Asmah, 2012). The bioactive compounds in fruits can be affected by several different factors such as the species of crop, the season, the climate, the farming techniques, and the transportation, handling, and storage of the fruits (Wall, 2006). The chemical makeup of food plays a role in both avoiding illnesses and nutritional treatment. It is essential to have access to accurate and current nutritional data to inform research and guide evidence-based dietary and nutritional decisions (Nurul & Asmah, 2014). Pitaya, also known as pitahaya, is known as dragon fruit mainly because of its scabious peel (Tucker et al., 2020). Pitaya comes in three different varieties, namely white-flesh pitaya with red peel (*Hylocereus undatus*), red-flesh pitaya with red peel (*Hylocereus polyrhizus*), and white-flesh pitaya with yellow peel (*Selenicereus megalanthus*) (Nurul & Asmah, 2014). The Pitaya fruit is a species of vine cactus belonging to the Cactaceae family (Patwary et al., 2013). Pitaya fruits are becoming increasingly popular in the nutritional and medical disciplines due to their significant nutritional composition (Sonawane, 2017). Because of its nutritional content, the pitaya fruit is regarded as a significant economic fruit species across the world (Rifat et al., 2019). Several factors influence the bioactive components found in pitaya fruit, such as the cultivar, season, weather conditions, cultural methods, transportation, handling conditions, and storage. Pitaya fruit has great potential as a new Mediterranean crop due to its adaptability to high temperatures and low water requirements (Trivellini et al., 2020). It is a water-soluble fiber-rich fruit that is strong in vitamin C and antioxidants such as Flavonoids, Betalains, and Hydroxycinnamates. It has a range of health benefits, including the potential to help in weight loss, digestion, blood LDL cholesterol lowering, and immune system boosting (Fernandes et al., 2023). Hydroxycinnamates are known to reduce the risk of cancer, while flavonoids are known to reduce the risk of heart disease by acting on the cells of the brain and blood arteries. It also has antibacterial and antifungal properties, as well as being beneficial to the body's overall functioning. (Hossain et al., 2021). Pitaya fruit is native to Mexico's tropical and subtropical forest areas, as well as Central and South America. From the center of its origin, this fruit migrated throughout tropical and subtropical America, Asia, Australia, and the Middle East. It is well widely grown in Israel, Peru, Sri Lanka, Nicaragua, China, Australia, Japan, Philippines, Thailand, Spain, Taiwan, Cambodia, Vietnam, and South-Western USA (Patwary et al., 2013). Pitaya fruit production has

increased in recent years as a result of its nutritional and marketing value. It's being used as a source of functional materials to provide phytochemicals with strong antioxidant properties (Hossain et al., 2021). The pitaya fruit, which has emerged as having tremendous potential due to its sugary taste, can be used in juices, ice cream, jams, and sweets, or it can be consumed in its natural state. The fruit's nutrient qualities and pulp color make it an appealing raw food for a variety of beverages, including fermented beverages and enzyme-based beverages (Yien Ong et al., 2012). There has not been plenty of study conducted on how the vitamins, minerals, and phytochemicals in pitaya combine and the way they impact the well-being of individuals. Investigations focusing on antagonistic or synergistic effects might throw insights on how to utilize fruit to its utmost capacity enhance health. This review discusses the nutritional benefits and phytochemical potential of pitaya fruit which is based on current literature and certain research findings. The objective of this review is to highlight the nutritional profile, phytochemical and health benefits of *Hylocereus undatus* in detail.

2 | MORPHOLOGY OF PITAYA FRUIT PLANT

The plant of pitaya fruit has leafless thin vine-like branches that can reach 1.5–2.5 m in height due to its rapid growth (Hossain et al., 2021). The stem of the pitaya fruit is soft and its appearance is vine-like, having many branches, each segment contains three wings and one to three spines, or it may be spineless (Crane & Balerdi, 2005). The plant's aerial roots grow under the stems and also maintain them on vertical surfaces. Pitaya flowers are usually white, and the fruits are 25–30 cm long and 15–17 cm wide (Hossain et al., 2021). The fruit is magnificent, with brilliant red skin covered with green scales and white flesh containing a slew of small blacked seeds and requires to hold up the vine from falling (Nabhan & Piñera, 2023). In general, three varieties of pitaya fruits are grown in various regions. These are *Hylocereus ubdatus* (fruit with red skin and white meat), *Hylocereus costaricensis* (fruit with red skin and red flesh), and *Hylocereus megalanthus* (yellow-skinned fruit with white flesh) (Hamidah et al., 2017). Research on the pitaya fruit plant is currently focused on determining the most appropriate plant type for each country, as well as the most effective growth strategy and management (Hossain et al., 2021).

3 | BIOCHEMICAL PROFILE

3.1 | Pitaya pulp nutritional composition

The nutritional composition of pitaya fruits depends on the seasonal harvesting and handling conditions

(Liaotrakoon, 2013). Because of the effect of growing environmental conditions, the nutritional content and phytochemical characteristics of red pitaya fruit vary substantially (Nurul & Asmah, 2014). Pitaya fruit is high in minerals, glucose, fructose, fiber, antioxidants, and vitamins (Yasmin et al., 2024). It is stated that pitaya fruit includes higher levels of minerals such as potassium, phosphorus, salt, and magnesium than other tropical fruits like the mango, mango-steen, and pineapple. It also contains higher amounts of vitamins, with vitamin C being the most abundant (Choo & Yong, 2011).

Depending on the species and provenance, 100 g of fresh dragon fruit pulp contains more than 80% of moisture, 8.5–13.0 g of carbs, 6.0 g of total sugar, and 0.4–2.2 g of protein (Nurul & Asmah, 2014). The concentration of vitamin C in pitaya fruit varies depending on the type of growth and maturity stage and cultivation parameters. The amount of minerals and vitamins in fruits depends on their holding and storage conditions (temperature around 8°C) for better fruit's quality properties (Nurul & Asmah, 2014). Therefore, vitamin C levels can vary depending on species, crop, provenance, fruit maturity stage, and extract. The nutritional composition found in 100 g of pitaya fruits is shown in Table 1.

In addition to being high in nutrients such as vitamin C, pitaya fruit also has a high quantity of fiber and minerals such as calcium, iron, and potassium, as well as having a low carbohydrate and fat content. Additionally, some researchers examined the oil extracted from pitaya dragon fruit seeds and discovered a large concentration of essential lipids, specifically linolenic and linoleic acid, as well as other fatty acids such as cis-vaccenic acid, oleic acid, and palmitic acid (Asghar et al., 2024). Essential fatty acids are well-known for their health benefits. These

acids, for example, have been shown to help lower low-density lipoproteins (LDL) and very low-density lipoprotein (VLDL) ratios, which have been associated with high blood cholesterol levels. Linoleic and alpha-linolenic acids are also necessary for the normal transmission of nerve impulses, cell membranes, and brain function (Glick & Fischer, 2013; Jerônimo et al., 2015).

The pulp comprised approximately two-thirds of the fruit, while the peel comprised approximately one-third. Pitaya peel has a betacyanin content of 150.46 mg/100 g (Norziah et al., 2008). This makes betalains a desirable pigment for low-acid foods such as dairy products because they can maintain their appearance over a wide pH range of 4–7. When Pitaya ripens, the pigmentation process causes the peel to turn reddish, giving the fruit its distinctive appearance (Phebe et al., 2009). In terms of pectin content, the pitaya peel has a lower percentage (10.8%) than the apple pomace, which has a higher percentage of pectin (10.9%). The total dietary fiber content of the pitaya peel was approximately 69.3% (Table 1). The proportion and proximate concentration of pitaya peel are demonstrated in Table 1. As according to Table 1, pitaya fruit powder contains betacyanin, as well as protein, fat, fiber, and ash. Natural colorants are regarded to have a variety of health benefits due to the antioxidant activity of polyphenols and color components (Wybraniec & Mizrahi, 2002). Furthermore, the pitaya powder's nutritional composition is described in Table 1.

3.2 | Phytochemical potential of pitaya fruit

The essential nutrients in pitaya fruit, such as vitamins, minerals, complex carbohydrates, dietary fibers, and antioxidants, make it healthy and nutritious for human health. According to recent research, a variety of phytochemicals derived from natural sources have shown a strong potential for protecting human health against oxidative stress caused by reactive oxygen species (ROS), which includes free radicals like hydroxyl, peroxy, alkoxyl, and superoxide, as well as non-radical molecules like hypochlorous and hydrogen peroxide (Valentão et al., 2002). The remarkable significance of fruits containing nutrients in lowering the risk of diseases such as cardiovascular disease, cancer, arthritis, cognitive dysfunction, and inflammation as well as accelerated ageing syndromes has also been disclosed by several studies in recent years (Reddy & Katan, 2004).

3.3 | Health benefits

3.3.1 | Anticancer properties of pitaya

Related to cactus, the pitaya is a tropical fruit often referred to as dragon fruit. Its attractive look, unique

TABLE 1 Biochemical composition per 100 g of pitaya fruit (De Mello et al., 2014; El-Nashar et al., 2024; Nurhadi et al., 2024; Reyes-García et al., 2024; Zhuang et al., 2012).

Components (Units)	Pitaya pulp	Pitaya peel	Pitaya powder
Moisture (%)	80 ± 0.09	92.65 ± 0.10	4.01 ± 0.12
Protein (g)	0.4–2.2 ± 0.08	0.95 ± 0.15	0.18 ± 0.02
Carbohydrates (g)	8.5–13 ± 0.15	6.20 ± 0.09	ND
Fat (g)	0.4 ± 0.02	0.10 ± 0.04	1.203 ± 0.09
Ash (g)	0.54 ± 0.05	0.10 ± 0.01	0.794 ± 0.28
Vitamin C (mg)	20.5 ± 0.28	ND	ND
Betacyanin (mg)	ND	150.46 ± 2.19	44.72 ± 0.15
Dietary fibers (mg)	30.0 ± 0.17	69.30 ± 0.53	38.051 ± 7.58
Iron (mg)	1.9 ± 0.05	ND	ND
Calcium (mg)	8.5 ± 0.15	ND	ND
Phosphorus (mg)	22.5 ± 0.20	ND	ND

Abbreviation: ND, no data.

flavor, and myriad health benefits which may include anticancer effects have helped it gain greater notoriety. This essay explores at the various components and methods that pitaya employs in the battle against cancer. Bioactive compounds such as polyphenols, betalains, and flavonoids are plentiful in pitaya. These compounds have been recognized for their antioxidant properties, which play a crucial role in preventing cancer by scavenging radicals that are free and decreasing oxidative stress. As an example, several studies have shown that betalains, which are pigments found in pitaya, have potent anticancer effects (Padmavathy et al., 2021; Singh & Kumar, 2023).

Oxidative stress is one known component that leads to the growth of cancer. By absorbing radicals that are harmful and protecting cells from damage to their DNA, pitaya's antioxidants may mitigate this danger. Pitaya extracts have potent antioxidant properties due to their elevated levels of phenolic compounds. Pitaya inhibits oxidative damage, thereby helping halt the onset and spread of cancer. Inflammation that is persistent is a crucial element that also contributes significantly to the growth of cancer. Due to its anti-inflammatory effects, pitaya may help reduce the risk of cancer by modulating inflammatory pathways. Pitaya may have anticancer properties via preventing inflammatory reactions, as demonstrated by its ability to reduce inflammation markers in experimental mice (Padmavathy et al., 2021).

One essential method through which chemotherapy drugs operate on cancer cells is apoptosis, or programmed cell death. Studies have shown that compounds in pitaya can trigger apoptosis in many cancer cell types. Pitaya extracts cause female cancerous breast cells to undergo apoptosis by activating caspase enzymes, that are necessary for the apoptotic process. Pitaya has also been found to impede the proliferation of cancer cells. Pitaya's polyphenolic compounds interrupt the cell process in cancer cells, preventing them from multiplying and expanding. Pitaya extracts were shown to significantly suppress colon cancer cell growth, emphasizing their potential as an organic anticancer drug (Padmavathy et al., 2021). Growth of tumors and spread are dependent upon angiogenesis, the formation of new blood vessels. Thus, inhibiting vasculature might serve well as a strategy against cancer. Pitaya chemicals have shown evidence of suppressing angiogenesis. Pitaya extracts prevent the vascular endothelial growth factor from being generated, which is essential for the angiogenesis of cancer cells. By protecting DNA, pitaya also aids in the prevention of cancer. Pitaya's oxidants scavenge harmful chemicals that might cause mutations, protecting the integrity of DNA. In cell culture models, pitaya extracts significantly protected DNA from oxidative damage (Padmavathy et al., 2021).

Pitaya has an array of cancer fighting abilities due to its unique composition of bioactive compounds. Its anti-inflammatory, antioxidant, apoptosis-inducing, anti-proliferative, angiogenesis-inhibiting, and DNA-protecting

qualities are primarily responsible for its potential as an alternative anticancer medication. While these findings are promising, additional research including clinical trials is required to fully understand pitaya's mechanisms and efficacy in the prevention and treatment of cancer. (Wu et al., 2006). Numerous high-nutrient food components can serve as anticancer molecules, assisting in the prevention of different types of cancers. Various studies have reported that pitaya consumption could be beneficial in the reduction of cancer risk. Guimarães et al. (2017) looked at the anticancer effects of the pulp of *H. polyrhizus*. MCF-7 (ER+) cells examined with the pulp of pitaya showed a reduction in cell proliferation ($500\text{--}1000\text{ g mL}^{-1}$). Phytochemical constituents of *H. undatus* pulp and peel extracts and their apoptosis-inducing activities against breast and colorectal cancer cell lines were evaluated by Salam et al. (2022), in which caffeic acid, chlorogenic acid, ferulic acid, and rutin were found at the highest concentration in pitaya peel and pulp extracts. Both extracts displayed cytotoxic activity against MCF-7 and Caco-2 cancer cells after 48 h of treatment at IC_{50} values ranging from 14 to $53\text{ }\mu\text{g/mL}$ with high selective indices against normal WI-38 and MCF-10A cell lines. However, an increase in apoptosis was revealed by the overexpression of p53, BAX, and caspase-9 and the downregulation of antiapoptotic Bcl-2 mRNA and protein expressions. The results from their study indicates the use of *H. undatus* extracts as an anticancer therapy.

According to cell cycle studies, the pulp extract caused a higher in the G0/G1 period followed by a lower in the G2/M period. In addition, the pitaya samples induced programmed cell death in MCF-7 cells and stifled gene expression of BRCA1, BRCA2, Er (estrogenic receptor), and PRAB (progesterone receptor isoform A and B). (Guimarães et al. 2017). In another study by Paško et al. (2021), it was found that, red-skin pitaya fruits had the maximum levels of phenolic compounds and betacyanins and it can exhibit highest antioxidant activity than other species. The cytotoxic effect of *H. costaricensis* on cancer cells was greater than that of *H. megalanthus* and *H. undatus*, they concluded that pitaya fruit species have functional properties than helps in preventing cancer. (Paško et al., 2021). The anti-proliferative efficacy of pitaya fruit for the B16F10 melanoma cell was also demonstrated by Wu et al. (2006). In this study, the antiproliferative potential of the pitaya peel extract was shown to be greater than that of the pulp extract on B16F10 melanoma cancer cells (Wu & Ng, 2008). Additional clinical trials under controlled conditions are needed to properly examine the therapeutic effects of pitaya in individuals with cancer. Another study conducted by Paško et al., 2021 on the cytotoxic activity of pitaya fruits against cancer and normal cells of skin, gastrointestinal and prostate accompanied by anti-inflammatory assay. They examined fruits from two different origins showed significant cytotoxic activity toward colon and prostate cancer

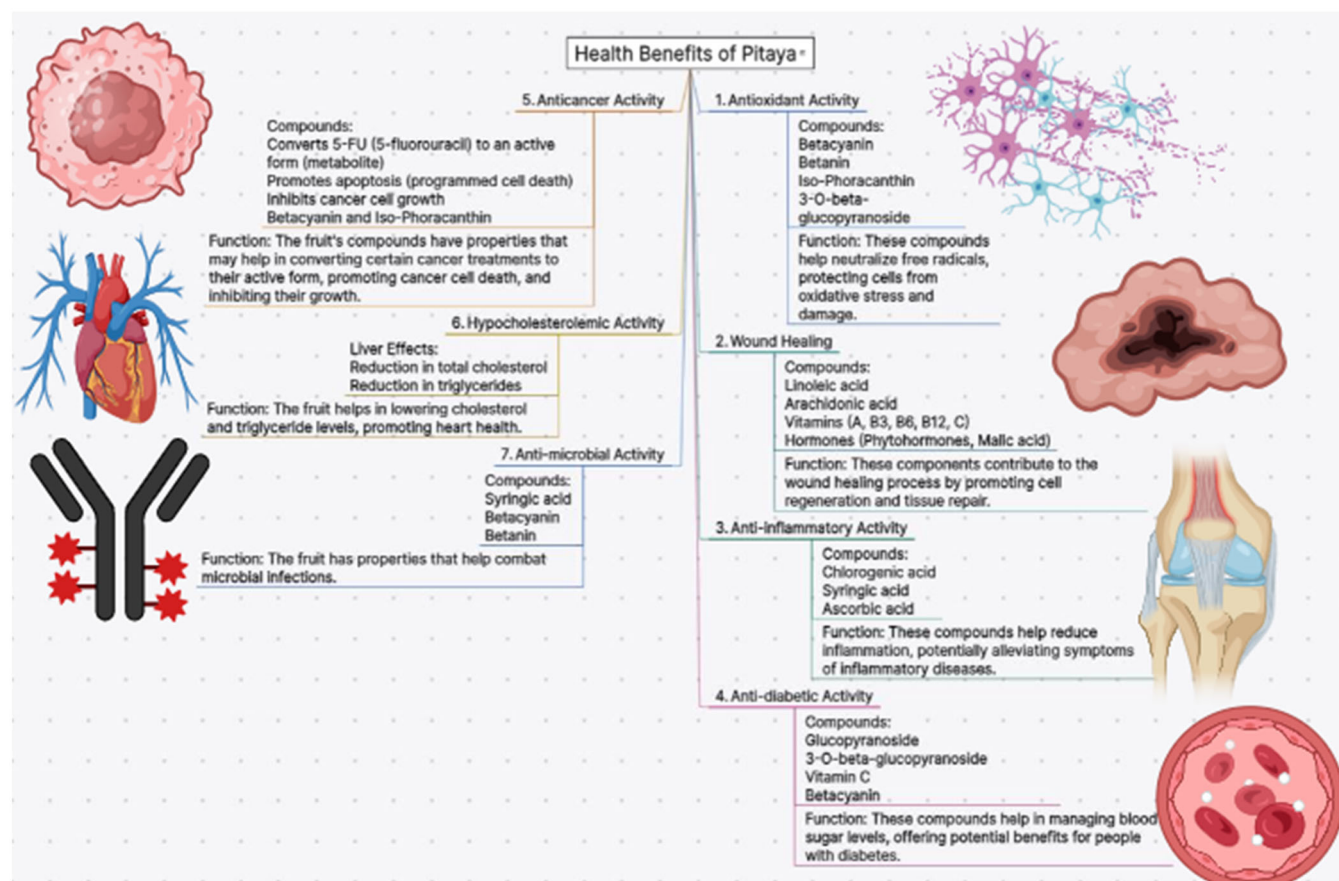


FIGURE 1 Health benefits of pitaya.

cells, with no toxic effect on normal cells, with no anti-inflammatory effect (Paško et al., 2021) (Figure 1).

3.3.2 | Antifungal activity of pitaya

The vibrant and nutritional pitaya, often referred to as dragon fruit, belongs to the family of cacti, particularly to the genus *Hylocereus* and *Selenicereus*. Pitaya, which is highly valued for its abundance of bioactive compounds, is also recognized for several additional health advantages, including antifungal properties. The mechanisms and components that underpin pitaya's antifungal activity are investigated in this essay. Pitaya's antifungal effects are mediated by many mechanisms. One of the key processes is the decomposition of fungal cell membranes. Flavonoids and phenolic acids, two of pitaya's bioactive compounds, can interact with fungal membranes to increase susceptibility and ultimately induce cell death. These chemicals have the ability to break down the lipid bilayer of the fungal cell membrane, that can lead to the seepage of cell contents and a reduction of fungal growth (Hendra et al., 2020; Omedi et al., 2019).

For most infections caused by fungi, spore germination is the first stage. Pitaya extracts are being shown to

prevent the germination of fungal spores, hence halting the spread of disease. The development of *Aspergillus niger* spores, a common fungal disease, was successfully impeded by pitaya extract (Omedi et al., 2019). Pitaya's ability to restrict the growth of spores makes it a potential treatment for fungal diseases. Pitaya's antioxidant properties additionally contribute to its antifungal efficacy. Oxidative stress encourages the growth and dissemination of fungus. Pitaya's antioxidants can stop the growth of fungi by reducing oxidative stress and scavenging free radicals that cause damage. The strong antioxidant action of pitaya extracts have been linked to their phenolic content, which is important in preventing the development of fungi (Omedi et al., 2019).

Another intriguing feature of pitaya's antifungal properties is that it can boost the potency of conventional antifungal drugs. Compounds found in pitaya may enhance the treatment of fungal ailments when used with antifungal medications. It has been demonstrated that pitaya extracts enhance the antifungal efficacy of fluconazole, a commonly used antifungal drug, against *Candida albicans*. Due to this synergy, pitaya may be used as an adjuvant medication in antifungal therapies. The antifungal effects of pitaya have several practical applications. A natural preservative that may be added

to food products to ward off fungal rotting is pitaya extract. A growing number of people are turning to natural antifungal remedies as concerns throughout the safety of artificial preservation agents increase. Furthermore, topical use of pitaya-based antifungal compositions can be created to skin fungal infections (Hendra et al., 2020; Singh & Kumar, 2023). In the end, pitaya has remarkable antifungal qualities through a variety of mechanisms, including rupturing fungal cell membranes, inhibiting spore germination, and acting as an antioxidant. Pitaya's antifungal properties are mostly dependent on its bioactive elements, particularly its phenolic acids, flavonoids, and betalains. Pitaya could exhibit synergistic effects with traditional antifungal medications, which emphasizes its potential as an adjuvant in antifungal therapy. Although these findings are promising, further research including clinical trials is needed to fully understand pitaya's mechanism of action and effectiveness in antifungal applications (Omedi et al., 2019).

3.3.3 | Hypolipidemic activity of pitaya

The tropical fruit pitaya, frequently referred to as dragon fruit, is popular due to its eye-catching color, unique flavor, and numerous medicinal properties. Among these benefits, pitaya has been shown to have potential hypolipidemic activity, or the ability to lower levels of lipids in the blood. This essay examines the mechanisms and components that pitaya employs to create its hypolipidemic effects. Pitaya's multitude of essential minerals and bioactive compounds are to blame for its health-promoting properties. In addition to a variety of phytochemicals such as flavonoids, polyphenols, and and betalains, there is dietary fiber, calcium, phosphorus, iron, and various other minerals. These compounds have been recognized for their antioxidant and anti-inflammatory effects, both of which are critical for the metabolism of lipids (Holanda et al., 2021). These substances are well-known for having anti-inflammatory and antioxidant qualities, which are important in lipid metabolism.

One of the main ingredients in pitaya that contributes to its hypolipidemic action is dietary fiber (Holanda et al., 2021). Oxidative stress is one of the main causes of hyperlipidemia and other related cardiovascular conditions. Pitaya's antioxidants, comprising betalains, flavonoids, and polyphenols, scavenge free radicals and reduce oxidative stress. Reducing oxidative stress may delay LDL cholesterol oxidation, which is an essential component in the development of atherosclerosis (Holanda et al., 2021). Pitaya may help maintain a healthy level of fat by preventing LDL from oxidizing. Chronic inflammation is intimately linked to lipid metabolic issues and heart disease. Pitaya possesses anti-inflammatory properties that can influence inflammatory pathways and enhance lipid profiles. In animal models, pitaya inclusion reduced

markers of inflammation, suggesting a possible relationship between pitaya's hypolipidemic and anti-inflammatory characteristics. Pitaya may help stop the progression of hyperlipidemia and associated illnesses by lowering inflammation.

Multiple investigations have demonstrated that pitaya improves lipid profiles. Lipid profiles of rats fed a high-fat diet were impacted by red pitaya (*Hylocereus polyrhizus*). The results showed that while levels of high-density lipoprotein (HDL) cholesterol risen, levels of triglycerides, total cholesterol, and LDL cholesterol were significantly reduced when pitaya was supplemented. These results support the possibility of pitaya as an alternative therapy for hypolipidemia (Holanda et al., 2021). The hypolipidemic consequences of pitaya have multiple explanations. First off, the fruit's high fiber content aids in the body's bile acid elimination and reduces the absorption of dietary fats. Second, the antioxidants in pitaya help prevent the oxidation of LDL cholesterol. Thirdly, the anti-inflammatory properties of pitaya promote an appropriate metabolism of cholesterol. Lastly, the direct influence of betalains and other phytochemicals on lipid metabolic pathways may further enhance pitaya's hypolipidemic effects (Holanda et al., 2021). Pitaya indicates noteworthy hypolipidemic achievement due to its high level of antioxidants, anti-inflammatory substances, and dietary fiber. The fruit lowers cholesterol, reduces oxidative stress, and modifies inflammatory pathways to improve lipid profiles. Pitaya has demonstrated great promise as a natural hypolipidemic medication in various studies; nevertheless, further research—including clinical trials—is needed to fully understand its mechanisms of action and practical applications in humans. Pitaya may be a useful addition to a balanced diet to help reduce hyperlipidemia while enhancing cardiovascular health (Nishikito et al., 2023).

3.4 | Diuretic potential of pitaya

Pitaya's diuretic qualities come from its unique phytochemical composition, which includes a variety of bioactive substances such polyphenols, flavonoids, and vitamins. It is shown that these drugs influence renal function and promote diuresis. Studies have demonstrated that consuming pitaya causes an increase in urine production, suggesting that it serves as a natural diuretic (Choo et al., 2011). Pitaya has numerous mechanisms of action when it involves diuretics. One major handle is a change of the electrolyte a state of equilibrium Pitaya is high in potassium, which is required to maintain the equilibrium of electrolytes and fluids in the body (Singh & Kumar, 2023). A rise in potassium-rich food consumption may promote natriuresis, the excretion of salt via urination, which raises urine volume. Moreover, pitaya's diuretic properties are backed by two antioxidants: betalains and vitamin C.

By protecting kidney cells from oxidative stress, these antioxidants improve renal function and stimulate the extrusion of surplus fluid (Safira et al., 2021) (Figure 2).

Pitaya has demonstrated diuretic actions in many studies using in vitro and in vivo experiments. Rats who received pitaya extraction generated noticeably more pee than rats in the control group. The result supports the traditional homeopathic use of pitaya for conditions needing diuresis. In another investigation, the impacts of pitaya on human beings were evaluated (Prasetyo et al., 2018). Respondents experienced a stronger diuretic reaction, as shown by increased urine output and reduced blood pressure, after a period of daily pitaya juice drinking. These results emphasize the possibility of using pitaya as a functional meal for the treatment of cardiovascular diseases that include hypertensive (Prasetyo et al., 2018). Pitaya has a strong diuretic impact due to its high potassium level and diverse phytochemical composition. Due to its capacity for stimulate the production of urine and aid in the expulsion of excess fluid, the fruit is a helpful natural therapy for diseases including retention of fluids and hypotension. While clinical and experimental research supports up these assertions, additional research is required to comprehend the fundamental processes and provide standard processes for implementing them. As when using natural medicine, the first step to ensuring its security and efficacy is to consider individual health circumstances and communicate with medical professionals (Safira et al., 2021).

3.5 | Hypolipidemic effects of pitaya

Pitaya, which belongs to the *Hylocereus* genus, has the ability to lower blood cholesterol levels because of its

abundance of vital nutrients and bioactive compounds. The fruit has notable concentrations of dietary fiber, minerals, vitamins (particularly C), and antioxidants such flavonoids and polyphenols (Holanda et al., 2021). These medications have an essential function in controlling the breakdown of lipids and decreasing oxidative stress, both of which that contribute to the occurrence of hyperlipidemia and related cardiovascular disorders. Several hypolipidemic ideas have been proposed to explain the effects of pitaya. One of the primary processes is the decrease in intestinal cholesterol absorption. Pitaya has dietary fiber and phytosterols that can bind to bile acids and encourage their excretion, hence reducing the absorption of cholesterol (Holanda et al., 2021). This procedure lowers overall cholesterol levels in the blood (Safira et al., 2021).

Antioxidants such as betalains, flavonoids, and vitamin C present in pitaya also protect LDL cholesterol against oxidative modification. Oxidized LDL is a major contributor to atherosclerosis, a condition characterized by the buildup of plaques in the arterial walls. Pitaya works by preventing LDL oxidation, which supports cardiovascular health and proper lipid profiles. Pitaya's hypolipidemic qualities have been the subject of substantial research. Based on an in vivo study, rats fed pitaya extract had significant reductions in their levels of triglycerides, LDL cholesterol, and total cholesterol against the control group (Holanda et al., 2021). HDL cholesterol, which is good for cardiovascular health, was also shown to have increased in the research (Safira et al., 2021). Pitaya intake has been demonstrated to enhance lipid profiles in a human clinical experiment. According to (Holanda et al., 2021), Daily pitaya supplementation resulted in substantial decreases in total and LDL cholesterol levels and increases in HDL

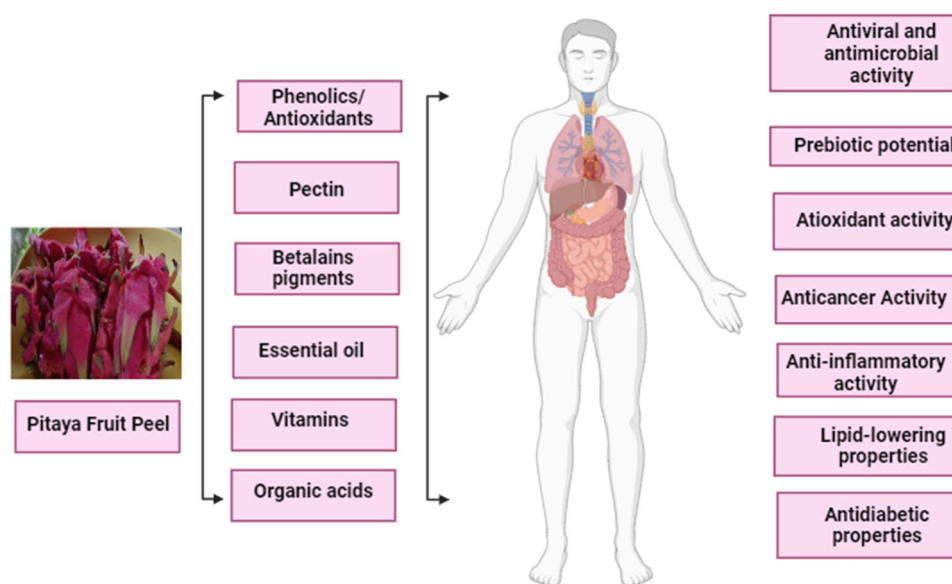


FIGURE 2 Antioxidant effects of pitaya fruit peel on health.

cholesterol in individuals taking the supplement for 8 weeks. This research shows that pitaya might be a useful meal to regulate hyperlipidemia and reduce the risk of cardiovascular diseases. Combining pitaya with other dietary or medical supplements might enhance its hypolipidemic impact. Pittaya and statins, for instance both of which are often used as hypolipidemic drugs might work in concert to enable statin dosage reductions and perhaps mitigate their side effects (Holanda et al., 2021). Pitaya can also improve lipid profiles and cardiovascular health in general when combined with a diet rich in other hypolipidemic foods like nuts, oats, and fatty fish (Singh & Kumar, 2023).

Pitaya has high levels of dietary fiber, antioxidants, and phytochemicals, which have been demonstrated to have a significant reduced blood cholesterol effect. Due to its ability to raise HDL cholesterol and lower LDL, triglyceride, and total cholesterol while increasing total cholesterol, the fruit is a useful natural therapy for hyperlipidemia and a low-risk cardiovascular disease. Both experimental and clinical research substantiate these benefits; nevertheless, further study is needed to fully comprehend the underlying processes and offer consistent application guidelines. Specific health concerns and dietary preferences should be considered, just like with any natural therapy. Consultation with qualified medical advice is necessary to ensure safe and effective usage (Holanda et al., 2021).

3.6 | Hepatoprotective potential of pitaya

Vitamin C is especially plentiful in pitaya, along with other essential minerals and bioactive compounds including flavonoids, polyphenols, and betalains. These chemicals have a crucial role in reducing oxidative stress and liver damage because of their well-known antioxidant capabilities (Parmar et al., 2019). Oxidative stress is a primary cause of liver damage and other liver diseases. It arises from an imbalance between the body's levels of antioxidants and free radicals. The hepatoprotective benefits of pitaya are caused by several mechanisms. Its primary mechanism is its antioxidant action. Antioxidants from pitaya scavenge free radicals and reduce oxidative stress, protecting liver cells from damage. For instance, research has shown that betalains and vitamin C from pitaya can reduce oxidative damage to liver tissues and boost the body's antioxidant defenses (Parmar et al., 2019). Additionally, the dietary fiber in pitaya can aid in preventing the accumulation of liver fat. Especially important is preventing nonalcoholic fatty liver disease, a condition characterized by an abnormal buildup of fat in the liver (Choo et al., 2011). By slowing down the absorption of dietary fats and improving lipid metabolism, pitaya fiber reduces the chance of developing liver fat. Numerous studies have looked at pitaya's hepatoprotective properties. In an *in vivo* study, rats

administered pitaya extract showed a strong protective effect against chemically induced liver injury. The study demonstrated that pitaya extract enhanced overall liver function and decreased liver enzyme levels, such as ALT and AST, which are indicators of liver impairment (Parmar et al., 2019; Yeh et al., 2020).

In another study, the impact of pitaya on human liver health was evaluated. Regular pitaya consumers showed reduced liver inflammatory indicators and better liver enzyme profiles than the control group. In light of these findings, pitaya may protect against liver diseases and support liver function (Parmar et al., 2019). To further bolster its hepatoprotective effects, pitaya possesses anti-inflammatory properties. The development of liver problems is mostly attributed to chronic inflammation, therefore reducing inflammation can help prevent liver damage. The hepatoprotective effects of pitaya flavonoids and polyphenols have been shown to inhibit inflammatory pathways and reduce the production of pro-inflammatory cytokines (Parmar et al., 2019). Pitaya aids in the process of detoxification as well. The primary organ in charge of the body's detoxification of harmful substances is the liver. The high level of antioxidants in pitaya helps the body eliminate toxins more naturally and neutralizes them, which helps with liver detoxification (Singh & Kumar, 2023). Pitaya has been demonstrated to possess significant hepatoprotective potential due to its rich phytochemical composition, high antioxidant, vitamin, and dietary fiber content. Thanks to its ability to reduce oxidative stress, improve lipid metabolism, and decrease inflammation, the fruit is a valuable natural remedy for preserving liver health and preventing liver diseases. Studies in both laboratory and clinical settings have demonstrated these benefits; however, further research is needed to fully understand the underlying mechanisms and provide consistent application guidelines. Particular medical conditions and dietary preferences should be considered, just like with any natural therapy. It is advisable to get professional medical advice to ensure safe and effective usage (Yeh et al., 2020).

3.7 | Antimicrobial potential pitaya

Pitaya has a wealth of bioactive compounds, including as flavonoids, polyphenols, betalains, and vitamins, particularly C. These compounds are largely responsible for the fruit's antibacterial properties because they are highly recognized for their antioxidant properties. Because pitaya has a high concentration of antioxidants, it guards against oxidative stress, which can inhibit or kill bacteria (Vijayakumar et al., 2017).

Pitaya has antimicrobial properties that stem from many pathways. One of the primary causes is the rupture of microbial cell membranes. Flavonoids and polyphenols, two of pitaya's bioactive compounds, can interact with the lipid bilayers of microorganisms to increase permeability

and ultimately induce cell lysis. This method effectively stops pathogenic microbes from multiplying and developing. Another strategy is to block microbial enzymes. Enzymes are necessary for the life and development of microorganisms. According to Fernandes et al. (2019), it has been shown that compounds found in pitaya, such as phenolic acids and betalains, inhibit these enzymes and impede the growth and activity of microorganisms (Fernandes et al., 2019). Numerous studies have indicated that pitaya possesses antimicrobial properties. According to an in vitro investigation, pitaya extracts shown potent antibacterial action against a range of pathogenic bacteria, including *Salmonella typhi*, *Staphylococcus aureus*, and *Escherichia coli*. A larger concentration of pitaya extract showed stronger inhibitory effects; the antibacterial properties, according to the study, were dose-dependent. Pitaya's antibacterial effect targets both Gram-positive and Gram-negative bacteria, further demonstrating its broad-spectrum antimicrobial capability (Vijayakumar et al., 2017).

Pitaya is suspected to have antifungal properties in addition to its antibacterial properties. *Aspergillus niger* and *Candida albicans* were two of the fungal species that pitaya extracts effectively inhibited from growing. Pitaya's antifungal qualities are a result of the high quantity of flavonoids and phenolic compounds it contains, which harm fungus cell walls and membranes. Pitaya's antiviral qualities have also been studied recently. Pitaya contains bioactive compounds such as flavonoids and betalains that have been shown to have antiviral properties by preventing virus assembly and replication. For instance, a study found that pitaya extracts inhibited the growth of certain viruses, suggesting that pitaya could find value in medicine as a naturally occurring antiviral medication (Vijayakumar et al., 2017). Pitaya's ability to inhibit germs can be enhanced by mixing it with other synthetic or natural antimicrobial agents. When used with essential oils or medications, pitaya, for example, may have synergistic advantages that increase efficacy and diminish resistance. This method can be very helpful in creating novel antimicrobial therapies and tactics. Because of its high quantities of antioxidants, vitamins, and bioactive components, as well as its rich phytochemical composition, pitaya has been shown to demonstrate substantial antibacterial action (Fernandes et al., 2019; Singh & Kumar, 2023). The fruit is an effective natural treatment for both preventing and curing infections because of its capacity to damage microbial cell membranes, inhibit microbial enzymes, and counteract oxidative stress. These advantages are supported by both experimental and clinical research; nevertheless, more investigation is required to completely understand the underlying mechanisms and provide standardized recommendations for its application. As with any natural therapy, specific health issues and dietary preferences should be taken into account. To guarantee safe and efficient use,

competent medical guidance should be consulted (Fernandes et al., 2019).

Different bioactive components, particularly secondary metabolites with stronger antibacterial capabilities like flavonoids, terpenoids, steroids, phenolic acid, glycosides, lectins, and polypeptides are linked to the advantages of plant consumption against a wide spectrum of harmful microbes. Antimicrobial activity is increased by bioactive components present in pitaya and these components are flavonoids, terpenoids, phenolic acids, lignans, coumarins, alkaloids, steroids, glycosides, saponins, tannins, and polypeptides. Plant extracts and their bioactive compounds have antimicrobial activity through a variety of mechanisms, including promoting lysis of cell walls of microbes, inducing the production of antioxidants to disruption of microbes, preventing bacteria from forming biofilms, and inhibiting cell wall construction. Nurmahani et al. (2012) assess the antibacterial activities of ethanol, hexane, and chloroform extracts in research regarding the use of peels of pitaya as a natural resource of antimicrobial attributes from *H. polyrhizus* and *H. undatus* against nine pathogens (*Bacillus cereus*, *Listeria monocytogenes*, *Campylobacter jejuni*, *E. coli*, *Klebsiella pneumoniae*, *S. aureus*, *Yersinia enterocolitica*, *Salmonella typhimurium*, and *Enterococcus faecalis*) by utilized disc diffusion and broth microdilution techniques. Their findings revealed that all of the samples had inhibition zones of 7–9 mm against specific microbes and this inhibition zone showed activity against both Gram-positive and Gram-negative bacteria. Pitaya peels, both red and white, had the highest antibacterial potential, with red peel pitaya having a stronger antibacterial potential than white peel pitaya. The researchers highlighted the importance of pitaya peel as a source of antibacterial compounds that are underappreciated, and is often discarded as household garbage (Nurmahani et al., 2012).

3.8 | Neuroprotective potential of pitaya

Vital minerals and bioactive substances such betalains, which flavonoids, polyphenols, or and vitamins (especially C) are rich in pitaya. These compounds are known to possess powerful antioxidant properties. These substances support neurological protection by averting the development of oxidative stress, which is a major contributor to neuronal damage and neurological disorders. Pitaya's neuroprotective benefits are attributed to many pathways. One of the main procedures is the reduction of the effects of oxidative stress. Antioxidants found in pitaya, including vitamin C and betalains, scavenge radicals that are free and shield neurons from oxidative damage. Since oxidative damage has been linked with the pathogenesis of a number of neurological conditions, reducing it can help preserve the health and functioning of neurons (Rathi et al., 2023; Tamagno et al., 2022). In addition, pitaya's bioactive components have anti-inflammatory effects. Long-term inflammation of the

brain and spinal column promotes the development of neurodegenerative diseases. Pitaya's flavonoids and polyphenols suppress the generation of cytokines that are pro-inflammatory and regulate pathways associated with inflammation, shielding neurons from inflammation's negative effects (Rathi et al., 2023). Pitaya could additionally enhance neurogenesis and plasticity of synapses, two processes essential to sustaining brain wellness and cognitive function. Neurogenesis is the act of creating new neurons, whereas neural plasticity is the process of enhancing or decreasing synapses, the connections between neurons. Research suggest that the existence of antioxidants along with other bioactive substances in pitaya could improve memory and learning (Rathi et al., 2023; Tamagno et al., 2022). The neuroprotective properties of pitaya have become the focus of several investigations. The study discovered that rats administered pitaya extract functioned more efficiently cognitively and showed fewer signs of injury to the brain (Singh & Kumar, 2023).

A different investigation evaluated the impact of pitaya on the mental health of human subjects. Those who frequently ate pitaya exhibited less evidence of cognitive decline and improved cognitive performance when compared to the control group. These findings indicate that pitaya may support brain health and minimize cognitive decline associated with age. Pitaya's neuroprotective properties are particularly significant when taking neurological conditions into account. For instance, the antioxidant and anti-inflammatory qualities of pitaya may assist to reduce the harm that Alzheimer's illness does to the brain. Similarly, through promoting neurogenesis and plasticity of synapses, the bioactive components in pitaya may improve cognitive function possibly shorten the development of Parkinson's disease (Tamagno et al., 2022). Pitaya's neuroprotective affect can be increased through combining it with other artificial or natural neuroprotective therapies. For instance, the combined benefits of pitaya and omega-3 fatty acids, which are renowned for their neuroprotective effects, may improve mental well-being and memory retention (Rathi et al., 2023). Pitaya on has been proven to possess significant neuroprotective effects due to its rich botanical compounds makeup, and elevated levels of antioxidants, vitamins, and bioactive elements. The fruit's capacity to reduce oxidative damage, alter inflammatory processes, and promote neurogenesis and synaptic plasticity makes it a valuable natural remedy for protecting brain health and preventing neurodegenerative diseases. Both clinical and experimental studies substantiate these benefits; however, additional research is needed to fully understand the fundamental mechanisms and offer consistent implementation guidelines. Individual medical issues and eating habits should be considered, just like with any alternative medicine. It is recommended to get medical guidance from professionals to ensure secure and efficient usage (Tamagno et al., 2022).

3.9 | Anti-inflammatory activity of pitaya

Eldeen et al. (2020) studied the anti-inflammatory effects of *H. undatus* pulp and peel and discovered the major bioactive components. They discovered betalains, have strong radical scavenging activities and squalene has a polyunsaturated hydrocarbon (C₃₀H₅₀), designed by six isoprene units as the main constituent in the fruit pulp. Additionally, these bioactive components exhibited inhibitory activities against three inflammatory enzymes (5-lipoxygenase, cyclooxygenase-2, and acetylcholinesterase) with EC₅₀ values ranging from 46 to 47 $\mu\text{g mL}^{-1}$. Eldeen et al. (2020) discovered that pitaya can prevent neuronal and inflammatory diseases via a variety of mechanisms, including leukotrienes, prostaglandins, and cholinergic pathways (Eldeen et al., 2020). Flavonoids, betalains, which polyphenols, or and vitamins particularly C are abundant in pitaya and are renowned for their antioxidant and anti-inflammatory effects. By decreasing oxidative stress and altering inflammatory pathways, these compounds have a dual impact on the control of inflammation (Nishikito et al., 2023). The anti-inflammatory properties of pitaya can be ascribed to several factors. A significant mechanism is the reduction of cytokines that promote inflammation. Cytokines are signaling molecules that are crucial to the inflammatory response. Pitaya is rich in biologically active substances known as flavonoids and polyphenols, or which have a capacity to inhibit the creation of inflammatory cytokines such as TNF- α and interleukin-6 (IL-6), therefore mitigating inflammation (Safira et al., 2021). An alternative approach involves altering the signaling pathway protein nuclear factor-kappa B (NF- κ B). Many genes that are associated with inflammation are expressed differently depending on a transcription factor called NF- κ B. Pitaya is rich in substances, commonly particularly betalains, which have been shown to inhibit NF- κ B activation. This inhibits the transcription of genes that promote inflammation, thus decreasing inflammation. Oxidative stress, which is characterized by an imbalance in the body's levels of antioxidant and free free radicals, is a major cause of persistent inflammation. Pitaya can help fight free radicals because of its high antioxidant content, thereby decreasing the effects of oxidative stress and the ensuing inflammation. For example, the body's resiliency to oxidative harm and inflammatory processes is boosted by the potent antioxidants betalains, which and vitamin C from pitaya (Nishikito et al., 2023; Safira et al., 2021).

Pitaya is especially beneficial in managing persistent inflammation because of its anti-inflammatory qualities. For example, prolonged inflammation of the arterial walls in heart conditions might lead to atherosclerosis. Due to its antioxidant and anti-inflammatory properties, pitaya may help lower inflammation and hence lower the risk of cardiovascular disease (Singh & Kumar, 2023).

Joint deterioration and pain can be brought on by ongoing inflammation in the setting of arthritis. Due to pitaya's anti-inflammatory qualities, individuals who have arthritis may experience a better quality of life by experiencing less joint inflammation and discomfort. Furthermore, since pitaya has a capacity to inhibit inflammatory cytokines and NF- κ B activation, it can help regulate responses to inflammation in autoimmune disorders (Safira et al., 2021). The anti-inflammatory in nature characteristics of pitaya have been the focus of several studies. In an *in vivo* study, pitaya extract was demonstrated to significantly reduce inflammation in a mouse model of induced inflammation. According to the study, pitaya extracts decreased inflammatory markers and stopped pro-inflammatory cytokines from being generated in the treated mice. In a second study, in comparison to the control group, individuals who regularly ate pitaya had lower levels of inflammatory indicators including C-reactive protein (Nishikito et al., 2023).

Pitaya contains anti-inflammatory characteristics that can be increased when coupled with other anti-inflammatory foods. Pitaya, for example, can work in concert with other antioxidant-rich vegetables and fruits or meals powerful in omega-3 fatty acids, like fish and the seeds of flax to even more decrease inflammation. Using this technique to create comprehensive food regimens for managing ongoing inflammation can be helpful (Safira et al., 2021). Pitaya possesses considerable anti-inflammatory properties due to its complex phytochemical makeup, and substantial amount of antioxidants, vitamins, and bioactive components. Since the fruit can alter NF- κ B signaling, lessen oxidative stress, and inhibit inflammatory cytokines, it is an effective natural medicine for controlling and avoiding persistent inflammation. Experimental and clinical research both support these advantages; however, further study is needed to fully understand the fundamental mechanism and offer unified recommendations for its implementation. Dietary choices and individual health concerns should be taken into account, similar to with any alternative medicine. Expert medical guidance should be sought for the purpose to ensure secure and efficient usage (Nishikito et al., 2023).

3.10 | Antiulcer activity of pitaya

To properly study the antiulcer effects of pitaya, commonly referred to as dragon fruit, it is essential to understand the origins of ulceration and how the bioactive substances in pitaya contribute to potential therapeutic advantages. Ulcers, especially gastric ulcers, destroy the lining of the gastrointestinal tract and are mostly caused by *Helicobacter pylori* infection, a frequent intake of nonsteroidal anti-inflammatory drugs, and stress. These diseases increase the production of acid

in the stomach and weaken the mucosal defense mechanisms, which destroys mucosa and leads to the development of ulcers (Jadhav & Jadhav, 2023). Numerous beneficial compounds, including as dietary fiber, flavonoids, polyphenols, and betalains, are plentiful in pitaya. All of these components work together to provide it gastroprotective, antioxidant, and anti-inflammatory properties. Pitaya's antioxidant activity contributes to the decrease of oxidative stress and eliminates free radicals, both of which that are vital to the emergence and advancement of ulcers (Jadhav & Jadhav, 2023; Safira et al., 2021).

Pitaya's main method mechanism of action for its antiulcer benefits is to safeguard the stomach mucosa. The mucosal membranes of the stomach acts as a barrier to keep out acid from the stomach and other irritants. Flavonoids and betalains, two compounds found in pitaya, enhance mucosal defense mechanisms by stimulating the development of mucus and bicarbonate, which neutralizes stomach acid and protect the stomach lining (Safira et al., 2021). A excessive amount of stomach acid is an important variable in the development and worsening of gastric ulcers. The production of gastric acid is inhibited by pitaya, which has been shown to decrease stomach acidity. By reducing the detrimental impact of acid on the intestine mucosa, this inhibitor helps ulcers heal. Prolonged gastric irritation might exacerbate the onset of ulcers and hinder the process of healing. Pitaya's anti-inflammatory properties, attributed to its flavonoids and polyphenolic content, serve regulate pathways of inflammation and reduce the creation of pro-inflammatory cytokines. By suppressing inflammation, pitaya aids in the healing of stomach ulcers and inhibits their reappearance (Jadhav & Jadhav, 2023; Safira et al., 2021).

Numerous trials have demonstrated the antiulcer effects of pitaya. Research has shown that pitaya extracts can enhance mucosal protection, reduce ulcer size and severity, and speed up the healing process of ulcers. Increased production of mucus, increased blood supply to the mucosa, and decreased production of stomach acid are all benefits of the fruit. Clinical study with human subjects who had stomach ulcers has shown that regular pitaya ingestion improved ulcer healing rates and reduced ulcer symptoms. The potential for pitaya to be utilized therapeutically in the therapy of stomach ulceration is demonstrated by the participants' claims of less gastric pain and discomfort (Bhadauria et al., 2024; Singh & Kumar, 2023). Pitaya has promising antiulcer effectiveness through many mechanisms, including as mucosal protection, inhibition of stomach acid secretion, and anti-inflammatory properties. Due to its rich phytochemical makeup, which contains flavonoids and antioxidants, the fruit may have significant therapeutic and prophylactic effects for stomach ulcers. More research is needed to pinpoint the specific bioactive ingredients that give pitaya its antiulcer properties and to develop standardized guidelines for its therapeutic use, even if the

data that is already available supports these benefits. Dietary choices and individual health concerns should be considered, just like with any natural remedy. Seek individual medical advice from a professional (Bhadauria et al., 2024; Safira et al., 2021).

3.11 | Health benefits of antioxidant activity

Pitaya's antioxidant action is mediated by many pathways. One main method is the transfer of electrons or hydrogen atoms to free radicals, which stabilizes them and stops them from oxidatively damaging lipids, proteins, and DNA in cells. Pitaya's vitamin C and polyphenols are very useful in this capacity. The chelation of metal ions is another method. Certain antioxidants found in pitaya have the ability to attach to metal ions, such as copper and iron, which might cause the body to produce free radicals more quickly. Pitaya serves to lower oxidative stress and stop these ions from taking part in oxidative processes by chelating them (Nishikito et al., 2023). Pitaya's antioxidant qualities support several health advantages, including Pitaya antioxidants shield cells from oxidative damage caused by free radicals, which is linked to ageing, cancer, cardiovascular disease, and neurological illnesses. By shielding immune cells from oxidative stress, antioxidants improve immune function by strengthening immune cells' capacity to fight infections and preserve immune system integrity. Pitaya contains vitamin C and carotenoids that protect skin from UV rays and encourage the synthesis of collagen, which keeps skin supple and youthful-looking. By avoiding oxidative damage to blood vessels and lowering inflammation, antioxidants found in pitaya, such as flavonoids, may help lower blood pressure, enhance blood vessel function, and lessen the risk of cardiovascular illnesses (Nishikito et al., 2023). Pitaya's robust phytochemical makeup fuels its antioxidant activity, which promotes general health and wellbeing by shielding cells from oxidative stress and lowering the chance of developing chronic illnesses. The fruit's wide range of antioxidants, which include carotenoids, vitamin C, polyphenols, and betalains, combine to combat free radicals and support cellular health. A balanced diet that includes pitaya can help boost immune system performance, lower the risk of illnesses linked to oxidative stress, and strengthen antioxidant defenses. Pitaya's potential health benefits and uses in therapeutic and preventative nutrition will become clearer with more study into its bioactive ingredients and mechanisms of action (Singh & Kumar, 2023).

Pitaya fruit's antioxidant components, specifically vitamin B, C, E, phenolic, flavonoids, carotenoids, and tannins, are primarily responsible for scavenging free radicals and inhibiting peroxidation (Hernández et al., 2006; Lim et al., 2007; Rehman et al., 2022). In addition to being low in calories, Pitaya fruit is high in antioxidants,

cholesterol-free, and has been shown to prevent heart disease and stabilize blood pressure (Ahmad et al., 2022; Andualem, 2023; Hossain et al., 2021). The pulp of the pitaya fruit contains a significant number of polysaccharides (Xu et al., 2016), which function as favorable factors for the growth of *Lactobacilli* and *Bifidobacteria*. (Wichienchot et al., 2010). Polyphenolic compounds are powerful antioxidants and they play a vital role in maintaining human healthy life (Barros et al., 2015). An antioxidant is a chemical that can slow down the oxidation of lipids, proteins, and nucleic acids by inhibiting oxidative chain reactions, therefore avoiding oxidative stress on the cells. This can be accomplished by methods such as free radical scavenging, possible complexing of pro-oxidant metals, and singlet oxygen quenching.

Chen et al. (2021) studied the polyphenolic contents in different species of pitaya fruit. The conducted different experiments i.e. mass spectroscopy, HPLC analysis and other antioxidant tests for various portions of the fruit and suggested that dragon fruit or pitaya fruit peel had greatest concentrations of phenolics than pulp. The results highlighted that both dragon fruit peel and pulp are potential sources of phenolic compounds, with peel in particular being a source of antioxidant phenolics with potential as ingredients for the food and pharmaceutical industries. The pulp of red pitaya is high in Betalains, which helps to meet the expanding market demand for antioxidants and natural food coloring by providing a natural source (Perween et al., 2018). Rodriguez et al. (2016) discovered *Hylocereus polyrhizus* peel extract has that maltodextrin-encapsulated and nonencapsulated betalain which supports anti-inflammatory action. Betalains are susceptible to degradative variables such as light, pH, temperature, or oxygen, but their bioactivities can be prolonged by adding a protective and impermeable covering (Rodriguez et al., 2015). Peel of pitaya contains Betalains that have anti-inflammatory potential, which may be attributed to their high antioxidative parameter. Furthermore, betacyanins linked to N-heterocyclic compounds are a family of molecules that can be used as antioxidants (Wong & Siow, 2015). The simplest betacyanins are betanidin and isobetanidin, there are now 30 betacyanin structures that have been identified and preserved (Herbach et al., 2006). The bulk of betacyanins found in plants is betanin, which is the predominant red-violet pigment in red pitaya (Wagh, 2010).

The antioxidant activity of pitaya is mostly attributable to the presence of ascorbic acid (Vitamin C). Pitaya fruit contains vitamin C about 20.5 mg per 100 g (Elmarzugi, 2016). Ascorbic acid is a vitamin that has several physiological functions in living organisms, including acting as a reducing agent to protect cellular molecules from oxidative stress. Ascorbic acid can act as a scavenger for free radicals and oxygen-derived species such as singlet oxygen, hydroxyl radicals, and hydrogen peroxide during their oxidation. The regular consumption of pitaya fruit in human diets can help in the

prevention and treatment of cough, sneezing, and asthma, as well as the improvement of wound healing as well as the promotion of liver functions (Elmarzugi, 2016). A recent study was conducted by Huang et al. (2022), in which they use red pitaya powder for the development of functional bread. The prepared bread with pitaya powder not only increased the polyphenolic content but also improves the mineral profile and insoluble dietary fiber along with bread firmness and moisture content. oat and wheat were used as a basic raw ingredient for bread production. The oat-wheat bread was found to have the lowest predicted glycaemic response, but 5%, 10% and 15% red pitaya powder formulated oat-wheat bread showed a lower glycaemic response than plain wheat bread as well as red pitaya powder. Table 2, is presenting the functions and properties of major bioactive compounds in Pitaya fruit.

3.12 | Antidiabetic attributes

Diabetes mellitus is a well-known disease that affects people all over the world. It is characterized by hyperglycemia, which is caused by a pancreatic defect in insulin production and/or by cells that are partially sensitive to insulin reactions. Pitaya fruit has been extensively studied for its potential antidiabetic properties. Omidizadeh et al. (2014) studied the anti-insulin resistance effectiveness of pitaya fruit (*Hylocereus polyrhizus*) in insulin-resistant rats persuaded by fructose feeding. Pitaya was shown to decrease insulin resistance in this study, implying that the antioxidative and dietary fiber (soluble) concentration of pitaya's pulp is responsible for its anti-insulinemic resistance potential (Omidizadeh et al., 2014). Poolsup et al. (2017) conducted an analysis and evaluated the effects of

pitaya fruit with no therapy in prediabetes or type 2 diabetes individuals. Although higher pitaya doses resulted in a greater reduction in blood glucose, additional clinical trials under controlled conditions are needed to properly examine the therapeutic effects of pitaya in those with prediabetes and type 2 diabetes (Poolsup et al., 2017). Gold nanoparticles having size of 25.31 nm were prepared by (Al-Radadi, 2022) using *Hylocereus polyrhizus* (Red Pitaya) extract, the prepared gold nanoparticles were well-analysed using anti-diabetic, anti-inflammatory, anti-Alzheimer, and anti-oxidant (DPPH), and cytotoxic investigations. The NPs also showed a dose-dependent cytotoxic activity against HCT-116, HepG2 and MCF-7 cell lines, with IC₅₀ of 100 µg/mL for HCT-116 cells, 155 µg/mL for HepG2, and for MCF-7 cells the value was 165 µg/mL respectively. Finally, the outstanding biocompatibility of Au-NPs has led to the conclusion that they are a promising choice for various biological applications (Al-Radadi, 2022).

In research by (Abd Hadi et al., 2016) the outcome of pitaya intake on blood sugar levels and fatty acids profiles of type 2 diabetic individuals were investigated. The 7-week trial was divided into 3 stages: 1 week before therapy (stage 1), 4 weeks of therapy (stage 2), and 2 weeks following therapy (stage 3). A diabetic sick person was given pitaya dosage (400 and 600 g) on daily basis throughout stage two, with precautions. Throughout the trial, fasting blood samples and anthropometric measures were taken to see how pitaya affected blood glucose, triglyceride, and cholesterol levels which include, HDL and LDL. While eating 400 g of fruit was highly beneficial in decreasing triglyceride concentration, eating 600 g was considering good in lowering blood sugar, LDL, and total cholesterol, and raising HDL cholesterol, according to the research (Abd Hadi et al., 2016) Figure 3.

TABLE 2 Functions of major antioxidants in pitaya fruit.

Components	Amount	Functions	References
Flavonoids	Red fleshed 46.29 ± 2.47 mg RE/100 g FW	Lower the risk of heart disease Maintains blood pressure	Kumar (2024); Singh & Kumar (2023)
Betalains	42.71 ± 2.48 mg/100 g fresh pulp	Protect against oxidative stress Help lose weight and boost your immune system	Singh & Kumar (2023)
Hydroxycinnamates	Minor amounts of hydroxycinnamic acids	Helps to prevent cancer	Singh & Kumar (2023)
Carotenoids (beta-carotene)	1.4 mg/100 g	Reduced risk of cancer and cardio-vascular diseases	Singh & Kumar (2023)
Lycopene	3.4 mg/100 g	Inhibiting the cell growth of various human cancer cell lines	Charoensiri et al. (2009)
Linoleic acid and linolenic acid	Seeds rich with 50% of essential fatty acids	Decrease the risk of cardiovascular disease	Jimenez-Garcia et al. (2022)
Vitamin C	Red fleshed 20.00 ± 1.33 mg/100 g FW	Improves wound healing qualities and speeds up the healing of cuts. Boosts the immune system	Singh & Kumar (2023)

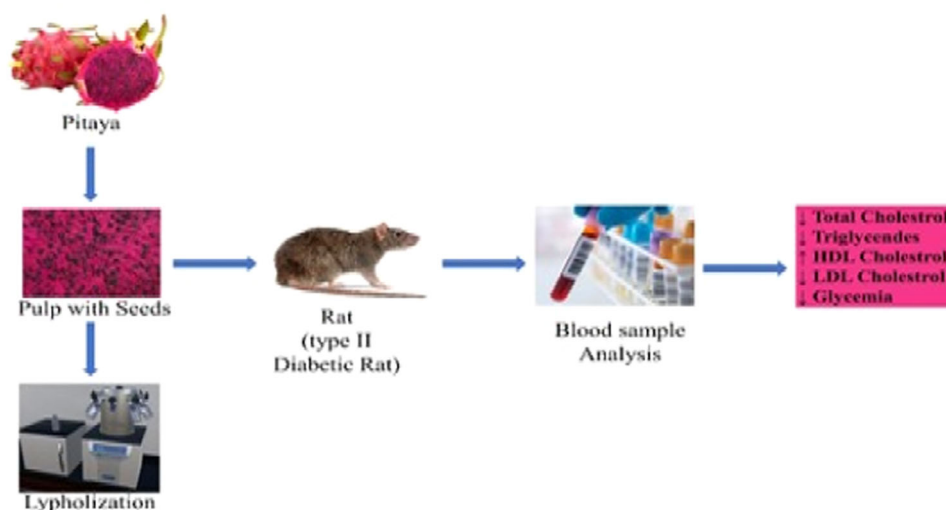


FIGURE 3 Antidiabetic potential of pitaya.

4 | CARDIOVASCULAR PROTECTIVE ACTIVITY

Cardiovascular disease is the leading cause of death globally. A higher level of arterial rigidity is associated with a higher risk of coronary heart disease. Vascular stiffness associated with a range of medical disorders can be reversed with a change in lifestyle and/or the administration of the appropriate therapy. Antioxidants found in Pitaya have attracted researchers' interest because of their potential to treat and prevent oxidative stress-related disorders. According to Omidizadeh et al. (2014), the cardioprotective components of red pitaya are polyphenols and antioxidant content. They also recommended that when it comes to food processing, adopting the right thermal processing methods is critical for retaining the nutritional content and cardioprotective benefits of tropical fruits (Omidizadeh et al., 2014). Swarup et al. (2010) demonstrated that pulp extracted from red pitaya significantly reduced aortic stiffness, as assessed by pulse wave velocity, in streptozotocin-induced diabetic rats as nutritional supplementation. In high-carb and high-fat syndrome rats, Ramli et al. (2014) found that supplementing pitaya juice decreased diastolic stiffness of the heart. Additional studies are required to properly examine the impact of pitaya fruit in the prevention of cardiovascular diseases.

4.1 | Antihyperlipidemic and antiobesity activities

The evaluation of Adhi et al. (2018) revealed that the pitaya (*H. costaricensis*) extract has antiobesity and hypolipidemic potential. This study exhibited that the pitaya extract was given to obese rats at 100 mg kg⁻¹ BW (per dosage) (Adhi et al., 2018). In vitro antioxidant,

antidiabetic, and anti-lipase activity of white pitaya juice extract was studied by Sudha et al. (2017). The presence of bioactive substances (flavonoid, alkaloid, saponin, and triterpenoid) was discovered by the phytochemical screening of the white pitaya fruit (Sudha et al., 2017). In conclusion, bioactive components identified in dragon fruit extracts, such as phenolic, crude fiber, polyphenolic, and flavonoid content, aid in the reduction of fatty acids profiles by blocking cholesterol absorption in the stomach and enabling its removal through feces (Setiawan et al., 2018) (Figure 4). However, more studies are required to explore the anti-hyperlipidemic and antiobesity potential of pitaya.

5 | WOUND HEALING ACTIVITY

Wound healing is a multiphase process involving the activity of many cell types as well as the action of mediators to restore the integrity of injured tissues (Velmar et al., 2009). Additionally, efficacy proof of pitaya fruit in wound healing activities was discovered by Juliastuti et al. (2020), specifically during the growth of collagen fiber density. A 30% concentration of *H. polyrhizus* peel ethanol extracts have a greater effect on collagen fiber density in Wistar rats than in the control group (Juliastuti et al., 2020). Additional studies are required to properly examine the wound healing activity of pitaya fruit. Pitaya's high vitamin C focus is one of the primary variables that contribute to its ability to heal injuries. Collagen, an essential protein in the skin that supports wound healing and preserves skin integrity, is synthesized only through the help of vitamin C. Vitamin C's antioxidant properties shield the wounded region from oxidative stress, that can impede the healing processes. Talaains are a class of carotenoids with strong anti-inflammatory and antioxidant properties that are

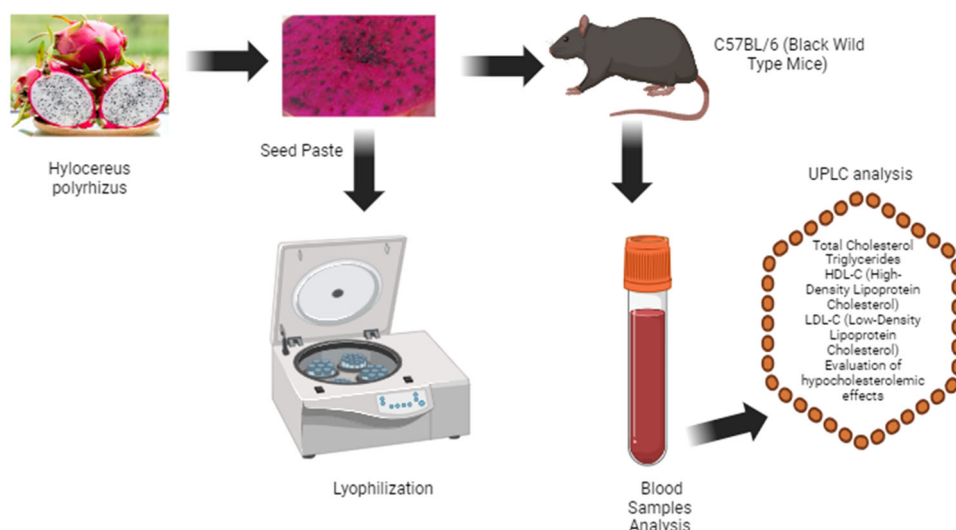


FIGURE 4 Hypcholesterolemic effects of pitaya.

abundant in pitaya. betalains assist in the decrease of oxidative stress and inflammation at the site of the lesion, promoting faster and more efficient healing. The anti-inflammatory qualities are especially important as persistent wounds may arise from excessive inflammation, which can obstruct the healing process (Mande et al., 2023). It was recently discovered that the pitaya peel shows antibacterial properties that help in wound healing. A vital component of the healing process is the avoidance of wound infections, which is made possible by the natural antibacterial substances found in pitaya peel. Pitaya's antibacterial qualities can help promote healing because infections can cause serious problems and greatly slow down the healing process. There are many recognized techniques by which pitaya facilitates wound healing. Pitaya's high level of vitamin C encourages the development of collagen, which is necessary for the healing of new tissue at the site of the wound. Higher levels of collagen help wounds heal more quickly and with more durability (Vijayakumar et al., 2017).

Vitamin C and betalains, which two antioxidants discovered in pitaya, work to counteract the effects of free radicals in the wound region. This lessens oxidative stress, which may damage cells and impede their ability to repair. Pitaya contains betalains along with other anti-inflammatory chemicals which serve to lessen inflammation at the site of wounds. While optimal wound healing requires controlled inflammation, high levels of inflammation can cause tissue damage and lengthen the duration of healing. Pitaya peel contains antimicrobial compounds that suppress the proliferation of bacteria and other pathogens, thus avoiding illness. This guarantees a sanitary setting that promotes healing. Research into pitaya's capacity to heal wounds has shown positive results (Joshi & Prabhakar, 2020).

Rats that were utilized in a study that investigated the impact of pitaya extract on healing wounds showed a

significantly greater rate of tissue regeneration and closure of wounds than control groups. The study related pitaya's high antioxidant and anti-inflammatory in nature compound material to these benefits. Another study on the antimicrobial qualities of pitaya peel discovered that it successfully stopped the growth of a number of common bacteria that cause infections in wounds, such as *Escherichia coli* and *Staphylococcus aureus*, among others. The presence of flavonoids and phenolic compounds in the peel is believed connected to its antimicrobial activity. Pitaya has a capacity to heal wounds, which can be useful in a number of circumstances. Pitaya extract can be used in topical formulations like creams and ointments to treat wounds and encourage regeneration of the skin (Tahir et al., 2020). In addition, incorporating pitaya to dietary supplements could offer systemic benefits for healing wounds and skin health. Because pitaya (dragon fruit) contains an elevated level of bioactive compounds such as vitamin C, betalains, and antimicrobial substances, it has significant benefits for wound healing. Together, these substances increase the production of collagen, lessen the effects of inflammation and oxidative stress, and fend away infections to help injuries heal quicker. The encouraging outcomes of numerous studies emphasize pitaya's potential as an indoor remedy for accelerating the healing process of wounds (Martínez-Rodríguez et al., 2022).

6 | ANTIANEMIA ACTIVITY

Pitaya is high in vital nutrients, including vitamins B₁, B₂, B₁₂, C, E, and minerals (iron), which are required for erythropoiesis. Rahmawati et al. (2019) experimented to assess the effects of pitaya fruit on postpartum women having the risk of anemia. For 14 days, postpartum women were given 400 ccs of juice (made from 500 g of

TABLE 3 Uses of pitaya (dragon fruit).

Category	Uses
Culinary uses	
Fresh consumption	Consumed like fresh fruit—that is, using a spoon.
Smoothies	Added into smoothies to offer color and minerals.
Salads	Added to salads with fruit or greens.
Desserts	Utilized in pastries, ice creams, or sorbets as snacks.
Juices	Fortify into refreshing juices and beverages. convert into beverages and smoothies that are refreshing.
Jams and Jellies	Kept as a component in jams, jellies, and condiments.
Garnishes	Utilized as a delicious and decorative garnish.
Nutritional uses	
Dietary fiber	Used up for its extraordinary fiber content to aid digestion.
Antioxidants	Included in the diet for its antioxidant properties.
Vitamin C source	Used as a natural source of vitamin C.
Cosmetic uses	
Skin care products	Used in face masks, scrubs, and creams for its hydrating and antioxidant properties.
Hair care products	Included in hair masks and conditioners for its nutrient content.
Medicinal uses	
Anti-inflammatory	Consumed for its potential anti-inflammatory benefits.
Immune support	Taken to boost the immune system due to its vitamins and antioxidants.
Agricultural uses	
Animal feed	Peel and other by-products can be used as animal feed.
Compost	Used in composting due to its organic matter content.
Industrial uses	
Natural colorants	Used as a natural colorant in food and cosmetics due to its betalain pigments.
Bioactive compounds	Extracted for use in nutraceuticals and pharmaceuticals.
Cultural uses	
Traditional medicine	Used in traditional medicine practices in some cultures.
Symbolic uses	Used in festivals and ceremonies for its exotic appearance and symbolism.

Source: Safira et al., 2021.

pitaya). When compared to the control group, the range of hemoglobin, rose considerably in the therapy patient. According to Rahmawati et al. (2019), the vitamin C concentration in pitaya fruit is responsible for its anti-anemia properties, since it aids in the utilization of iron required for blood formation as well as nonheme iron (Table 3).

7 | CONCLUSION

The pitaya fruit (*Hylocereus undatus*) provides a wide range of health advantages as a result of its high nutritional content and diverse bioactive profile. It is a

good source of micro and macro minerals, vitamins, and dietary fiber. Furthermore, the presence of various phytochemicals (betacyanin, polyphenolic, vitamin C, lycopene, and carotenoids) makes it effective against various health maladies including diabetes, obesity, hyperlipidemia, mental health disorders, and cancer. It has strong antioxidant and antimicrobial potential against wide spectra of microbes. The results of various studies exhibited that its extract has effective hepatoprotective, cardiovascular, immunological, and prebiotic properties. It has a wide range of applications in the domain of food processing, pharmacy, value addition, nutraceuticals, and cosmeceuticals.

8 | FUTURE RECOMMENDATIONS

Future studies for *Hylocereus undatus* (Pitaya) ought to focus on discovering its bioactive components, establishing its advantageous effects on health through clinical studies, and evaluating its effect on persistent illnesses including heart disease and diabetes. Its health significance could also be maximized by research on the effects of environmental conditions on its nutritional and phytochemical the material's composition.

AUTHOR CONTRIBUTIONS

Ashok Kumar Bishoyi: Validation. **Farhan Saeed:** Validation. **Umer Shehzadi:** Visualization. **Amar Shankar:** Formal analysis. **Jadhav Balaji:** Formal analysis. **Jaspreet Kaur:** Data curation. **Muhammad Afzaal:** Writing—original draft. **Ali Imran:** Resources; software. **Musarrat Rasheed:** Visualization. **Bilal Hussain:** Validation. **Muzzamal Hussain:** Software. **Aftab Ahmed:** Validation. **Fakhar Islam:** Validation. **Abdela Befa Kinki:** Validation.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Even though adequate data has been given in the form of tables and figures, however, all authors declare that if more data is required then the data will be provided on a request basis.

ETHICS STATEMENT

None declared.

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