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SHORT REVIEW

Passiflora edulis: A Bioactive Bounty – A Comprehensive Review

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Abstract

Passiflora edulis, commonly known as passion fruit, transcends its delightful taste by harbouring many medicinal properties. Rich in antioxidants like vitamin C and polyphenols, passion fruit displays robust free-radical-scavenging effects, suggesting potential anti-inflammatory and cardiovascular benefits. Studies underscore its anti-cancer potential, necessitating further exploration. Passion fruit, especially its leaves, emerges as a potent source of antioxidants, as demonstrated through *in vitro* and *in vivo* assessments. Compounds like vitexin and isoorientin contribute to its antioxidative effects. Passion fruit exhibits analgesic and anti-inflammatory properties, with butanoic fractions and C-glucosyl flavones showing promise in alleviating pain and suppressing inflammation. The fruit peel demonstrates anti-inflammatory effects in inflammatory bowel disease models, reinforcing its potential therapeutic role. Studies unveil passion fruit's anti-hypertensive prowess, attributed to compounds like luteolin and γ-aminobutyric acid. Yellow passion fruit pulp and peel extract effectively reduce blood pressure, showcasing its vasodilatory effects. Passion fruit emerges as a hypolipidemic agent, countering hyperlipidemia-related risks. Juice, peel flour, and seed extracts exhibit lipid-lowering effects, attributed to compounds like pectin and linoleic acid. In the realm of antidiabetic activities, passion fruit demonstrates glucose-lowering effects in diabetic models. Aqueous leaf extracts mitigate diabetes-related complications, emphasising their potential as a preventive measure. Passion fruit peel flour improves insulin sensitivity and protects against insulin resistance. Remarkably, passion fruit unveils antitumor potential, hindering tumour growth and inducing apoptosis in various cancer cells. Polysaccharide fractions and ethanolic extracts exhibit significant anticancer effects. Finally, passion fruit manifests antidepressant properties, with cyclobutane triterpenoids identified as potential bioactive components. Ethanol extracts reduce immobility time, suggesting a role in modulating dopaminergic and serotonergic pathways. In essence, passion fruit, with its diverse bioactive compounds, holds promise as a multifaceted therapeutic agent, warranting further exploration for its extensive medicinal applications.

Keywords: Antidepressant, Anti-hypertensive, Anti-inflammatory, Lipid-lowering Effects, *Passiflora edulis*

1. Introduction

The *Passiflora* genus, which includes perennial, evergreen climbing vines with woody stems, belongs to the Passifloraceae family and is found extensively in the tropical areas of America, Asia, and Africa[1,2]. The *Passiflora* genus comprises more than 500 species, mostly grown for gardening and decorative uses, with around sixty of these species producing fruits that are edible[3,4]. The leading species, *P. edulis*, commonly known as "passion fruit," has seen a surge in popularity for its economic, medicinal, and culinary value. Noted for its unique taste and fragrant properties, *P. edulis* extends its usefulness beyond just being a tasty fruit. As such, it has become an important focus of research in horticulture, agriculture, and nutritional science. Among tropical fruits, passion fruit ranks third in importance, following pineapple and mango[3]. With its complex aroma that echoes the scents of over 130 different fruits, including apple, guava, banana, strawberry, mango, and pineapple, passion fruit has been dubbed the "king of fruit juice," as well as "*maracujá*," "love fruit," "fruit lover," and "spice fruit". This diverse fragrance profile has inspired a wide range of passion fruit-derived products, such as jelly, ice

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cream, yoghurt, cake, tea, wine, vinegar, jam, soup bases, condiment sauces, and more. Additionally, passion fruit is used in traditional medicine across various cultures and has found its way into the cosmetics industry in numerous countries as a moisturizing agent[5]. Significant strides have been taken in recent decades to conduct pharmacological research on *P. edulis*. Various extracts from passion fruit, as well as its fruit juices and isolated compounds, have demonstrated a spectrum of biological effects, including hepatoprotective[6], neuroprotective[7], anti-hypertensive[8], antitumour[9], antimicrobial[10], sedative[11], antidepressant[12], anxiolytic-like properties[13], lung-protective activities[14], free radical scavenger activity[15], anti-diabetic[16], and anti-inflammatory properties[17]. The myriad health benefits of passion fruit are closely tied to its rich content of bioactive compounds, including polyphenols, triterpenes, flavonoids, and polysaccharides. This fruit is also packed with essential nutrients like minerals, dietary fibre, and vitamins, making it a prime candidate for classification as a "functional food." However, despite its nutrient-dense profile and significant potential for promoting health, passion fruit remains underappreciated in several areas, highlighting a clear need for greater awareness and exploration. The primary goal of this concise review is to provide a comprehensive summary of recent progress in the understanding of the chemical and biological properties of various parts of *P. edulis*. This includes an investigation into the unique chemical compositions and biological effects of the fruit, stems, leaves, and peel of *P. edulis*, aiming to consolidate and present the existing knowledge on these aspects.

2. Medicinal Properties of *Passiflora edulis*

Passiflora edulis is celebrated not just for its delicious flavour but also for its medicinal qualities, thanks to its high antioxidant content, including vitamin C and polyphenols. These compounds help combat free radicals, aiding in health maintenance. The fruit is known for its anti-inflammatory effects, which could play a role in treating inflammation-related disorders. Moreover, it has been suggested that *P. edulis* can enhance heart health by lowering cholesterol and maintaining blood pressure levels. Although preliminary studies suggest its antioxidants might offer anti-cancer benefits, more research is needed to confirm these findings.

2.1 Antioxidant Activity

Research has highlighted the importance of passion fruit as a potent source of natural antioxidants. These antioxidants are essential for moderating the body's oxidative balance, either by neutralizing free radicals or inhibiting their actions. Various parts of *P. edulis*, such as the seeds, fruit, peel, leaves, and bark, have been examined for their antioxidant capabilities and their ability to scavenge radicals, utilizing a range of *in vitro* methods (including ABTS, ORAC, DPPH, AAPH, FRAP, HOCl scavengers, and ferrous ion assays). Moreover, numerous in vivo studies have been undertaken to assess the efficacy of these extracts in real biological systems[18,19]. In this study, both *in vitro* and *in vivo* methods were used to investigate the antioxidant properties of passion fruit leaves. Through HPLC-PDA and ESI-MS/MS analyses, researchers probed for bioactive compounds, with a focus on polyphenols, present in the water extract of *P. edulis* leaves. In animal tests, the leaf extract demonstrated antioxidant activity by decreasing TBARS levels in the liver, increasing GSH levels in the kidneys, and affecting the activities of enzymes like SOD, GR, and GPx. The extract was found to contain significant compounds such as vitexin, isovitexin, and isoorientin. Moreover, its consumption resulted in alterations in the gut microbiota and an increase in short-chain fatty acid production. The study concludes that *P. edulis* leaf extract may act as a valuable antioxidant source, offering a defence against oxidative stress[20]. This review examined the antioxidant and anti-inflammatory properties of a water-based extract derived from *P. edulis* leaves, containing isoorientin, vitexin, and isovitexin. The study found that oral administration of *P. edulis* extracts at a concentration of 1100 µg/mL significantly increased intrinsic antioxidant levels and reduced lipid peroxidation in the bloodstream, liver, and colon in a colitis model induced by 2,4,6-trinitrobenzene sulphonic acid. Additionally, the extract demonstrated anti-inflammatory effects in the colon, notably reducing levels of cytokines such as TNF-α and IL-1β. These results suggest that the *P. edulis* leaf extract has therapeutic potential for managing oxidative stress and inflammation, observed in both healthy rats and a colitis-induced model[21].

2.2 Analgesic and Anti-inflammatory Activity

Comparative studies in thermal stimulation pain models revealed that the analgesic effectiveness of n-butanol extracts obtained from *P. edulis* leaves is dependent on the dosage administered[22]. Moreover, the analgesic effects were exhibited by the polysaccharide extracted from the dried fruit of *P. edulis* in models involving acetic acid-induced writhing and formalin-induced paw licking. Interestingly, results from the hot plate test did not show significant increases in response times, suggesting that the analgesic mechanism of the polysaccharide may be associated with peripheral pathways[17]. The study delved into the anti-inflammatory properties of individual compounds and sub-fractions isolated from the butanol fraction of *P. edulis* var. *flavicarpa* leaves. The butanol fraction demonstrated significant anti-inflammatory effects, particularly in its ability to impede the infiltration of leukocytes and neutrophils. Notably, sub-fraction C exhibited remarkable efficacy among the sub-fractions tested. Compounds isolated from sub-fraction C, including Isoorientin, Vicenin-2, and Spinosin, displayed anti-inflammatory activity by suppressing both neutrophils and leukocytes. Intriguingly, both isoorientin and the butanol fraction also showed a decrease in myeloperoxidase activity. These findings suggest that C-glucosylflavones extracted from *P. edulis* leaves may play a role in the observed anti-inflammatory effects in a mouse model of pleurisy[23]. This study examined the impact of *P. edulis* peel, known for its high dietary fibre and polyphenol content, on inflammatory bowel disease. In an animal model, the consumption of *P. edulis* peels demonstrated anti-inflammatory effects in the intestines, effectively reducing colonic damage induced by DSS. This was evidenced by a decrease in disease activity index values and improvements in histological assessments. Biochemical and molecular analyses indicated a strengthened intestinal protective barrier and a decrease in the expression of pro-inflammatory cytokines. Additionally, there was an increase in the production of short-chain fatty acids, which could have prebiotic effects. Mice treated with the polysaccharide fraction obtained from the dried fruit of *P. edulis* at a dose of 3 mg/kg exhibited a reduction in paw oedema caused by various inflammatory agents such as 48/80, carrageenan, histamine, 5-HT, and prostaglandin E2. Furthermore, it significantly reduced vascular permeability and lowered the levels of TNF-α and IL-1β[17].

2.3 Anti-hypertensive Activity

The study explored the potential antihypertensive properties of luteolin at a dose of 50 mg/kg and the methanol extract obtained from the rind of *P. edulis* at concentrations of 10 mg/kg and 50 mg/kg. When administered orally to Spontaneous Hypertensive Rats (SHRs), both the extract and luteolin exhibited a significant decrease in systolic blood pressure. Quantitative analysis using liquid chromatography-tandem mass spectrometry (LC-MS/MS) revealed that the extract contained luteolin (20 µg/g dry weight) and luteolin-6-C-glucoside (41 µg/g dry weight). Additionally, γ-aminobutyric acid (GABA), recognized for its blood pressure-lowering effects, was detected at levels of 2.4 mg/g dry weight (determined by LC-MS/MS) or 4.4 mg/g dry weight (based on amino acid analysis). The findings suggest that the main antihypertensive impact of the extract in SHRs is associated with its substantial GABA content, complemented by the vasodilatory properties of luteolin and other polyphenols[25]. In this investigation, five consecutive days were spent giving yellow passion fruit pulp orally via gavage at varying doses (5, 6, or 8 g/kg b.w.). Tandem mass spectrometry and high-performance liquid chromatography with photodiode array were used to establish the presence of phenolic chemicals, ascorbic acid, carotenoids, and flavonoids in yellow passion fruit pulp. The highest dose of passion fruit pulp showed a noteworthy drop in Thiobarbituric Acid Reactive Substances (TBARS), an increase in glutathione (GSH), and a considerable reduction in systolic blood pressure. Remarkably, there were no alterations observed in renal function parameters or the frequency of micronuclei in bone marrow cells. The research concludes that the antihypertensive effects of yellow passion fruit pulp can be attributed, at least in part, to its elevated antioxidant content. However, for a comprehensive understanding of the mechanisms underlying this observed effect, further investigation is deemed necessary[8]. The study demonstrated the antihypertensive efficacy of compounds derived from

both yellow and purple passion fruit in spontaneously hypertensive rats. Administration of *P. edulis* peel extract orally to these rats resulted in reductions in blood pressure, serum nitric oxide levels, and hemodynamic parameters according to studies[26,27].

2.4 Hypolipidemic Activity

The study underscores the considerable health risks associated with hyperlipidemia, encompassing conditions like atherosclerosis, inflammation of the pancreas and coronary artery disease. Passion fruit emerges as a promising preventive measure against hyperlipidemia. The offspring of diabetic Wistar rats exhibited a significant reduction in Total Cholesterol (TC), Triglycerides (TG), and Low-Density Lipoprotein Cholesterol (LDL-C) levels after receiving 580 mg/kg of passion fruit juice daily for 30 days. There was also a discernible rise in High-Density Lipoprotein Cholesterol (HDL-C) levels at the same time[28]. Additionally, in the context of diet-induced obesity in rats, peel flour derived from *P. edulis* exhibited positive effects by reversing cumulative body weight gain, reducing adiponectin levels and adiposity, and increasing leptin levels[29]. The research validated the effectiveness of orally administering pectin derived from the peel of *P. edulis* fruit at doses between 0.5 and 25 mg/kg for 5 days, leading to a significant reduction in triglyceride levels in diabetic rats[30]. Moreover, the non-soluble fibre extracted from *P. edulis* seeds demonstrated a cholesterol-lowering effect by increasing the levels of bile acids, total lipids, and cholesterol in the faeces of golden Syrian hamsters.

Concurrently, it led to a reduction in serum TG, TC, and liver cholesterol levels[31]. In this research, the hypolipidemic potential of *P. edulis* variety seed oil (PE) from west Cameroon was explored in both females and males. Rats that were administered PE showed a notable reduction in TG, TC, and LDL-C levels. In contrast to untreated male rats, the groups receiving PE demonstrated a significant elevation in HDL-C levels. A similar pattern was observed in female rats concerning TG, with the lowest values observed with 1 ml of olive oil. The study suggests that the elevated linoleic acid content in PE may contribute to its hypolipidemic effects, resembling those of olive oil[32]. The group administered *P. edulis* juice showed reduced levels of free fatty acids and low-density lipoprotein-cholesterol, along with increased levels of high-density lipoprotein-cholesterol compared to the control group. There were no statistically significant differences observed in SOD activity, GSH concentration, TG levels, and LDL levels between the two groups. However, the concentration of thiobarbituric acid-reactive chemicals significantly decreased in the treated group, indicating a reduction in lipid peroxidation. These results suggest that *P. edulis* juice contributed to a decrease in lipid peroxidation and had positive effects on the lipid profile in Wistar rats under the specified experimental conditions[33].

2.5 Antidiabetic Activity

Several studies suggest that *P. edulis* peel flour, juice, and seeds may exert anti-diabetic properties by dropping glucose tolerance in diabetic rats and mice. In a specific study, streptozotocin-induced diabetic rat pups exhibited a significant decrease in glucose levels when orally administered passion fruit juice (580 mg/kg) once daily for thirty days[28]. The study persuaded diabetes in Wistar albino rats using alloxan and explored the potential anti-diabetic properties of the water leaf extract of *P. edulis* Sims. After the aqueous extract was given continuously for 30 days at a dose of 200 mg/kg, lipid parameters, glycosylated haemoglobin, and blood glucose levels all significantly decreased. Additionally, the extract markedly elevated haemoglobin, HDL, and plasma insulin levels. *P. edulis* also demonstrated a significant increase in glycogen and liver protein levels, accompanied by the normalization of enzymes involved in carbohydrate metabolism. Based on these findings, the study concluded that *P. edulis* significantly mitigates diabetes risk in rats induced with alloxan[34]. Furthermore, db/db mice and rats induced with diabetes via streptozotocin exhibited reduced blood glucose levels following the administration of extracts derived from passion fruit seeds or leaves[35,36]. Administering diabetic rats, induced with alloxan, a daily dosage of pectin extracted from *P. edulis* fruit peel (ranging from 0.5 to 25 mg/kg) for five consecutive days led to a notable decrease in blood glucose levels. This indicates a potential novel treatment strategy for type 2 diabetes[30]. In a study conducted by Lima *et al.*, rats fed a high-fat diet to induce obesity exhibited improved insulin sensitivity when supplemented with *P. edulis* peel flour. This improvement was evidenced by elevated levels of glucagon-like peptide-1 (GLP-1)

and Glucose-Dependent Insulinotropic Polypeptide (GIP). Moreover, *P. edulis* peel flour was found to shield rats from insulin resistance induced by a low-fructose diet. Furthermore, the leaf extract of *P. edulis* enriched with flavonoids demonstrated health benefits in diabetic conditions by delaying the onset of associated complications[37,38].

2.6 Antitumor Activity

The study focused on a polysaccharide fraction (PFCM) extracted from *P. edulis* using hot aqueous extraction. When administered to Sarcoma 180 tumours, PFCM demonstrated a growth inhibition ratio ranging from 40.59% to 48.73%, depending on the dosage and method of administration (either orally or intraperitoneally). Toxicological evaluations revealed no significant changes in biochemical markers or organs such as the kidneys and liver, but rather an increase in cell types associated with essential defense mechanisms. Intriguingly, compared to treatment with 5-fluorouracil, PFCM treatment increased spleen weight[9]. The study aimed to investigate the potential inhibitory effects of the ethanolic extract from *P. edulis* leaves on colorectal adenocarcinoma cells, specifically Caco-2 and SW480. The extract exhibited a significant impact on cell viability and anti-proliferative activity, assessed through clonogenic and 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide tests. Flow cytometry analysis revealed that the extract could control cell cycle progression and trigger apoptosis. After 48 hours of treatment, a notable inhibition of cellular proliferation occurred in both cell lines, with determined half maximum inhibitory concentration (IC50) values for the extract. Moreover, the extract increased the proportion of necrotic and apoptotic cells, upsetting the cell cycle phase distribution by elevating SubG1 and G2/M populations and initiating pathways that result in cell death. All of these findings suggest that P. edulis could be a valuable source of phytochemical substances with notable anticancer effects, especially when it comes to the treatment of colorectal cancer[39]. The administration of yellow passion fruit ethanol extract in vivo showed a significant 48.5% inhibition of tumour development. Moreover, the extract increased the lifetime of male Balb/c mice carrying Ehrlich cancer cells by nearly 42 per cent. With particular emphasis on lauric acid, the presence of medium and long-chain fatty acids is probably responsible for this advantageous result[40].

2.7 Antidepressant Activity

The antidepressant capabilities of extracts from *P. edulis* stems and leaves have been verified through *in vivo* studies. Over seven days, mice given oral ethanol extracts from *P. edulis* aerial parts at doses equal to 10 and 2 g/kg of the plant material showed signs of an antidepressant-like effect by showing a reduction in immobility time in forced swim and tail suspension tests. Furthermore, at a dosage of 50 mg/kg, cycloartane triterpenoids, namely cyclopassiflosides IX and XI, showed an antidepressant-like effect, indicating that these compounds may be the main bioactive ingredients accountable for *P. edulis's* antidepressant properties[41]. Oral dosages of *P. edulis* Sims extracts (300 mg/kg), ethyl acetate (50 mg/kg), and butanol (50 mg/kg) exhibited a reduction in the length of immobility time in mice in the forced swimming test; these effects were comparable to those observed with fluoxetine and nortriptyline. Notably, the ethyl acetate and butanol extracts enriched with flavonoids exhibited a preference for displaying antidepressant qualities. The antagonistic actions of sulpiride, α-methyl-DL-tyrosine chloride, and p-chlorophenylalanine indicated a specific relationship with the modulation of dopaminergic and serotonergic transmission through D2 receptor, 5-HT, and catecholamine pathways[42].

3. Conclusion

In conclusion, the multifaceted properties of *P. edulis*, commonly known as passion fruit, present a captivating narrative of its potential contributions to human health. Beyond its delightful taste, passion fruit emerges as a powerhouse of medicinal benefits. Rich in antioxidants, such as vitamin C and polyphenols, it demonstrates formidable free-radical-scavenging effects, contributing to overall well-being. The anti-inflammatory attributes of passion fruit suggest promising prospects in managing inflammatory conditions, while its recognized natural sedative and anxiolytic effects offer a calming influence, potentially aiding in anxiety and insomnia. Moreover, *P. edulis* may play a role in cardiovascular health by reducing cholesterol levels and supporting optimal blood

pressure. The fruit's fibre content not only promotes digestive health but may also hint at anti-cancer potential, although further research is warranted for conclusive evidence. Laden with essential vitamins and minerals, passion fruit proves to be not just a culinary delight but a nutritional powerhouse contributing to holistic well-being. The extensive research on its antioxidant, anti-inflammatory, analgesic, anti-hypertensive, hypolipidemic, antidiabetic, antitumor, and antidepressant activities underscores its potential as a versatile and valuable natural resource in the realm of preventive and therapeutic health interventions.

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