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Exploring The Bioactive Richness Of Purslane: Phytochemical Profiles And Therapeutic Implications

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Abstract
Today, above and beyond the ever-present concern for nutrition, the realm of food research is primarily centered around the development and advancement of functional food items. These innovative products are specifically designed to not only provide sustenance but also deliver substantial health benefits, all while effectively balancing and regulating the body's metabolism. In recent times, an array of diverse plant-derived products such as leafy vegetables, lentils, fruits, and more, have gained widespread recognition as exceptional sources of functional food. The integration of these plant-based wonders into our daily dietary intake has shown promising results in significantly reducing the prevalence and impact of various metabolic afflictions that plague society. It is worth noting that the vast majority, if not all, of the essential dietary bioactive metabolites required by the human body stem from plant sources as well as other living organisms. Once ingested, these bioactive metabolites work relentlessly, targeting numerous molecular sites within the body, in turn exhibiting remarkable potential in effectively combating and even offering potential cures for life-threatening ailments such as cancer, diabetes, cardiovascular diseases, and an array of neural disorders. Despite the vast array of edible plants out there that are naturally rich in bioactive metabolites, only a select few have garnered recognition as regular, reliable sources of dietary supplements, offering individuals consistent access to these wondrous bioactive phytochemicals. One such noteworthy plant is the humble Purslane. This unassuming plant boasts elevated levels of an assortment of dietary antioxidants, making it rise above the rest as the preeminent source of omega-3 fatty acids, vitamin A, vitamin C, vitamin E, and various vital minerals. Moreover, Purslane effortlessly delivers an extensive range of vital vitamins, essential lipids, crucial minerals, high-quality proteins, complex carbohydrates, and an abundant supply of dietary fibers, all working in unison to optimize and enrich overall health and well-being.
Despite the recognition that purslane is rich in bioactive metabolites, it has not found regular usage in the daily diet and pharmacopeia due to its seasonal availability. In this review, specific emphasis has been placed on various stages of purslane life, including its seed, extracts, active metabolites, and the pharmacological activities related to the bioactive richness of purslane. Furthermore, this discussion covers the phytochemical and pharmacological peculiarities of purslane to promote the utilization of this plant as a regular source of health-promoting nutraceuticals and pharmaceuticals.
Key Words: *Pursulane, bioactive metabolites, pharmacological peculiarities, nutraceuticals, pharmaceuticals.*

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I. Introduction

Species *Portulaca oleracea*, more commonly known as purslane, is a versatile and intriguing plant that is highly valued and widely consumed across numerous cultures and regions, particularly in North America and Africa, thanks to its excellent and diverse nutritional properties. This remarkable vegetable boasts a distinct and delightful flavor profile, which is further complemented by its refreshing, juicy, and crispy texture, making it an incredibly sought-after ingredient for a wide variety of culinary dishes, including vibrant and colorful salads, invigorating smoothies, and various other preparations. In addition to its sensory appeal and culinary uses, *P. oleracea* has also earned a prominent and respected place in the realm of traditional medicine. It has been utilized for centuries by various cultures as a natural remedy to combat a wide range of health issues. Its well-documented antipyretic qualities are known to help reduce fevers effectively, while its impressive anticancer properties have shown remarkable promise in the fight against harmful cancerous cells[1]. Moreover, *P. oleracea* is revered and recognized for its valuable antiviral attributes, which can aid significantly in both the prevention and treatment of various viral infections. It has also proven to be quite effective in alleviating distressing conditions, such as insomnia and thoracalgia, which refers to pain in the chest area. Recent scientific studies on *P. oleracea* have exhibited an impressive array of biological functions and benefits. The plant's antioxidant capacity is particularly noteworthy, as it effectively combats the harmful effects of free radicals in the body, promoting overall health and well-being. Furthermore, P. oleracea has showcased its analgesic potential, providing much-needed relief from pain and discomfort, which can greatly enhance a person's quality of life. Its recognized antidiabetic properties play an essential role in the regulation of blood sugar levels, making it especially beneficial for individuals living with diabetes or for those at risk of developing the condition. Similarly, its antihypertensive attributes are significant in helping maintain healthy blood pressure levels, thus supporting cardiovascular health. Last but not least, *P. oleracea* has also exhibited hepatoprotective qualities, effectively safeguarding the liver from damage caused by external toxins and harmful substances that can enter the body[2]. In conclusion, *Portulaca oleracea*, better known as purslane, represents an extraordinary and multifaceted plant that not only delights the palate with its unique flavor and appealing texture in various culinary creations but also holds immense potential in the field of traditional medicine, where it has been cherished for generations. Its extensive range of beneficial properties, which includes but is not limited to its remarkable antioxidant, analgesic, antidiabetic, antihypertensive, and hepatoprotective functions, truly make it a valued and remarkable addition to any well-balanced and health-conscious lifestyle[3].

There are limited amounts of comprehensive evaluations that address the potential therapeutic utilization of *P. oleracea*, specifically diving into the underlying mechanisms and constituents responsible for these functionalities. A multitude of dynamic constituents have been successfully pinpointed from *P. oleracea*, encompassing saponins, alkaloids, fatty acids, vitamins, carotenoids, flavonoids, polysaccharides, and mineral ions, all of which have a longstanding history of clinical employment[4]. These components manifest in various functional capacities, including but not limited to antioxidant, anti-inflammatory, immunomodulatory, and anticancer activities, all of which will be given utmost priority and emphasis within the scope of this comprehensive review. Recent breakthroughs in the classification of bioactive compounds, alongside their extraction and separation techniques, as well as diverse potential therapeutic applications and their interconnected mechanisms, will be thoroughly explored. The primary aim of this exhaustive analysis is to furnish an authoritative point of reference for the judicious application of *P. oleracea* and to unravel potential avenues for further investigation and research in this field[5].

Background and Significance

The search for potentially beneficial substances in food items, more than just a source of energy and nutrients and capable of promoting health and preventing illness, is gaining considerable interest as a result of an advanced understanding of human dietary needs[6]. Although most of these active compounds, including vitamins, minerals, and a variety of bioactive substances, come from the whole food matrix, they eventually generate a greater variety of biological interactions in the body, such as those present in fruits, vegetables, grains, and nuts. Simple or compound classification depends on their chemical structures and bioactivity features. Some of the likely health results achieved by the consumption of bioactives are anti-inflammatory, anti-mutagenic, anti-toxic, anti-carcinogenic, and cardio-protective effects[7]. Furthermore, natural antioxidants contained in fruits and vegetables are of the most interest to human health, as they are proven to decrease the incidence of diseases such as coronary heart disease, certain types of cancer, and neurological degenerative disorders prompted by the harmful effects of free radicals. All age groups can prevent or minimize various illnesses as the bioactive compounds in fruits and vegetables help in improving health and promoting overall wellness[8].

Research Objectives

The objectives of this review article are to:

1. provide an overview of phytochemical and bioactivity profiles of purslane with particular emphasis on the role of ecosystems in its secondary metabolite production,
2. give an account of recent preclinical and clinical studies on purslane for potential pharmaceutical applications, and
3. cover a topic that has not been comprehensively addressed before and contributes to the expanse of our current understanding of a plentifully available wild herb in nature that holds a great richness of phytochemicals with potential therapeutic implications, the leafy weed *Portulaca oleracea*.

The ecosystems bring the herb into close contact with various types of physical and biological stress. Research provides substantial evidence revealing the strong influences of variations in the plant's ecological environments on the types and concentrations of its secondary metabolites[9]. Knowledge about the influences of various types of ecosystems on different types of phytochemicals in purslane is essential and relatively useful in the context of conservation and cultivation. Currently, a number of eloquent review articles have appeared that have focused on many aspects of flavonoids, betalains, phenolic acids, amino acids, vitamins, fatty acids, organic acids, and polysaccharides of purslane, for which detailed re-emphasis is useful[10]. Besides, we are relying heavily on these review articles to enhance the opinions relevant to this primary topic. However, a review that focused on investigating the influences of variations in the plant's ecological environments on the types and concentrations of its secondary metabolites has not been reported. The significance and achievements in attempts to understand the pathways of genes coding the enzymes involved in the metabolic synthesis of the health-promoting secondary metabolites of purslane under different types of stress are also emphasized. Overall, we aim to organize what is known about the relationship between secondary metabolite accumulation and environmental conditions for purslane in consideration of direct applications in promoting its commercial and medicinal importance[11].

II. Botanical Description And Distribution

Portulaca oleracea, also known as purslane, is a succulent, annual herb that originated from East India and then spread throughout the world. *P. oleracea* has many other names in various countries: pigweed, verdolaga, little hogweed, red root, Pursley, and moss rose. Plants of this species have straight, somewhat reddish-streaked, and thick, fleshy stems[12]. *P. oleracea* is distributed globally in warm climates. It grows in fields, along roadsides, in gardens, waste areas, and some other disturbed sites. The cold is the only environmental factor that kills the plant. However, the plant will likely kill itself after growing a thick root, and then being pulled, and piled in the fridge. It may appear in late spring and grow vigorously in early summer. Nevertheless, most of the plant types are often damaged by hot and humid weather long before the end of fall. Under suitable conditions, it grows into a small clump covering generally between 10 and 60 cm in diameter. Its spreading fine root system has a taproot. Its smooth, shiny leaves are hairless and arranged alternately, growing from the base and along edges. Some varieties have tiny hairs growing along the leaves[13].

Taxonomy and Classification

Purslane is the common name for a group of low-growing weedy annuals that are native to Europe, the Middle East, India, and Australia, including species of the genera Portulaca and Claytonia, which belong to the Portulacaceae family. Also occurring in North America and referred to as "common purslane" is *Portulaca oleracea*. This species originated in Persia and spread into the regions of the Mediterranean, Africa, Australia, and Central Asia, and has been distributed worldwide[14]. The variety sativa (Purslane), with larger leaves and fleshy, mucilaginous taproots, is an ancient edible plant that has been consumed from prehistoric times and used in folk medicine throughout history. Purslane contains 93% water, 20-30% carbohydrates, and appreciable levels of vitamins A, C, B1, and B2, and some minerals, such as magnesium, calcium, potassium, and iron. It also contains many bioactive compounds.

In the Persian language, *Portulaca oleracea* was referred to as "khurfa". The Hebrew name is "reglous", which is related to the word "footprint" because of its low growth habit. There are no ancient Egyptian names for this herb and leaves, and only the generalized term was found. Leaves either of Bit Rumali or derived from *Portulaca oleracea* were used as a medicinal drug. In Sanskrit, it is known as "punt suite"; Panna was the ancient name, often translated in the texts as spinach. In Arab Spain, the names "rad-rakah" or "bezrdu harak" were used, and in Andalusia, it is known as "churva". The Persians in Malabar are called "brestanan". The Andalusian Arabs and Nigerians referred to it as "rashk". The ancient Hebrews, Phoenicians, Kurds, and Zurkhnain refer to it as "rigalusch". The old Czech name was "rejlach"[15].

Table-1: Taxonomical Classification of *Portulaca oleraceae* L.

Kingdom	Plantae
Sub kingdom	Tracheobionta
Division	Magnoliophyta
Class	Magmoliopsida
Sub-class	Caryophyllidae
Order	Caryophyllales
Family	Portulacaceae
Genus	Portulaca L.
Species	*Portulaca oleraceae* L.

Fig 1. *Portulaca oleracea*

Habitat and Geographical Distribution

The succulent annual herb, *P. oleracea*, being a waste plant that originated from Persia, is well naturalized all over the world, adapted to a variety of soils, and commonly found in the Mediterranean countries. It grows on sandy, stony, or loamy soils, as well as in waste places, roadsides, cultivated fields, and gardens. It grows in temperate and tropical regions and likes warm air temperature conditions with plenty of sunlight and humidity, and a one-foot spacing distance is desirable. In propagation, the plant prefers tuberculate growth, and its growth is optimal in P^H conditions between 6.0 and 7.5. The stem has different colors and an annual growth habit, and it grows fast. The leaf texture is also smooth and thick, fleshy, with broad leaves, which are bright green and lighter ones are popular to eat in salads or as cooked vegetables[12].

III. Phytochemical Composition Of Purslane

The bioactive chemical compounds found in purslane are extensive and varied. These include lipophilic pigments such as carotenoids and chlorophylls, and hydrophilic secondary metabolites like phenolic compounds, alkaloids, proteins, amino acids, polysaccharides, flavonoids, terpenoids, and many others. The objective of this manuscript is to comprehensively summarize the chemical composition and pharmacological activities of purslane in order to shed light on its vast biohorizons[10]. These diverse bioactive compounds could potentially explain its remarkable and multifaceted bioactivities as well as its long-standing utilization in traditional medicine practices. Therefore, this comprehensive review aims to serve as a foundational resource and starting point for further rigorous analysis and exploration of the yet undiscovered and hidden potential of *P. oleracea* that awaits to be unveiled and harnessed for the betterment of human health and well-being[16,17].

The chemical composition generally refers to small molecules in a non-water soluble form, which are extracted with organic solvents involving ethanol and methanol. The convention is that herbal methanolic extract is called ethyl acetate extract; a residue after removal of chlorophylls and lipids from the ethyl acetate extract is called ethyl acetate extract. The chemical compounds enriching the biochemical composition of the purslane picloride fraction are carotenoids. Since 1910, when these pigments were ejected and isolated from the purslane extract, their structure and composition of them gradually became known, which caused them to have unique potential phosphatic value. The antioxidant activity of carotenoids is in the highly conjugated double-bond chain, the chemical property of the oxygen double bond at both ends and the hydroxyl group of the link is well-documented.

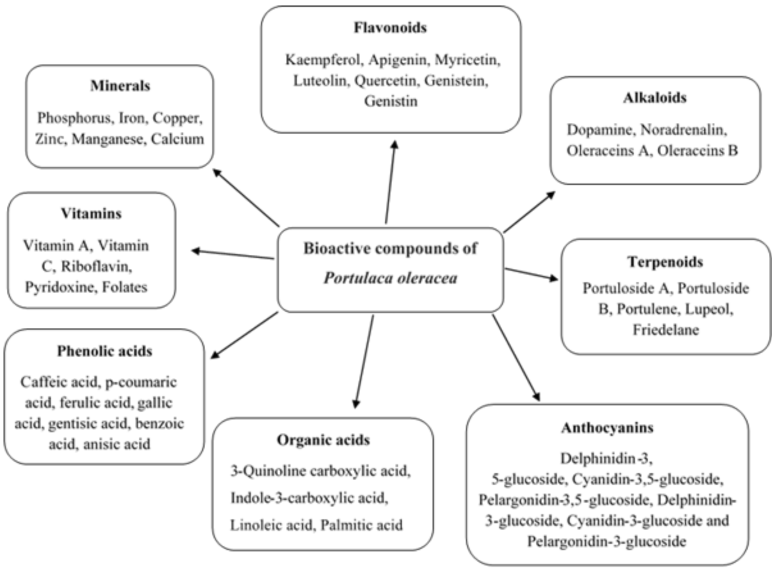

Fig 2: Phytoconstituents of *Portulaca oleracea*

Primary Bioactive Compounds

Purslane is a treasure house of numerous essential oils and other primary bioactive compounds widely recognized all over the world because of their wide range of bioactivities. The major bioactives identified in purslane belong to primary and secondary metabolites. Essential oil extracted from the plant contains various primary and trace metabolites. The primary bioactives with high percentages in the oil include α-Pinene, γ-Terpinene, α-Phellandrene, and Limonene. High concentrations of non-polar terpenoids in essential oil can be correlated with high antioxidant and antiproliferative activity. Despite the rich diversity of phytoconstituents, the range of bioactivities of the plant and its effectual therapeutic roles have not been completely explored. The highly effective role of the extracts and tea prepared from the fresh aerial parts or distressed plant at controlling diabetes and associated complications signifies the high therapeutic potential of the plant. It is widely used in various regions of the world with a wide range of demographic conditions, but unfortunately, scientific evidence backing or disclaiming these claims is also non-existent. Recently, the small herb has been gaining notable importance because of its richness in flavonoids[18]. To our knowledge, except for a few studies, few of the common flavonoid constituents of purslane have been identified and tested for any therapeutic role. The roles of the individual isoforms of the flavonoids present and their complicated interactions with the active components of the whole plant extracts also remain largely underexplored. In this regard, because the plant produces these phytoconstituents under highly adaptable environmental stress, we speculate that isoforms of the flavonoids produced under varying stress types could have more diverse therapeutic roles and that the preparatory processes should also be devised accordingly[9].

Secondary Metabolites

Secondary metabolites, the chemically complex, structurally diverse, and economically indispensable low molecular weight compounds, constitute a valued Northern constellation of bioactive agents characterized by a wide range of structural variety and biological activities. Numerous groups of secondary plant metabolites have been identified in HP, encompassing phytoestrogens, fatty acids, betalains, hydrolyzable tannins, carotenoids, saponins, coumarins, cerebrosides, alkaloids, lignans, flavonoid glycosides, flavonols, sterols, flavones, flavanones, ascorbic acid derivatives, tocopherols, kaempferol, rutin, and other polyphenolics, like phenolic acids and anthocyanins[19]. To date, about 100 secondary metabolites with diverse health-promoting functionalities have been discovered in HP, yet it is quite probable that far more remain to be discovered in HP. The vast array of secondary metabolites found in HP is a testament to the incredible chemical diversity and functional potential of this plant species. Researchers continue to explore and uncover new secondary metabolites with unique properties and applications. It is an ongoing journey of discovery and a reminder of the untapped potential that exists within nature. The identification and characterization of these secondary metabolites not only contribute to our understanding of HP as a medicinal plant but also open doors to the development of new drugs, treatments, and therapies. As we delve deeper into the world of secondary metabolites, we are likely to uncover a treasure trove of bioactive compounds waiting to be harnessed for their beneficial effects on human health. The future of secondary metabolite research in HP holds great promise, and it is an exciting prospect to witness the continued expansion of our knowledge in this field[20,21].

After two centuries of uninterrupted biomedical experimentation on HP, the totality of its bioactive phytoconstituents remains far from being fully explored and mapped, especially during the last two decades. Choosing the proper methods is important to successfully detect the individual secondary plant metabolites. Traditional methods include multifluid solvents, like phytochemical investigation, analytical spectrophotometric methods, primarily mass spectrometry, nuclear magnetic resonance, thin layer chromatography, high performance liquid chromatography, and extremely strong gas chromatography. More modern techniques used for detecting plant metabolites in HP include liquid chromatography-mass spectrometry, non-destructive imaging techniques like mass spectrometry imaging, and nuclear magnetic resonance imaging. Such tactics revolutionize mass spectrometry scans by providing all the necessary direct sample analyses. In contrast, chromatography-based procedures merely offer pre-purification from a large number of chromatographically separated compounds in order to make further processing steps profitable. As a rule, only a fraction separated from the original matrix could be used as normal mass spectrometry. These methods differ considerably based on the composition of the extract[22,23].

IV. Health Benefits And Medicinal Uses

The numerous health benefits of purslane have been evidenced in preclinical and several clinical studies via various bioassays using extracts and isolated compounds. Common folklore has extensively mentioned the therapeutic benefits of basic daily consumption of handpicked or homegrown purslane; for example, the whole plant can be consumed as a fresh salad, while its mildly bitter seeds and stem can replace okra in soup for the purpose of nourishing the body and treating heat-related conditions. Treatment of worm infection in humans and animals, earache, damaged eye cornea, cuts, burns, severe headache, eczema, contact dermatitis, abdominal pain, diarrhea, dysentery, and diabetes have also been described. In classical African and Asian traditional medicines, purslane has a long history of being used to promote digestion and alleviate health complaints such as heart disease, liver stagnation, jaundice, cardiovascular diseases, diabetes, dyspepsia, headache, cough, dermatitis, fever, inflammation, intestinal diseases, and urinary diseases. Prior folkloric evidence on purslane herbs has described their beneficial effects in respiratory diseases, expulsion of toxic heat, treating irregular menstruation, swollen gums, sore throat, various skin diseases, sunstroke, inflammation of the mouth, deodorization of ulcerous sores, weight control, strengthening of the immune system and body, taking the heat away, and promoting bodily health, as well as its purgative, slimming, diuretic, and stomachic effects. Moreover, the intake of purslane was particularly said to relieve environmental stress while stimulating other plants and generally benefiting from a healthier crop [24,25].

Traditional Uses

Traditional medicine approaches represent an incredibly important and valuable source of knowledge when it comes to the potential beneficial effects that *P. oleracea* can offer in terms of both preventing and treating various health problems. In the context of this present work, extensive studies and in-depth analysis of documents relating to the ethnopharmacological and traditional medicine uses of *P. oleracea* have been conducted. As a result, a wealth of relevant ancient knowledge regarding both wild and cultivated purslane biotraiters has been uncovered, providing valuable insight that is still applicable in our modern society. It is unfortunate that populations with a higher income and better access to medical resources and health services have, perhaps inadvertently, contributed to the degradation and disappearance of traditional knowledge. As a consequence, countless essential healthy practices, formulations, and recipes have been forgotten or remain unknown in many parts of the world, especially in economically developed countries. Nevertheless, the evidence collected in this study unequivocally supports the broad spectrum of therapeutic applications that *P. oleracea* possesses. The potential benefits of P. oleracea are vast and diverse. Its remarkable properties include anti-inflammatory, antinociceptive, antioxidant, anti-obesity, prenatal brain enhancement, mild mood enhancement, anticonvulsant, antidepressant, neuroprotective, hepatoprotective, antipsoriatic, immunomodulatory, antimycobacterial effects, just to name a few. Additionally, *P. oleracea* has demonstrated efficacy in the management and prevention of numerous health problems, ranging from osteoporosis, asthma, and hypertension, all the way to type 2 diabetes mellitus, neurocognitive disorders, atherosclerosis, cardiovascular diseases, and even certain skin problems that may arise after cosmetic surgeries. Moreover, the polysaccharides found in P. oleracea have been found to possess remarkable biological activity. They exhibit antinociceptive, anti-inflammatory, and antidiabetic properties, which can significantly reduce pain, inflammation, and assist in regulating insulin and glucose levels. These polysaccharides hold immense promise in the field of medicine and have the potential to bring about substantial advancements in our understanding and treatment of various health conditions. In conclusion, the vast array of therapeutic applications and potential health benefits that P. oleracea offers are truly astounding. Its inclusion in traditional medicine practices and its centuries-old usage attest to its effectiveness and inherent value. As we progress in our understanding of traditional medicine and its impacts on human health, P. oleracea stands as a powerful example of nature's ability to provide us with invaluable remedies and solutions to a wide range of health problems [9,14,26].

Modern Research Findings

Purslane gained attention mainly after the extensive research conducted on omega-3 fatty acids and a plethora of other health-promoting bioactive compounds, such as phenolic substances, vitamins, and minerals. It is truly remarkable that the consumption of purslane and its immensely beneficial oils can significantly improve human health and longevity by providing protection against a diverse range of diseases. These diseases, ranging from cancer, inflammation, type II diabetes, to cardiovascular diseases, are being effectively combated through the incorporation of purslane into the diet. The popularity of purslane stems from its remarkable composition of many beneficial ingredients that have been widely acknowledged as safe elements, affirming its indisputable worth[27]. Notably, purslane is naturally enriched with an exceptionally high amount of omega-3 fatty acids, which are lauded as being among the most crucial polyunsaturated fatty acids, playing an integral role in the intricate physiology of the human body. Furthermore, it is truly fascinating that purslane not only contains a substantial quantity of linolenic acid but also boasts significant amounts of linoleic, stearic, arachidic, behenic, palmitic, and myristic acids, making it an exceptional source of these essential compounds[28].

It is known that linolenic acid has a biological role in the human body. Furthermore, purslane contains a considerable amount of γ-tocopherol and approximately 3 mg of α-tocopherol[29]. Purslane also has valuable amounts of carotenoid pigments, such as β-carotene with xanthophylls, and thereby acts as a necessary pro-vitamin A source. Purslane is also a source of valuable phenolic substances, which have antioxidant characteristics outside of altogether free radical scavenging effects in vivo; flavonoids that have hypoglycemic, antihyperglycemic, anti-inflammatory, and anticoagulant properties; and ascorbic acid, also known as vitamin C[30]. It is also efficient in protecting humans from damage caused by reactive oxygen species created in the presence of metals. Purslane is useful as a dietary source of chromium and calcium for humans with diabetes, as it can reduce the risk of the disease and regulate glucose metabolism in the human body. Purslane is also a remarkable food source of folic acid.

V. Bioavailability And Pharmacokinetics

It is most important to know the bioavailability of a desired compound from a given medicinal plant because, unlike pure forms, the efficacy and safety of natural extracts are greatly determined by their bioadoption and bioconversion inside the body. Partially purified mixtures are often better absorbed and utilized biochemically by the body and, at times, are superior to the equivalent amounts of a highly purified ingredient present in a pharmaceutical grade. Alternatively, some extracts may be rich in unwanted substances, much too high in the required therapeutic dose, and are subject to metabolism for slow conversion or escape biotransformation, accruing in the blood as a toxic entity or causing an adverse effect. After reaching cells and tissues, bioactive compounds should hold the property to act and initiate the required biological effect[31]. In the particular case of a potent cancer chemoprotective agent, it is important to understand the tissue distribution and bioaccumulation; that is, whether the compound can reach and hold sufficient concentrations in accessible cancer sites as well as be efficiently cleared from the system or just cling on to pose a long-term toxic threat[32]. These concerns make us explore bioavailability, pharmacokinetics, transport, accumulation, and metabolism of natural compounds like alpha-linolenic acid, vitamins, carotenoids like zeaxanthin, lutein, and beta-carotene, polyphenolics like flavonoids and chlorogenic acids, and phytosterols like beta-sitosterol and melatonin, which are present abundantly in purslane as we embrace it to explore the most active natural resource in our search for hope in disease treatment.

Absorption and Distribution

The ability of purslane to exert its biological activities depends largely on the bioaccessibility and bioavailability of its active phytochemicals in the gastrointestinal tract. Various methods have been used to model the behavior of different classes of phytochemicals from purslane, from digestion to action. As part of the majority of leafy vegetables, the first stage is the destruction of the cellular organization of the leaf tissue, leading to the release of the phytochemicals contained within the tissue. In a similar manner to carotenoids and lutein esters, follow-up studies showed that the passive diffusion of lutein from purslane homogenates across the dialysis membrane increased linearly with the concentration of lutein, which, coupled with the linear relationship between temperature and lutein permeability, suggests that the diffusion of these lipophilic molecules was due to simple Fickian permeation. This suggests that the process by which purslane releases its phytochemicals is influenced by various factors, including the concentration of the active compounds and the temperature. Further studies could investigate the specific mechanisms by which these lipophilic molecules permeate the dialysis membrane, shedding light on the potential bioaccessibility and bioavailability of purslane's phytochemicals in the gastrointestinal tract. Understanding these processes can contribute to the development of strategies aimed at maximizing the health benefits of purslane consumption. With its rich array of phytochemicals, purslane holds promise as a valuable dietary component, and unraveling the mechanisms of its bioaccessibility and bioavailability is an important step towards harnessing its full potential[33,34,35,36].

In vivo, carotenoids are absorbed through cellular uptake into lipid droplets of the mucosal cells, followed by uptake into chylomicrons, a hypothesis supported by the lipophilic nature of carotenoids. With similar properties to carotenoids, it is likely that the absorption behavior of carotenoids in the antioxidant-rich purslane complex may be observed for polyphenols in purslane. Human digestion and absorption are akin to an added step whereby the upper small intestine contains gut wall segments that can be isolated and mounted in incubation chambers, exposing the gut lumen to digesting food. Due to the variable nature of food, dietary ingredients, and their interactions, which include macronutrients, food matrices, antinutrients, micronutrients, and other bioactive compounds, unpredictable interactions can arise that influence the physicochemical properties of candidate phytochemicals[37,38,39].

Metabolism and Excretion

Purslane's phenolic compounds are subjected to various biotransformation reactions such as the opening of epoxide rings, O-methylation, and glucuronidation under the catalysis of Phase I and Phase II metabolizing enzymes. Despite the loss of the parent compounds, hydroxylation can result in metabolites that are similar to those identified in the metabolic pathways of phenolic biosynthesis, which also have potential health benefits. Following absorption, some metabolites can be detected in various tissue samples, which further confirm their importance in cancer prevention and other health-promoting effects. Despite their significant bioactivities, the metabolism and excretion of purslane phenolic compounds in vivo were not comprehensively covered. Therefore, further studies are needed to completely explore the metabolic pathways and to locate the pivotal sites during biotransformation. Moreover, the metabolites' distribution in different target tissues will determine their metabolic fate, which could further confirm the active components that contribute to the targeted health benefits. In addition, understanding the kinetics of these reactions and their impact on the overall bioavailability of purslane phenolic compounds is crucial for a comprehensive evaluation of their therapeutic potential. Further investigations should also focus on elucidating the specific mechanisms involved in the conversion of these compounds and their subsequent elimination from the body. This will provide valuable insights into the optimal dosage and administration strategies, as well as potential drug interactions that may affect the effectiveness of purslane as a medicinal plant. Additionally, it is essential to explore the effects of various factors such as age, gender, and underlying health conditions on the metabolism and disposition of purslane metabolites. This information will contribute to personalized healthcare approaches and guide the development of targeted interventions for individuals at risk of cancer and other chronic diseases. Moreover, investigating the synergistic effects of purslane phenolic compounds with other bioactive substances, such as antioxidants and anti-inflammatory agents, could further enhance their therapeutic potential and pave the way for the development of novel combinational therapies. Ultimately, a comprehensive understanding of the metabolism, distribution, and therapeutic effects of purslane phenolic compounds will not only benefit scientific research but also provide a solid foundation for the utilization of this natural resource in the prevention and treatment of various diseases[40,41].

VI. Toxicological Considerations

This review examines recent studies focusing on identifying and quantifying the richness of secondary metabolites in this plant and categorizes these into main chemical families including carotenoids, non-carotenoid aliphatic compounds, alcohols, aldehydes, ketones, sterols, coumarins, furans, lactones, benzoic acid derivatives, cinnamic and phenolic acids, flavonoids, alkaloids, saponins, betalains, tocopherol, and tocopherol-like steroids. The pharmacological importance of these bioactives is discussed, considering benefits associated with cardiovascular risks, type 2 diabetes, obesity, cancer cell tumors, and neurological protection. Finally, toxicological properties of *P. oleracea* are summarized with information on cytotoxic and genotoxic actions. The nutritional and phytochemical richness of the common weedy plant, Purslane, has been recognized for decades. In this review, recent studies focusing on categorizing the richness of secondary metabolites in this plant are surveyed, and results are categorically organized. In vitro and in vivo studies report that these compounds express significant anti-inflammatory, antioxidant, neuroprotective, anti-tumor, and anti-angiogenesis effects. The importance of these compounds is also widely studied with regard to their benefits for cardiovascular, diabetic, and obesity treatments, among others. However, excessive consumption of this plant can cause some problems due to cytotoxic and genotoxic actions. The potential mechanisms of this toxicity are also summarized[42,43].

Potential Adverse Effects

The pharmaceutical qualities of *P. oleracea* are postulated to be rooted in the diversity of secondary metabolites. Different species of this plant vary widely in their active ingredient profile. This indicates the importance of careful nomenclature and critical quality control to ensure desired pharmacological activities. In fact, despite the traditional uses and widely reported therapeutic benefits, because purslane has a mild toxicity, an overdose can cause harm. Aimed at evaluating the acute and subchronic toxicity and identifying cytotoxic effects, a study was conducted in Sprague-Dawley rats for 90 days, finding the No Observed Adverse Effect Level (NOAEL) of the aqueous extract of *P. oleracea* was 2553.5 mg/kg/day for both male and female rats, considerably greater than the recommended daily consumption dose for humans[44,45].

Except for the introduction, where a short section outlines the preliminary goals of the current work, there are no segment headings in the article. The text is divided into logical, numbered sections with descriptive headings. Additionally, a clear research scope with specific objectives and specific discussion would facilitate the use of this potential-rich source for a wide range of applications. Indeed, concentrations in preparations should be carefully selected to avoid potential negative effects[46].

Safety Assessment

Given the bioactive richness of purslane, its safe consumption is strategically important from a consumer's perspective. In the USA, purslane is found in the market, thus allowing it to be included in the largest market area[47]. Several studies are available regarding the safety profile of its consumption. In traditional medicine, the roots and seeds of purslane were consumed due to their multiple health benefits, including body building and therapeutic effects such as helping to reduce heat, remedy visual impairment, and diminish inflammation[48]. Overdosing is one of the main risks to be reckoned with when antioxidants are given individually; the high antioxidant capacity of polyphenols can paradoxically induce oxidative stress, causing potential liver damage. The treatment used in high doses was observed to cause eccentric nuclei, pyknotic, or necrotic changes in the liver[49,50].

A recent safety bioassay was performed using Sprague-Dawley rats to evaluate the safety of purslane extracts of varying durations and applied doses. At 1000 mg/kg/day, the high-dose practices had critical effects on hematological features, and pathological changes were observed in the liver, but these changes were prevented by treating rats with a low dose for 28 days. The low and medium herbal extract doses (250 and 500 mg/kg), administered to ICR mice in quantities of 1000 and 2000 mg/kg, yielded no clinical indication of possible acute exposure, symptoms of chronic poisoning, or acute mortality[51]. All rats consumed feed and demonstrated gains in body weight, with no major weight decreases in the liver, spleen, and kidney. Chronic animal exposure could lead to liver and kidney damage, primarily involving significant white and red patterns in liver cells. With acute hepatotoxic injuries in the liver, myocytolysis, renal tubular necrosis, and other complications were likely to occur. The root and leaf bark of purslane significantly improved the blood and liver organ volume ratio, while blood urea nitrogen, blood creatinine, aspartic aminotransferase, alanine aminotransferase, alkaline phosphatase, and associated tissue injuries were significantly improved by lowering the levels of endogenous antioxidants. Scientific evidence of the widespread use of this plant is one of the benefits of purslane in natural medicine. Various advantages of purslane extracts were produced using modern technology, which is a rich source of bioactive constituents for the meal, food, and nutraceutical sectors, as only purslane possesses powerful bioactive components[52,53].

VII. Nutritional Value And Culinary Uses

Purslane is considered one of the richest micro-nutrient vegetables. There is wide public acceptance of purslane as a table vegetable in various parts of the world. The vegetable is commonly used in Mediterranean, Indo-Pakistani, and Mexican cuisines both as a raw herb and in cooked dishes[54]. The succulent leaves and tender stem are similar in taste to spinach, with a mild refreshing flavor. The stems, especially, have a sour, lemony taste with a slightly saline flavor due to the oxalic acid, which renders a tangy zest in the culinary world[55]. Inroads for new product development were paved by its incorporation in beverages and jams for the health-conscious customer segment[56].

The high levels of chemical compounds inside purslane directly affect its taste, flavor, and texture, resulting in it generally being perceived as a salty, peppery, or refreshing leafy green[57]. Some of the many flavors reported from purslane are sour, salty, and peppery. In combination with its fleshy leaves, purslane's taste and flavor give it special value for those who enjoy a salad or cooked vegetable with potential health benefits; particularly, it is used as a salad herb in many parts of the world. Additionally, its use in soups, stews, turnovers, pickles, fritters, and as a steamed vegetable for breakfast is reported around the world in conjunction with its uses in salads[58,59,60,61].

Macronutrient and Micronutrient Content

Purslane is a surprisingly rich source of bioactive compounds, including certain autacoids, such as alpha-linolenic acid. As a green, its macro- and micro-nutrient content is also of interest. Macronutrient composition studies showed that protein, fiber, carbohydrates, and oxalate are the major compounds present in purslane. Among the macronutrients, moisture and ash as well as the macronutrients protein, fiber, and carbohydrates on a fresh weight basis were determined[12]. Concerning the micronutrient compositions, the phenolic content of purslane was divided into soluble-bound fractions and free-bound fractions, which were then quantified. The soluble fraction of the phenolics could be categorized into hydrophilic and lipophilic components. The total phenolic content was extracted using 70% methanol for the free-bound fractions. Additionally, the calculated contents of each individual phenolic glycoside and gallic acid equivalent in the bound-esterified phenolic component were specified[62].

Purslane also contains water-soluble and fat-soluble nutrients, including alpha-tocopherol, beta-carotene, vitamin C, and chlorophyll a. The water-soluble macronutrient content was also determined using the spectrophotometric method[63].Some reports showed that the water-soluble macronutrient content contains a high water-extractable polysaccharide content, which is rich in galacturonic acid and glucose residues[64]. Interestingly, the non-starch polysaccharide content reached a significant amount, which is higher than that of any plant. Another study found that the oxalate content in leafy greens was as important as their calcium content, with purslane having a remarkable increase in oxalate contents and thus yielding lesser antinutrient effect through a subjection to each light and blue light[65].

These findings indicate that the bioavailability of bioactive compounds in purslane, such as the soluble or dietary phenolic compounds, increased upon structural modification, from a bound to an esterified state, to reduce any deleterious factors due to their content[38]. The fiber, protein, and oxalate content in the purslane lamina can induce in vitro bile acid binding, antioxidant, and an immune modulatory response, which could be associated with the modulation of a stable digestion and colon health status[66]. The pigments, especially the chlorophyll, were shown to be the bioaccessible food emulsifiers from various succulent leafy greens[67]. These pigments are derived from various leafy greens, promoting similar emulsification properties as a mixture of dried egg yolk and purslane[68]. Yet, the micro- and macro-nutrient profiles of food or supplements prominently consisting of purslane have yet to be elucidated[69].

Incorporation in Recipes

Incorporating purslane in recipes that the general population typically enjoys may facilitate offering the health-promoting effects of purslane to people[70]. While destination food for the general population covers sweet biscuits, crunchy snacks, bread, and cakes, it is suggested that there is a great potential consumer market for the development of innovative, attractive, tasty, healthy, and bioactive-rich snack foods that meet the demands of snacks at any time and occasion, such as salty biscuits, pies, pickles, and candy[71], offering the health benefits of purslane, implying a good market potential for companies. In line with market demands for processed products with natural food additives[72], using purslane in meat products would provide a good amount of natural antioxidants and demonstrate an improvement in shelf life, sensory characteristics, and subsequently the keeping quality until the products are consumed[73]

The addition of purslane in yogurts could be a useful approach to incorporate such natural compounds into the diet while also benefiting from the health-promoting effects of probiotics. All forms of incorporation could be an easy and convenient way to bring the bioactive content of purslane into the diet on a regular basis for a wide segment of the population[14]. The present data provide preliminary information about the bioactive properties of purslane leaves, indicating the importance of increasing human consumption of this underused plant by developing new food applications that could increase the intake of natural bioactive compounds[74]. Freshly harvested purslane would be ideal for customers who walk in the market area with high purchasing power and are ready to enjoy unique products and experiment with new flavors[49].

VIII. Pharmacological Activities And Mechanisms

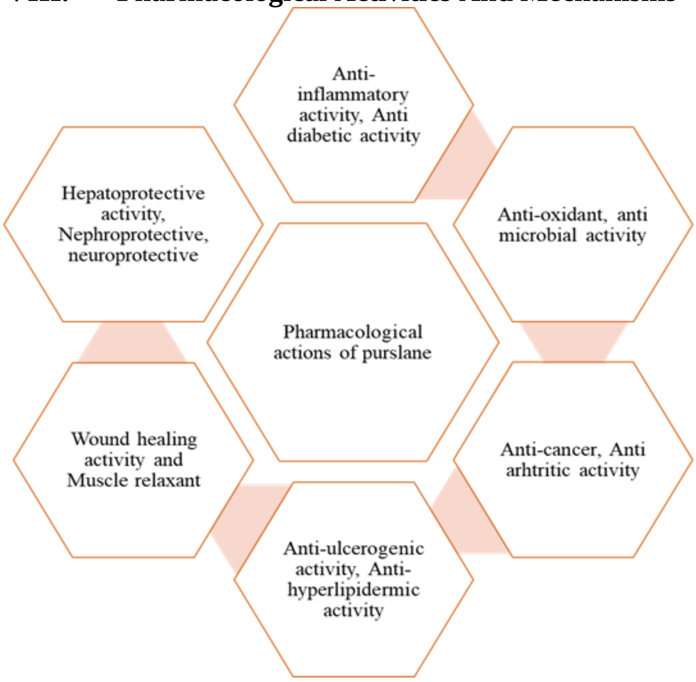

Fig 2: Pharmacological actions of *Portulaca oleracea*

Purslane exhibits diverse pharmacological activities, including accelerating wound healing, anti-inflammatory and analgesic effects, antifatigue activity, antiaging, antigastric ulcer, hepatoprotective effect, kidney protection, neuroprotective effect, cardiovascular protection, and antitumor activity, as well as antifungal and antimicrobial activities. Alpha-linolenic acid, flavonoids, and other phenolic compounds are suggested to be the primary bioactive constituents responsible for the rich pharmacological activities of purslane[19]. In addition, the mechanisms of action for several bioactivities and the structure-activity relationships have also been elucidated. Many pharmacological and mechanistic studies have verified that purslane has promising therapeutic potential in chronic noncommunicable diseases and infectious diseases, and purslane may serve as a beneficial rich source for the development of new pharmaceutical agents[48]. This comprehensive review aims to elucidate the in vitro and in vivo pharmacological contributions of purslane, which would provide solid proof for translating the studies from mice, rats, and in vitro experiments into humans and investigating its commercialization and further development[75]. Previous studies have proved that purslane exhibits diverse pharmacological activities, including accelerating wound healing, anti-inflammatory and analgesic effects, antifatigue activity, antiaging, antigastric ulcer, hepatoprotective effect, kidney protection, neuroprotective effect, cardiovascular protection, and antitumor activity, as well as antifungal and antimicrobial activities[76]. Furthermore, alpha-linolenic acid, flavonoids, and other phenolic compounds are suggested to be the primary bioactive constituents responsible for the rich pharmacological activities of purslane. In addition, the mechanisms of action for several bioactivities and the structure-activity relationships have also been elucidated. This comprehensive review aims to elucidate the in vitro and in vivo pharmacological contributions of purslane, which would provide solid proof for translating the studies from mice, rats, and in vitro experiments into humans and investigating its commercialization and further development[77,78].

Anti-inflammatory Properties

The anti-inflammatory potential of *Portulaca oleracea* has been confirmed through several works. The leaves, stems, or whole plant of *P. oleracea* have been reported to ameliorate LPS- and heat-induced neuroinflammation, lysozyme-induced peritoneal inflammation, as well as inflammation-related chronic diseases, including diabetes, primary dysmenorrhea, Parkinson's disease, and colon cancer growth, as well as joint inflammations such as rheumatoid arthritis caused by bacteria, viruses, or fungi. N-Benzyl-N(3-methyl-4O-methyl pyridyl) amine suppresses TNF-α-induced NF-κB activity without affecting the activity of specific IκB kinases. It also greatly inhibits the expression of TNF-α-induced TNF receptor-associated factor-2 and elevates the interaction of TRAF2 and IκB-α[79,80,81].

In TNF-α-stimulated HaCaT keratinocytes, it shows similar results but does not block the phosphorylation or nuclear translocation of ERK and p38 MAPK. These findings prove that it can be used as a positive drug for the treatment of diseases related to NF-κB and TRAF2. Homoprotocatechuate served as an intercellular antioxidant modulator and ERK and p38 MAPK inhibitor and directly targeted Keap1 to prevent the ubiquitination of Nrf2. This effect increased Shan-Lu, GSH, CAT, SOD, and HO-1 and diminished TNF-α. Further, it prevented LPS-induced inflammation. These outcomes suggested that it could serve as food additives and nutraceuticals to mitigate free radical damage and resolve inflammation. In addition, the commercialization of HPO should be considered. The main reason for this speculation is that it has a special molecular mechanism that autonomously regulates inflammation in the skin and body, thereby ameliorating chronic skin and systemic diseases[82,83].

Antioxidant Effects

Antioxidants have been well documented for their protective effects against various degenerative diseases, including cancers, aging, coronary heart disease, atherosclerosis, diabetes, and neurodegenerative diseases. Detection of antioxidant properties present in plants or plant-derived products is the most significant advantage of well-known antioxidant nutrients in food, herbal products, functional beverages, and nutraceuticals. Many synthetic antioxidants exhibit potential toxicity at high usage levels, raising concerns about potential human health problems. Hence, the development of natural antioxidants for use in food products is in progress. Since natural food antioxidants are much safer than their synthetic counterparts, great attention has been focused on research efforts to look for new and efficient natural sources of antioxidants. Natural antioxidants are of interest to the public and the food and pharmaceutical industries[84,85,86].

Some antioxidants scavenge radicals by acting as hydrogen donors and electron donors. By losing their hydrogens, lipids, proteins, and DNA can be protected from the damaging peroxide chain reaction catalyzed by oxygen. The OH group of phenolic compounds is responsible for their antioxidant power. Large amounts of natural antioxidants of different botanical origins, such as ascorbic acid, tocopherols, certain fatty acids, carotenoids, and phenolic acids, are present in the leaves of *P. oleracea*. As free radical scavengers, the phenolic components of P. oleracea seem to play important roles, possessing 12 diverse phenolic acids at levels as high as 400,000 mg/kg dry weight per each antioxidant type. In addition, apart from various polyunsaturated fatty acids and storage carotenoids, cyclo-DOPA can be found in the mucilaginous leaf arising from purine synthesis in the chloroplast and the subsequent plastidial conversion and transport of DOPA. Nonenzymatic autoxidative degradation of lithium phenylsilanole as a substrate was catalyzed, and thus monophenylsilanolic acid displayed the highest reduced absorption in a clean matrix of lettuce compared with other phenolic acids, even if slightly less antioxidant activity was measured according to the ferrous chelating and hydroxyl, peroxyl, and DPPH radical scavenging capacities. This may imply that phenolic acids and polyphenols have a protective metabolic role against active oxygen species. Moreover, betaxanthins synthesized from acylated betalains, solidinone, and dopaxanthin could effectively prevent DNA damage and decrease ROS generation in hippocampal cell culture. The antioxidant effects and radical-scavenging activity of different betalains improved hepatoprotection in chronic liver disease with hepatic fibrosis caused by congestive heart failure. The total antioxidant results of these bioactive abundant leaf compounds, along with the successful disinhibition of antioxidant enzyme-like activity, as well as the enzymatic activities of topoisomerase-I and creatine kinase, are significant[30,87,88].

Anticancer Potential

In recent years, research on the anticancer potential of purslane has yielded encouraging results, suggesting that this plant may inhibit the growth of various human tumor cell lines, particularly liver, lung, and breast cancer. The potential anticancer activity of purslane is related to its ability to effectively reduce oxidative stress and inflammation. Although the exact compounds responsible for the observed activities are not yet fully understood, they are likely to include polyphenols such as quercetin, as well as unsaturated acids such as linolenic acid and eicosapentaenoic acid. Quercetin has shown great potential due to its multifunctional involvement in the growth of lung, liver, and breast cancer cells. However, it should be noted that in one experiment, quercetin inhibited breast cancer cell division independently of the estrogen receptor status. Since activated Akt contributes to cell proliferation and is involved in apoptosis prevention, quercetin is administered in human breast cancer cells. But the mechanism of action in apoptosis requires further study. The biological activity of quercetin is also related to its cytotoxic effect on glioma stem cells. Ultimately, the pursuit of a mechanism to prevent migration, aggregation, cell cycle, and apoptosis in lung cancer cells is far from complete. Besides quercetin, the essential fatty acids linolenic acid and eicosapentaenoic acid have shown unique pharmacological potential in breast and liver cancer. The antitumor efficacy was achieved by decreasing microscopic activity through apoptosis and/or cell cycle checkpoints[51,66,89].

Wound Healing Activity

Since wounds are the most common skin trauma, their pathology attracts more attention than many other conditions. Numerous clinical studies have investigated the effectiveness of wound healing in humans. Topically used P. oleracea enhanced wound healing and tissue regeneration by increasing the levels of COX-2, EGF, and VEGF, along with higher mucus and collagen content. The nano-formulation of tragacanth hydrogel-chitosan nanoparticles and Urtica dioica-*P. oleracea*/Mel and Mond gel showed 30–60% wound contraction, 12–16 days of epithelialization, 43%–45% of breaking strength, and 37% of hydroxyproline activity. Additionally, zinc oxide-poloxamer nanocomposites combined with *P. oleracea* significantly increased fibroblast proliferation and antimicrobial activity, resulting in 86% wound healing with high tensile strength, body weight, tissue granulation, and complete re-epithelialization in 14 days in mice. The wound-healing boost is mainly attributed to the presence of polyphenols, flavonoids, polyunsaturated fatty acids, and vitamin E[90,91,92].

Enhanced wound healing and tissue formation were mediated via the stimulation of growth factors such as transforming growth factor-beta1 (TGF-β1) and connective tissue growth factor (CTGF) by quercetin, myricetin, and kaempferol. Despite P. oleracea's plethora of bioactivities regarding its wound healing and tissue formation, its novel application as a non-foam capable "gold nanoparticle-gelatin-*P. oleracea*" resulted from in vitro skin-drill scratch models. The gold nanoparticle-gelatin-doped patch considerably reduced ROS and TNF-α. Moreover, it encourages the isoforms of collagen and elastin required for healing. The P. oleracea-embroidered novel bioscaffolds considerably reduce ROS and protein levels that showed therapeutic potential on the tensile properties of fibroblast-inserted matrices and wound contraction. Double-layer silk fibroin/P. oleracea-chitosan composite nanofibrous wound dressings had promising properties with antibacterial infection, inflammation, toxicity, high tensile strength, and healing observation in terms of breaking strength, histology, and hydroxyproline content compared to those of untreated controls[93,94,95].

Neuroprotective Activity

This is one of the most remarkable properties of purslane. The traditional use of purslane extract to relieve sleep disturbances is justified by modern pharmacological studies, which proved that the extract possesses central nervous system (CNS) depressant activity, enhancing the hypnotic effect of pentobarbital. The bioactivity of purslane phenolic compounds is largely associated with their antioxidant activity and ability to neutralize free radicals. Flavonoids can protect neurons through several important mechanisms, including antioxidation, detoxification of reactive oxygen species (ROS), and free radical scavenging against the pathological process of neuron loss in neurodegeneration. Brain ischemia is one of the most lethal cerebrovascular diseases worldwide, resulting from a transient or irreversible loss of cerebral blood flow. Brain tissues are sensitive to ischemia due to their high metabolic demands and low oxidative defense capacities, making them especially vulnerable to excitotoxic damage, oxidative stress, and inflammation. Several treatments are available that relieve secondary brain injury by increasing blood supply and/or decreasing inflammation, but none of these treatments have yet been shown to be effective[96,97].

Surgical revascularization recanalizes arteries in ischemic areas but adds to the risk of bleeding during the perioperative period. Revascularization is effective in large infarcts but fails in small infarcts. The development of neuroprotective drugs for clinical treatment involves effectively improving cerebral ischemia. Flavonoids can play a neuroprotective role by improving blood supply to the ischemic brain and increasing the free radical scavenging capacity in brain tissue. Dietary polyphenols have demonstrated potential neuroprotective effects and may be useful as dietary supplements to reduce oxidative stress and ameliorate inflammation caused by ischemic stroke. It is worth noting that flavonoids have a higher bioavailability than many other food-derived compounds due to their ability to cross the blood-brain barrier, thereby interacting directly with the brain. These natural compounds are considered neuroprotective agents, showing multifaceted protective activity in several models of preclinical and clinical studies. They can reduce the risk of brain injury and improve prognosis, presenting a major therapeutic advantage[98,99].

Anti-hyperlipidemic Activity

The effects of purslane extracts on the anti-hyperlipidemia of high-fat-diet rats were examined by minnow valuation. It provided evidence that the methanol extract of *P. oleracea* has the potential in treating hyperlipidemia, and omega-3 fatty acids released from PUFA might be involved in this process. Dyslipidemia (hypercholesterolemia, hypertriglyceridemia, or both) is a major risk factor for coronary heart disease. Allium sativum is an alternative source of bioactive lipids containing PUFAs. Besides, n-3 PUFAs (alpha-linolenic acid) are available in some leafy greens of purslane, spinach, and hippophae. These PUFAs can lower cardio-metabolic risk factors, improve cardiovascular morbidity, and reduce mortality[50].

The bioactivities and potential mechanisms of PUFAs are very attractive for cancer prevention, alongside other reported bioactive effects on cardiology, brain, and inflammatory diseases[24]. Prior to now, the current knowledge on the therapeutic potential of purslane for hyperlipidemia is limited. Recently, the potential underlying molecular mechanism behind omega-3 PUFAs related to anti-hyperlipidemia is shown as a key biological regulatory cytokine, called fibroblast growth factor 21 along with the replication protein A2-M complex. The release of RPA2-M bridging molecules by omega-3 fatty acids affects FGF-21 signaling phosphorylation. These molecules might hydrolyze some lipid biomolecules in lipid wastewater. Since dietary plants rich in these omega-3 fatty acids may alter plasma lipid profiles by upregulating some molecular pathways, these findings are of medical importance as potential treatment targets for dyslipidemia, diet-induced obesity, and insulin resistance. In the hypertriglyceridemia study, the candidate pre-treated rats displayed an expected FGF-21 level, and no significant discrepancies were observed among the different treatment candidates. The triglyceride level was treated by the highest level in pre-HFD animals of 20, then followed by 0.05, a treatment[100].

Anti-ulcerogenic Activity

Peptic ulcer is a common gastrointestinal disorder with multiple factors such as prolonged use of nonsteroidal anti-inflammatory drugs, corticosteroids, imbalanced production of excessive amounts of gastric juice, and disintegration of the mucosal protective barriers. Research has demonstrated a close association between oxidative stress, reduction in the endogenous defense mechanism, and the development of peptic ulcer. Reducing oxidative stress is critical for successful ulcer therapy. The wound diameter of the ethanol-induced lesion group is 66%, while the sucralfate treated group is 21%. The pretreatments of the extract treated groups remarkably maintained the lesion diameter at 42% and 34%, respectively, which is significantly different from the disease group. These results have confirmed that the antioxidant capacity of AP could be beneficial in alleviating gastric mucosal injury and protecting against endothelial dysfunction[101,102,103].

Regarding the gastroprotective effect of AP, the potential mechanism might be due to the presence of total flavonoids, which cause prostaglandin release and reduce acid output, while the phenolic acids have been shown to increase mucus secretion and have an antioxidant effect on aggressive endogenous peroxides. However, a further in-depth study series on the mechanism of action is needed for a better understanding of AP in improving active peptic ulcer[104,105,106].

Anti-arthritic Activity

Anti-inflammatory compounds of purslane may be useful to consider for arthritis treatment, which is marked by chronic inflammation. Purslane samples were analyzed for phytochemical profiles using LC-DAD-ESI/HRMS. Ethanol extracts were tested on carboxymethyl cellulose-treated Balb/c mice with arthritis induced by Freund’s complete adjuvant. Hematology studies were conducted before and after arthritis induction. Paw nodule observation and the thymus index were performed at the end of the study. The synthesis of bone and cartilage biomarkers and rheumatoid arthritis biomarkers were analyzed using real-time qPCR. A total of 70 metabolites were obtained by creating a library of phytochemical profiles from campus purslane shoots. In anti-arthritis studies, 24 phytochemical compounds contained SAG. Conclusions: *P. oleracea* has great potential as a nutraceutical for use in arthritis management with 24 purified compounds. Future experiments should consider investigating the interaction among these compounds[107,108].

IX. Future Research Directions

Unraveling the therapeutic capability of PU can further be undertaken through more rigorous preclinical and clinical investigations[109]. Even though PU are edible and are consumed traditionally as a health element, caution should be given to using synthetic production of PU preparations. The consumption of PU could vary in certain individuals, and there is a scarcity of information on long-term effects[110,111]. Information on dosage, pharmacokinetics, and potential drug interactions remain inadequately discussed and require additional research for its pharmacology to be scripted and introduced to therapeutics. In vivo and in vitro research is required to unveil the therapeutic potential of PU to address inflammation, allergies, diabetes, cancer, insulin resistance, oxidative stress, and other health conditions. Such investigations could also present an emphasis on synergistic mechanisms and mutagenic actions[112,113,114,115].

Sensitization and irritant interactions, as well as side effects in vivo in humans, need to be considered. A careful precaution is also needed for intracellular pharmacokinetics and influencing pathways. To gain insight into the mechanism of action of PU that regulate phytopharmaceutical development, in vitro research is of particular relevance. Research studies could involve tests on the extract of PU and purified compounds or personalized dietary syrups consumed in the experimental environment to establish effective use and maximize patient acceptance of such compositions. Animal and human studies that follow the subsidiary model could also showcase benefits in a variety of defined human population subsets, particularly early in chronic therapy, and appear rational after assessing toxicity across species[116,117,118,119].

Exploration of Novel Compounds

Seeds and leaves of portulaca species are good sources of omega-3 fatty acids. Chemical and gas chromatography, along with high-performance liquid chromatography combined with biochemical methods, may be used for evaluating the different fatty acids present in purslane. Almost 35 fatty acids are present in purslane, and their composition in the plant changes with their geographical location. Compounds like tetrahydroisoquinolines, nortetrahydroisoquinolines, and quinolizine alkaloids have been isolated from the purslane methanolic extract and are perceived to be nerve relaxing as well as cytotoxic. Purslane possesses flavonoids in large amounts, exhibiting pharmacological activities such as being antioxidant, antitumor, antimicrobial, and hepatoprotective. Proteinase inhibitors extracted from plants such as purslane possess antiviral, antitumor, and neuropathic properties. The main proteins of purslane are associated with the mechanisms of resistance and defense against stress caused by plants. Furthermore, proteins participate in mechanisms involved in the secondary metabolism of plants as they contribute to the organization of the cellular cytoskeleton. The data related to the secondary metabolite contents of portulaca species may permit users to manipulate the system of purslane by increasing its nutrient contents or by enhancing the pharmacological activities such as antioxidative, antidiabetic, and cholesterol-lowering activities. These positive impacts can be useful for the fields of pharmaceuticals as well as nutraceuticals. Purslane contains lipid oxides, 7-epi-eicosapentaenoic acid, and hexadecanediol tetrahydrofuran-3, glucose, glycine, betalain, purpurin, blue malonin, beta-ethyl phenol, 3-pentanol, and hydrocarbons such as pentatriacontane and hexadecane, which are known for their anti-inflammatory and antioxidant properties. The number of secondary metabolites such as alkaloids, flavonoids, phylate, saponins, and tannins in the different locations of purslane and their approximate quantities are presented[14,120].

Clinical Trials and Evidence-Based Medicine

The cure of different diseases of the liver and heart by purslane in various ways has been reported by theoretical or preclinical studies. Numerous experimental studies have extensively explored the effects of purslane on various liver diseases, such as non-alcoholic fatty liver disease, alcoholic liver disease, hepatic fibrosis, and more, using animal models as a basis for investigation. The potential mechanisms of action are incredibly diverse, encompassing a range of beneficial properties. These include strong antioxidant capabilities, anti-inflammatory activities, lipid-lowering effects, insulin-sensitizing properties, amelioration of gut microbiota, and the suppression of detrimental signals. Despite the promising findings from preclinical research, the availability of clinical evidence validating the use of purslane, specifically for liver diseases, remains quite limited. Among the registered clinical trials, only one has been conducted thus far, offering a glimpse into the safety and efficacy of purslane seed oil. This particular trial focused on exploring the effects of purslane seed oil in patients with dyslipidemia, shedding light on its potential benefits. The results demonstrated that purslane seed oil had a significant impact on several crucial parameters related to cardiovascular health. It was found to effectively decrease levels of serum triglycerides, total cholesterol, and LDL cholesterol. Although the study had a relatively small sample size, the observed positive outcomes strongly suggest that the seed oil of purslane could potentially serve as a promising avenue for safeguarding against cardiovascular disease and promoting overall well-being[49,50,51,121].

X. Conclusion

In conclusion, increasing the consumption of a wide range of nutrient-rich and wholesome foods in the daily diet might not only significantly contribute to the prevention of numerous diseases but also possess the potential to facilitate the healing process within the body. It is essential to acknowledge that despite the extensive research conducted thus far, the analysis of only about 18% of all living vascular plant species has been completed. Remarkably, over the course of recent years, an exponential surge in interest and an ardent pursuit for alternative therapies have been witnessed. This surge emanates from the relentless quest to discover bioactive natural compounds that are devoid of the undesired side effects commonly associated with conventional therapies. Within this context, ongoing investigations and studies have presented promising leads and valuable insights regarding the utilization of Plant Metabolites (PMs) in the prevention and treatment of a myriad of diseases. As a result, it is increasingly becoming evident that PMs will undoubtedly emerge as one of the foremost alternatives of choice to effectively combat diseases without the manifestation of any undesirable side effects[122.123,124].

The realm of edible plants, with an emphasis on one such underrated gem known as purslane, appears particularly promising in its potential to serve as a cancer-preventive and adjuvant therapeutic strategy. Purslane, despite its currently underappreciated status, boasts a plethora of biologically active compounds that have been shown to confer significant health benefits. The inclusion of these compounds within the realm of cancer prevention and treatment holds tremendous potential for positively impacting the outcome of patients. To bridge the gap between traditional medicine and the advances of modern medical science, comprehensive research endeavors and extensive clinical trials are of paramount importance. The primary objective of these endeavors is to explore and decipher the precise molecular mechanisms underpinning the therapeutic effects of these plant secondary metabolites. By doing so, a comprehensive understanding of the intricate workings of cancer immunotherapy can be achieved, ultimately paving the way for a seamless integration of traditional and modern medical practices[125,126,127].

Summary of Key Findings

Purslane is a nutritious leafy green vegetable and traditionally a widely accepted remedy for various ailments. This paper selects more than fifty phytochemicals to introduce the chemical compounds of purslane, and mainly discusses the findings from certain research groups on the preliminary phytochemical profiling and nutraceutical properties. The perspective on the industrial and therapeutic importance of purslane in the present century is also briefly presented, giving an idea of the plant's potential significant role in the world's health system. Furthermore, the dietary intake role in human health may not be overemphasized with the views that make the plant, not just a common unwanted field weed in some regions, special and interestingly complex. A deep investigation to unravel the benefits of pursuing a biological approach to understand further the mechanisms of action for the cure of certain health disorders and examine future research needs in purslane usage is highly required. Therefore, this useful information could be beneficial for nutraceutical companies and food producers regarding the possible promotion of this valuable plant resource as well as for other various stakeholders[9,10,50].

Purslane likely has one of the most prolific seed banks of all the terrestrial plants on earth. This ubiquitous garden enemy is a succulent leaf vegetable, widely distributed, and present in all warm-temperate and tropical regions of the world. The species can be commonly found as a weed in virtually every arable land plot, providing it is not grown with other clean crop production where it is not critically considered intolerable. Purslane as a crop and the progress is likely smooth—if not also profitable for farmers in areas where the healthy delicacy is in demand, knowing the hardiness of the species, resistance, and especially its super ability to withstand the different degrees of harshness imposed by the main known worldwide climatic fluctuations, such as the unpredicted brief heavy rain or the prolonged drought periods including the summer short cycles due to the Earth's axis inclination[128,129,130,131].

Implications for Health and Medicine

Health benefits of purslane rely on its phytochemicals; hence, a comprehensive understanding of the phytochemical profiles of this vegetable is important for its utilization as functional food. Purslane is a summer leafy vegetable crop rich in numerous nutrients and phytochemicals. An important characteristic of this vegetable is the richness of omega-3 fatty acids, which possess very high antioxidant capacities that protect the delicate bioactive phytochemicals like alpha-linolenic acid and linoleic acid from degradation, and only a minor retention of these acids is typically observed after cooking. Some biomarkers of purslane have been identified that indicate it might be beneficial in obesity, hypertension, diabetes, depression, and generalized anxiety. The significant differences in bioactive compounds, especially antioxidant and anti-depressant associated compounds, in different purslane genotypes strongly indicate their health-promotion benefits being at least partially genotype-dependent. The effects of minor parts of these bioactive compounds, including cannabinoids, have not been well investigated, thus representing a potential area of further research in this crop. A comprehensive understanding of the phytochemical profiles of purslane is crucial due to the numerous health benefits it provides. This leafy summer vegetable is packed with essential nutrients and phytochemicals, making it an excellent choice for functional food. Notably, purslane stands out for its abundance of omega-3 fatty acids, which boast remarkable antioxidant capacities. These antioxidants play a crucial role in preserving the integrity of bioactive phytochemicals, such as alpha-linolenic acid and linoleic acid, preventing their degradation. Even after cooking, purslane exhibits excellent retention of these beneficial acids. Moreover, certain biomarkers found in purslane suggest its potential effectiveness in combating obesity, hypertension, diabetes, depression, and generalized anxiety. It is worth noting that different purslane genotypes display significant disparities in bioactive compounds, particularly those associated with antioxidants and anti-depressant properties. This finding strongly suggests that the health-promoting benefits of purslane are partly dependent on the genotype. Interestingly, the effects of minor components, including cannabinoids, in these bioactive compounds have not been extensively explored. Thus, further research in this area could uncover additional advantages of purslane and contribute to its overall potential as a crop with countless health benefits[30,40,57,132].

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