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Purslane (*Portulaca oleracea* L.): An underutilized wonder plant with potential pharmacological value

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Abstract
Purslane (*Portulaca oleracea* L.), believed to be the earliest vegetable consumed by human has been a part of traditional culinary and folk medicine system since long back. It is a rich source of vitamins, flavonoids, alkaloids, polysaccharides, omega-3 fatty acids (Especially alpha-linolenic and gamma-linolenic acids), terpenoids, sterols, proteins and minerals and has also been reported as the super food for the future. Owing to its diverse phytoconstituents, Purslane has been reported to possess potent pharmacological actions such as hepato-protective, neuroprotective, anti-inflammatory, antimicrobial, antidiabetic, antioxidant, anticancer, antihypertensive actions. However, molecular mechanisms of action of only few of these have been studied and more systematic clinical studies are needed to test the pharmaceutical properties of purslane. A detailed information on phytochemistry and pharmacology of purslane has been presented in this review for its full exploration by the research community.

Keywords: Purslane, *Portulaca oleracea*, phytochemicals, pharmacology, ethnobotany

1. Introduction
Purslane (*Portulaca oleracea* L.) is a widespread medicinal plant that is used not only as an edible plant, but also as a traditional medicine for alleviating a wide spectrum of diseases. It is known by various synonyms at various locations such as Purslane (USA and Australia), Pigweed (England), Pourpier (France), Andulam (Malaysia) [1]. Within India also it has several vernacular names in different languages such as sanhti, punarva, paruppu keerai, gangavalli or kulfa. The name *Portulaca* is thought to be derived from the Latin 'porto' meaning "to carry" and 'lac' meaning milk, since the plant contains a milky juice [2] and has been reported officially in the French, Mexican, Spanish, and Venezuelan Pharmacopoeias [3]. It is distributed widely in the tropical and subtropical areas of the world including many parts of the United States. It is eaten extensively as a potherb and is added to soups and salads around the Mediterranean and tropical Asian countries. Its soft stem and leaves are used raw, alone or with other greens [4]. Purslane is also used for cooking or used as a pickle.
Purslane also provides a source of nutritional benefits owing to its rich ω-3 fatty acids and antioxidant properties [5]. It has been used as a folk medicine in many countries as a febrifuge, antiseptic, vermifuge and in the treatment of burns, headache, and diseases related to the intestine, liver, stomach, cough, shortness of breath, arthritis so forth [6]. It exhibits a wide range of pharmacological effects, including antibacterial [7], anti ulcerogenic [8], anti-inflammatory [9], antioxidant [10], wound-healing [11] properties, purgative, cardiac tonic, emollient, muscle relaxant, diuretic treatment and in the treatment of osteoporosis and psoriasis [12]. The nutritional quality of Purslane has also been reported to be better than the major cultivated vegetables as it possesses comparatively higher β-carotene, ascorbic acid, alpha-linolenic acid (ALA) and antioxidant properties [13-14]. It has been reported to contain 5 times higher ω-3 fatty acids than spinach. Omega-3 fatty acids belong to a group of polyunsaturated fatty acids essential for human growth, development, prevention of numerous cardiovascular diseases and maintenance of a healthy immune system [15]. Generally, fish is the considered as the richest source of ω-3 fatty acids and is recommended to be consumed on regular basis to meet the ω-3 fatty acid requirement of the body while others sources have been reported to be limiting in ω-3 fatty acids [16]. Purslane has recently been identified as the richest vegetable source of alpha-linolenic acid, an essential omega-3 fatty acid [17] and hence can be considered as an important substitute of fish for vegetarian and vegan people. Besides its nutritional importance, its widespread distribution in different biogeographical locations and highly adaptable nature against many adverse conditions *i.e.* drought, salinity etc. substantiate its importance to be introduced as new cultivated vegetable [18-20].

It is listed by the World Health Organization as one of the most used medicinal plants and has been given the term "Global Panacea" which makes purslane a highly potential pharmacological agent to be used as human and animal food and in medicine [21]. Purslane has also been explored by some researchers for its food additive properties and as food supplement.

1.1 Distribution

Purslane grows from sea level to 2600m and is the most common plant in the temperate and subtropical regions, although it extends into the tropics and higher latitudes too [22]. It is reported that purslane was a common vegetable of the Roman Empire. The center of origin is uncertain, and is often considered as arid regions like North Africa [23]. Although spread to the New World was thought to have been due to post-Columbian humans [24], archaeological evidence (pollen analysis) suggests that Purslane arrived in the New World in pre-Columbian times. The succulent stems and fleshy leaves of purslane reflect that it may have originated and adapted to desert climates of the Middle East and India. It can be found in Europe, Africa, North America, Australia, and Asia [11].

Table 1: Classification of *P. oleracea* [25].

Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Caryophyllidae
Order	Caryophyllales
Family	Portulacaceae
Genus	Portulaca L.
Species	*Portulaca oleracea* L.

1.2 Botanical Classification and description

Portulaca oleracea L. (purslane) is an ancient, cosmopolitan species which belongs to genus *Portulaca* and family Portulacaceae with 21 genera and 580 species (Table 1). It is mostly an annual, but it may be perennial in the tropics. It has smooth, reddish and mostly prostrate stem, up to 30 cm long and 2-3 mm in diameter. Leaves are flat, fleshy, having variable shapes, obovate, 1–5 cm long, green or green with red margin, may be alternate or opposite and are clustered at stem joints and ends. Depending upon rainfall, the flowers appear at any time during the year. Flowers originate as single or cluster of two to five at the tips of stems. The flowers are minute or small having orange yellow, purple, or white pink color. Fruit consists of almost round to egg-shaped capsules, usually about 4–8mm long that open around the middle to release the seeds. Seeds are formed in a tiny pod, which opens when the seeds are mature. Purslane has a taproot with fibrous secondary roots and is able to tolerate poor compacted soils and drought.

1.3 Habitat

P. oleracea is common in fields, gardens, vineyards, lawns, driveways, dunes, beaches, salt marshes, waste areas, eroded slopes, bluffs and riverbanks.

2. Ethnobotany of *Portulaca oleracea*

Uses of purslane as medicinal herb have been reported at least 2000 years back whereas its use as food has been reported before this period. Ancient Romans used it to treat dysentery, intestinal worms, head ache and stomach ache [26]. In ancient Greece, Theophrastus (often considered the father of Botany) named Purslane as a must-grow herb, while Pliny the Elder (A.D. 23-79), a Roman author and naturalist, considered Purslane as one of the most reliable healing plants. The purslane plant has very important effects in the medicinal field and is considered as a "medicinal food" to consume like spinach [27]. It is frequently mentioned in alternative systems of medicine which include Ayurveda and Unani. Whole plant of purslane is used for as medicine in different diseases. Since time immemorial, this herb is used as vegetable, spice and medicinal plant globally. Its earliest recorded use was reported dates back to around 500 AD in China. Traditionally, it is considered sour tasting and cold with heat relieving and detoxicant properties. It is considered to have blood cooling and hemostatic properties hence useful internally in bleeding bacillary dysentery, hematochezia (bloody stool), bleeding haemorrhoids and metrorrhagia. Externally, it is useful in bleeding condition.

The plant is used in the treatment of hemoptysis and pulmonary diseases and decoction of leaf (macerated leaf in cold water) is useful in palpitation. The American Indians used purslane for the treatment of colds and decoction of the herb is also useful in gout and headache. In inflammation of male genitalia, the juice of the plant is beneficial. The leaves are infused in linseed oil as a liniment for stiff neck. The Indians use this plant for treating excessive menstrual flow, stomachache, hemoptysis [28], and inflammation of stomach [29]. The mixture of plant juice with honey is used for cough. The herb is also prescribed in the treatment of cardiovascular diseases, dysuria, hematuria, gonorrhea, dysentery, sore nipples and ulcers of the mouth. Fresh leaves bruised are applied to the temples to allay excessive heat and pain. It is also used as a cooling external application in erysipelas and an infusion is given as a diuretic [29-30]. Juice of the purslane stem is useful in cases of prickly heat and in burning sensation of hands and feet. Some other ethnobotanic uses of purslane in different countries have been presented in the Table 2.

Table 2: Ethnobotanical uses of *P. oleracea* in different countries.

Country		Vernacular Name(s)	Ethnobotanical uses	References
African countries		Wild water leaf Hogweed, Purslane	In Africa whole plant is considered as antiphlogestic and bactericidal in bacillary dysentery, diarrhea, hemorrhoids, enterorhagia and used as antidiabetic. It is used externally as cataplasm for maturing of the abscesses. The seeds are considered calmative and useful in polydypsia. In Nigeria, leaves are used as a local application to swellings while in Ghana plant is used for heart trouble.	[31-32]
India	Hindi	Kulfa, Jungali palak,	Used for the treatment of various ailments like skin diseases, fever, dysentery, diarrhea, bleeding piles, kidney, liver, spleen diseases, excessive menstrual flow, stomachache, hemoptysis.	[28, 29, 30, 31]
	Tamil	Paruppu keerai, punarva		
	Telugu	Gangapavilikura, Peddhapayilikura		

	Bengali	Nunia saag	The juice of plant is sometimes used in earache and toothache.	
	Gujrati	Motiloni, ghol		
	Assamese	Noniya, Malbhog-sak, Malbhog khutura, Khutura, Malbhog xak, Hah thegia, Nunia-sak		
	Kannad	Doodagooni Soopu, Dudagorai		
	Manipuri	Leibak Kundo		
	Sanskrit	Lonamala, Brihalloni, Lonica		
	Malayalam	Uppucheera, Kozhuppacheera, Karicheera, Manalcheera, Cheriyagolicheera, Koluppa, Suvandacheera, Kozhuppa		
	Marathi	Mhotighol, Kurfah, Bhuigoli		
England		Duckweed, garden purslane, little-hogweed, parsley, pusley; pussley	Purslane is used as food, spice and for medicinal purpose.	[31]
China		Ma-Chi-Xian	The whole plant and leaves are used in China as sour, diuretic, cooling herb that lowers fever and clears toxins. The leaves are used for poulticing tumors, bed wounds, ulcers and edematous swellings, also for hemorrhage and leucorrhea. The seeds decoction is considered as excellent diuretic	[31]
Srilanka		Genda kola	Useful in catarrhal and urogenital ailments.	[28]
Vietnam		Rau sam or sam	Entire plant except roots is used as an anti-inflammatory, antihelmintic and antibacterial. Macerated fresh plant (100g) juice diluted with water is used against oxyuriasis and ascariasis. It is administered in the morning for 3-5 days. Fresh leaves poultice is useful to treat boils, impetigo and mastitis	[28]
Egypt		Rigla	Plant is used as vegetable, spice and medicinal plant.	[31]

3. Phytochemistry of *Portulaca oleracea*

A number of phytochemicals have been isolated from *Portulaca oleracea* till date, including flavonoids (Apigenin, kaempferol, quercetin, luteolin, myricetin, genistein, and genistin), alkaloids, coumarins, anthraquinone glycoside, cardiac glycoside, fatty acids, terpenoids, polysaccharides, vitamins, sterols, proteins, and minerals (Fig. 1) [33, 12, 34].

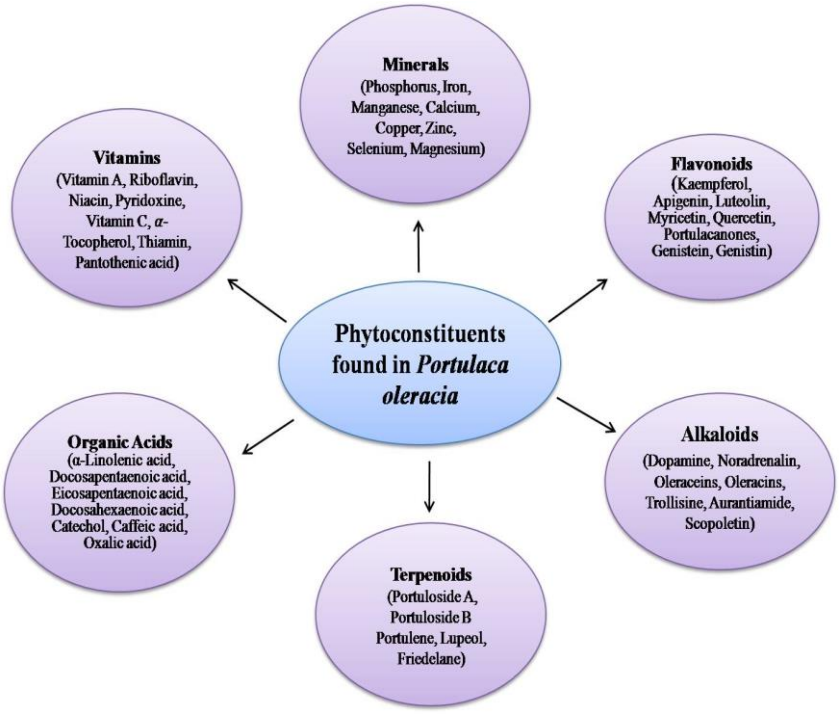

Fig 1: Different phytoconstituents found in *Portulaca oleracea.*

This green leafy vegetable is very low in calories (just 16 kcal/100g) and fats; nonetheless, it is rich in dietary fiber, vitamins, and minerals (Table 3 (a). It is an excellent source of Vitamin-A, (1320 IU/100 g, provides 44% of RDA) one of the highest among green leafy vegetables. Vitamin-A is a known powerful natural antioxidant and an essential vitamin for vision, maintaining healthy mucus membranes and protecting against lung and oral cavity cancers. It is also required to maintain healthy mucosa and skin. Consumption of natural vegetables and fruits rich in vitamin A is known to help to protect from lung and oral cavity cancers. Purslane is also a rich source of vitamin C, and some B-complex vitamins like riboflavin, niacin, pyridoxine and carotenoids, as well as dietary minerals, such as iron (1.99 mg/100g), magnesium (68 mg/100g), calcium (65 mg/100g), potassium (494 mg/100g) and phosphorus (44 mg/100g).

Table 3: Nutrient Profile of Purslane (*Portulaca oleracea*).

Principle	Nutrient Value	Percentage of RDA
Energy	16 Kcal	1.5%
Carbohydrates	3.4 g	3%
Protein	1.30 g	2%
Total Fat	0.1 g	0.5%
Cholesterol	0 mg	0%
Vitamins		
Folates	12 µg	3%
Niacin	0.480 mg	3%
Pantothenic acid	0.036 mg	1%
Pyridoxine	0.073 mg	5.5%
Riboflavin	0.112 mg	8.5%
Thiamin	0.047 mg	4%
Vitamin A	1320 IU	44%
Vitamin C	21 mg	35%
Electrolytes		
Sodium	45 mg	3%
Potassium	494 mg	10.5%
Minerals		
Calcium	65 mg	6.5%
Copper	0.113 mg	12.5%
Iron	1.99 mg	25%
Magnesium	68 mg	17%
Manganese	0.303 mg	13%
Phosphorus	44 mg	6%
Selenium	0.9 µg	2%
Zinc	0.17 mg	1.5%

Table 3 (a): Nutritive value of Purslane per 100 g (Source: USDA National Nutrient data base)

Table 3(b): The ALA content in different parts of the Purslane (values per kg of fresh mass).

Plant part	Content	Reference
Whole plant	481	[35]
Leaves	970-1,600	[13]
Leaves	3,000-4,000	[36]
Leaves	100-290	[37]
Leaves	700-1,330	[5]
Stems	70-210	[13]
Seeds	35,300-68,800	[13]

Table 3(c): Percentage content of some of the important fatty acids in edible portions of purslane.

Fatty acids	Percentage Content	Reference
Lipids (g kg-1 fm)	3.9	[38]
α-linolenic acid - 18:3 ω-3	32.60	
Palmitoleic acid - 16:1 ω-7	20.96	
Palmitic acid - 16:0	17.40	
Linoleic acid - 18:2 ω-6	16.82	
Oleic acid - 18:1 ω-9	5.89	
Stearic acid - 18:0	3.46	
Behenic acid-22:0	3.33	

Purslane is one of the richest green plant sources of omega-3 fatty acids. Fresh leaves contain surprisingly more ω-3 fatty acids (α-linolenic acid) than any other leafy vegetable plant. The ALA content in purslane leaves is several times higher than in spinach, mustard, and lettuce [36, 39]. One hundred grams of fresh purslane leaves can provide 300-400 mg of ALA. The ALA content in different parts of the Purslane is given in Table 3 (b). The difference in ALA concentrations reported by various authors in leaves may be due to differences in cultivars, sample material, sampling procedure, time of growth and analytical methods. In purslane, not only ALA is present in high amounts, but it also prevails over linoleic acid (LA) [36, 40, 41, 42] which is desirable. It is reported that in most of the plants, LA is present in greater amounts and competes with ALA for their conversion to longer chain omega-3 fatty acids, by sharing the same metabolic pathway and hence competing for the same enzymes [43].

Omega-3 fatty acid is a precursor of a specific group of hormones and research studies show that consumption of foods rich in omega-3 fatty acids may reduce the risk of coronary heart diseases and strokes and help prevent the development of Attention Deficit Hyperactivity Disorder (ADHD), autism and other developmental differences in children [44]. Percentage content of some of the important fatty acids in edible portions of purslane is given in Table 3 (c).

Unlike fish oils with their high cholesterol and calorie content, purslane also provides an excellent source of the beneficial ω-3 fatty acids without the cholesterol of fish oils, since it contains no cholesterol [45-46]. It has also been reported to contain 0.01mg per gram of eicosapentanoic acid (EPA), which is not present at all in flax oil. Besides, purslane is the richest source of gamma-linolenic acid (LNA, 18: 3 ω-3) (4mg/g fresh weight) among any green leafy vegetable. Subsequently, purslane contained 18:3 ω-3, 20:5 ω-3, 22:6 ω-3 (docosahexaenoic acid, DHA) as well as 22:5 ω-3 (docosapentaenoic acid, DPA) fatty acids [36-37].

Levels of flavonoids in *Portulaca oleracea* varies in different plant parts *i.e.* the highest levels have been found in the roots followed by stem and the leaf. Seven different flavonoids have been reported to be present in this plant, including kaempferol, myricetin, luteolin, apigenin, quercetin, genistein and genistin (fig.2 (I) [47]. Flavonoids are also widely present in foods such as fruits and vegetables.

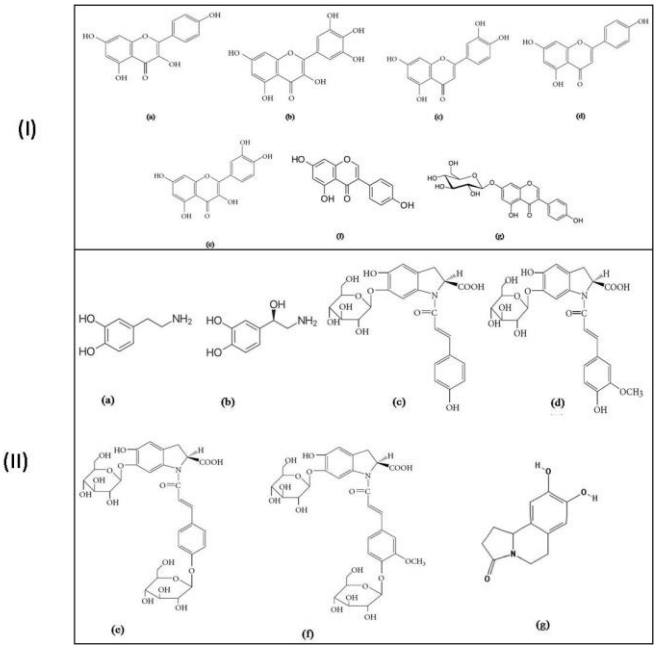

Fig 2: (I) Chemical structures of different flavonoids found in *Portulaca oleracea* (a) kaempferol, (b) myricetin (c) luteolin (d) apigenin (e) quercetin (f) genistein and (g) genistin. (II) Chemical structures of different alkaloids found in *Portulaca oleracea* (a) dopamine, (b) noradrenalin (c) Oleracein A (d) Oleracein B (e) Oleracein C (f) Oleracein D and (g) Oleracein E.

In addition to flavonoids, another important chemical found in this plant is alkaloids including dopa, dopamine and noradrenalin (fig. 2 (II). The content of dopamine and noradrenalin has been reported to be higher in leaves

compared to stem and seeds. The amount of these alkaloids varies depending on the extraction solvents [48]. Oleraceins A, B, C, D and E are cyclodopa alkaloids isolated from this plant and several analytes such as (3R)-3,5- bis(3-methoxy-4-hydroxyphenyl)-2,3-dihydro-2(1H)-pyridinone and 1,5-dimethyl-6-phenyl-1,2-dihydro-1,2,4-triazin-3(2H)-one have even displayed cytotoxic activities against human cancer cells [49-50].

Purslane also contains different polysaccharides which are potential therapeutic agents for the treatment of diabetes mellitus owing to their modulation of blood lipids, metabolism and decrease of blood glucose. This plant also contains ascorbic acid, α-tocopherol and B-complex vitamins for example, niacin, pyridoxine and riboflavin. Purslane leaves have been reported to contain seven times higher contents of α-tocopherolas compared to the leaves of spinach [12]. Likewise, the plant is rich in minerals like phosphorus, manganese, iron, calcium, selenium and the amino acids such as isoleucine, proline, leucine, lysine, phenylalanine, methionine, cystine, valine, threonine and tyrosine [4, 51]. Many other constituents have also been isolated from this plant, such as β-carotene, glutathione, melatonin, portulacerebroside A, catechol and bergapten.

4. Pharmacological properties of *Portulaca oleracea*

Portulaca oleracea has been reported to possess various pharmacological activities which have substantiates its therapeutic value as well as have established its importance as the functional food (Fig. 3) [33]. *P. oleracea* has been used throughout history for many different medicinal purposes. A patent was issued in 2002 directed to the novel use of *P. oleracea* for the treatment of cancer [52]. A summary of the important pharmacological properties of *P. oleracea* are presented below.

4.1 Antidiabetic activity

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia, abnormal lipid and protein metabolism along with specific long-term complications affecting the retina, kidney, liver and nervous system [53]. In Iranian folk medicine, roots, leaves and seeds of purslane have been recommended for treatment of diabetes mellitus [54]. It has been reported that treatment of purslane extract has hypoglycaemic and hypolipidemic effects in alloxan-induced diabetic rat in 28 days [54]. Li *et al*, (2009) also reported that polysaccharide extracted from *P. oleracea* L. can control blood glucose and modulate the metabolism of glucose and blood lipid in diabetes mellitus mice [55].

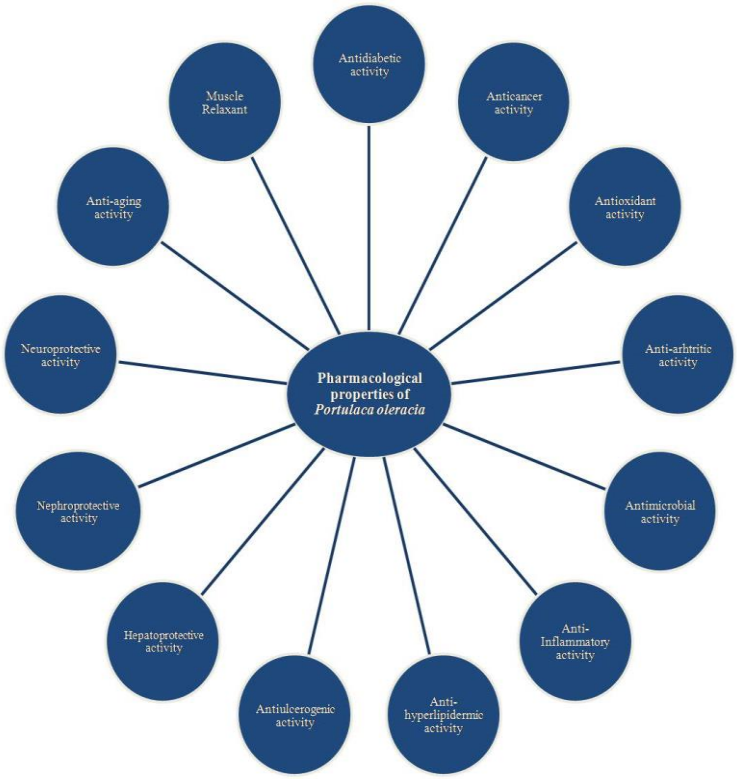

Fig 3: Various pharmacological properties of *Portulaca oleracea.*

P. oleracea L. also increases insulin sensitivity and ameliorates impaired glucose tolerance and lipid metabolism in rats with type 2 diabetes mellitus suggesting that *Portulaca oleracea* alleviates insulin resistance [56]. The aqueous extract of *Portulaca oleracea* also prevents diabetic vascular inflammation, hyperglycemia, and diabetic endothelial dysfunction in type 2 diabetic db/db mice, suggesting its protective role against diabetes and related vascular complications [6]. *Portulaca oleracea L.* has been reported to alleviate the blood glucose and lipid rising associated with diabetes, and improve the abnormal glucose metabolism and increase insulin secretion by restoring the impaired pancrease β-cells in alloxan-induced diabetic rats, which further provide evidence that *Portulaca oleracea* has the hypoglycemic potential and could be useful on the diabetes therapy [57]. Oral administration of a crude water soluble polysaccharide extracted from purslane named CPOP (crude *Portulaca oleracea* L. polysaccharide) has been reported to significantly increase the body weight and significantly improve the glucose tolerance in diabetic rats [58]. It was also found that CPOP could significantly reduce the Fasting Blood Glucose level, and elevate the Fasting serum insulin level and Insulin

sensitivity index value in diabetic rats. In addition, CPOP could significantly reduce TNF-α and IL-6 levels in diabetic rats; CPOP could also reduce MDA and SOD activities in the liver tissue of diabetic rats. In a recent study published in a reputed journal, researchers investigate the responses of atherosclerosis plaque biomarkers to purslane seed consumption and aerobic training in women with Type 2 Diabetes (T2D). 196 women with T2D were assigned into four different groups *i.e.* placebo (PL), aerobic training + placebo, purslane seeds (PS), aerobic training + purslane seeds. The data obtained from this study indicated that 16 weeks of aerobic training or/and purslane seed consumption were effective in regulation of diabetic parameters and biomarkers associated with atherosclerosis in women with T2D. This may be due to the synergistic effect of aerobic training and unsaturated fatty acids found in purslane seed which activate the AMP and AMPK pathways. Hence it was suggested that purslane seed consumption alongside exercising could improve atherosclerosis plaque biomarkers through synergistically mechanisms in T2D [59]. Recently also it has been reported that purslane supplementation has promising implications for improving glycemic status and blood lipid concentrations, especially in diabetic subjects, which have abnormal glucose and lipid metabolism [60].

4.2 Antioxidant activity

Antioxidants are vital substances which possess the ability to protect the body from damages caused by free radical-induced oxidative stress. Scientifically, purslane provides a rich plant source of nutritional benefits with high antioxidant properties. The antioxidant property of *Portulaca oleracea* is attributed to its constituents, such as gallotannins, omega-3 fatty acids, ascorbic acid, *α*-tocopherols, kaempferol, quercetin, and apigenin [9, 47]. Samarghandian *et al*, (2017) reported that Purslane treatment of diabetic rats improved GSH and TAS levels due to reduction in free radical production and enhancement antioxidant defenses [61]. Authors suggested that Purslane modulates oxygen radical production, which may be responsible at least in part for the amelioration hyperglycemia, inflammation, and oxidative stress seen in the Streptozotocin-diabetic rats. Studies have confirmed the protective effect of ethanol extract of *Portulaca oleracea* (EEPO) on the lung of mice exposed to hypoxia and demonstrated that prophylactic administration of EEPO could lessen vascular permeability and relieve pulmonary edema and suggested that the underlying mechanism of this protective effect of EEPO may be attenuating inflammatory pulmonary reactions in mice by decreasing oxidative stress under hypoxia [62]. Similar results have also been reported in another study where authors demonstrated that the ethanol extract from *Portulaca oleracea* L. could exhibit the effective protection for the DSS induced Ulcerative colitis by increasing the colon length, decreasing body weight loss and the disease activity index score, inhibiting oxidative stress response through the MDA, NO, SOD activities, reducing the mRNA expressions of pro-inflammatory cytokines (TNF-α, IL-1β and IL-6) and the protein expressions of TNF-α and NF-*k*B p65 [63].

4.3 Anticancer activity

Polysaccharides from *Portulaca oleracea* is reported to have bioactivities such as hypoglycemic and hypolipidemic activities, antioxidant and antitumor activities [64-65]. A water-soluble *Portulaca oleracea* polysaccharide (POL-P3b) has been reported to inhibit cell proliferation of HeLa cell and significantly inhibited tumor growth in U14-bearing mice [66]. It was also found that POL-P3b possesses the activity of inhibiting cervical cancer cell growth in vitro and in vivo at a concentration- and time-dependent manner, and the mechanisms were associated with Sub-G1 phase cell cycle arrest, triggering DNA damage and inducing apoptosis. Huan *et al*, (2013) purified a unique polysaccharide component (POP) from *Portulaca oleracea* and found that it had pronounced anti-tumor effects *in vivo* model [67]. Authors reported that POP could significantly inhibit the growth of transplantable sarcoma 180 and potentiate the animal's immune responses including an increase in the number of white blood cell (WBC) and $CD4^+$ T-lymphocytes, as well as the ratio of $CD4^+/CD8^+$. Furthermore, the serum aspartate transanimase (AST), alanine transaminase (ALT), urea nitrogen (BUN), and creatinine levels in S180-bearing mice were significantly reversed by POP. In addition to polysaccharides, other bioactive compounds such as cerebrosides, homoisoflavonoids, and alkaloids also show *in vitro* cytotoxic activities against human cancer cell lines. Portulacerebroside A stimulates human liver cancer HCCLM3 cell apoptosis via the activation of the p38MAPKand JNK-triggered mitochondrial death pathway and has been suggested as a new agent for leucocythemia treatment [68].

4.4 Anti-arhtritic activity

Anti-arthritic activity of petroleum-ether extract of *Portulaca oleracea* L. had been reported using Fruends adjuvant arthritis model in male wistar rats [69]. Similar results were also obtained in another study in which authors concluded that the petroleum ether extract of *Portulaca oleracea* possesses potentially useful anti-arrthritic activity and gave positive results in controlling inflammation in adjuvant induced arthritis model in rats [70]. In another similar study, Arthritis was induced in rats by injecting 0.05 ml of 0.5(w/v) suspension of killed Mycobacterium tuberculosis in paraffin oil into the left hind limb and the anti-arthritic activity of ethanolic extracts of *Portulaca olaracea* L. sativa leaves was investigated. It was found that oral administration of the extract showed the increase in WBC count was significantly suppressed and the increased lymphocyte count in adjuvant control group was significantly restored back to normal in the inflamed area which is similar to the action of most of the non- steroidal anti inflammatory agents which also exert their beneficial effect by inhibiting either release of lysosomal membrane which is responsible for inflammatory process [71].

4.5 Antimicrobial activity

Plant based antimicrobials represent a vast updated source of medicine. Antibacterials of plant origin have enormous therapeutic potential. Many studies have reported the antibacterial and antioxidant effects of *P. oleracea*. It has been showed the antibacterial activity of hydroalcoholic extract of some parts of *P. oleracea* against five pathogenic bacteria, including *Salmonella typhimurium* and *P. mirabilis* [72]. The highest inhibition zones for *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, and *Enterobacter aerogenes* were 14.56 ± 0.21 and 11.68 ± 0.13 mm, respectively, Londonkar and Nayaka in 2011 studied the ethanol extract of the aerial parts of *P. oleracea*, and showed its inhibitory effect against strains of *St. aureus*, *K. pneumonia*, *Bacillus cereus* and *Aspergillus fumigates* [73]. Another author reported that ethyl acetate extract of *P.*

oleracea had the highest antimicrobial activity against *S. aureus* and *Shigella dysenteriae* [74]. The antibacterial effect of the *P. oleracea* has been reported against nine bacterial strains including *S. pyogenes*, *S. pneumoniae*, *S. saprophyticus*, *H. alvei*, *A. baumannii*, *E. faecalis*, *P. mirabilis*, *S. marcescens*, and *S. aureus*, which were resistant to erythromycin, cefixime, ceftazidime, tetracycline, ampicillin, and amikacin [75]. A crude EtOAc extract obtained from *Portulaca oleracea* have been reported to possess antifungal activity against dermatophytes of the genera *Trichophyton* [76].

4.6 Anti-Inflammatory activity

A 10% ethanolic extract from the aerial parts (dried leaves and stem) of *Portulaca oleracea* L. subsp. sativa (Haw.) Celak. (a cultivar) have showed significant anti-inflammatory and analgesic after intraperitoneal and topical administration when compared with the synthetic drug, diclofenac sodium as the active control [9]. In a study, db/db mice were treated with aqueous extract of *Portulaca oleracea* L. (AP) (300 mg/kg/day, p.o.) for 10 weeks it was found that AP suppresses hyperglycemia and diabetic vascular inflammation, and prevents the development of diabetic endothelial dysfunction for the development of diabetes and its vascular complications [77]. Three novel alkaloids named oleracimine, oleracimine A and oleracone A were isolated from *Portulaca oleracea* L. and were investigated for the anti-inflammatory effects of oleracimine on lipopolysaccharide-stimulated macrophages. It was found that oleracimine showed remarkable anti-inflammation activity as indicated by the inhibited nitric oxide production and dose-dependent decrease of the secretions of interleukin 6, tumor necrosis factor α, nitric oxide, and prostaglandin E_2 in cell culture supernatants as well as the mRNA of cyclooxygenase-2 and inducible nitric oxide synthase [78].

In a recent study, the anti-inflammatory effects of purslane extract on lipopolysaccharide (LPS)-stimulated RAW 264.7 cells was evaluated. It is reported that purslane extracts significantly reduced LPS-induced synthesis of NO in a dose-dependent manner, as well as the expression levels of iNOS and COX-2. It was further reported that the productions of TNF-α and IL-6 were also significantly reduced at the higher dose of 400 μg/ml. The nuclear translocation of P65 was partially prevented by the extract, which explained the inhibition of NF-κB pathway. Authors also identified three flavonoids, named luteolin, kaempferol and quercitrin, in the extract, and suggested that these might be responsible for its anti-inflammatory effects [79].

4.7 Anti-hyperlipidermic activity

Hyperlipidemia is a major contributor to pathogenesis of cardiovascular diseases and diabetes mellitus. There are chemical drugs available (fibrates and statins) which has lipid-lowering potential. However, they fail to meet the demands for treatment further, patients prepare natural treatment rather synthetic drug due to their adverse effects and great drug dependence [80]. Hence, plant materials and their extracts became popular in treating hyperlipidemia with no adverse effects. In an attempt to investigate anti-hyperlipidemic activity of *P oleracea*, hyperlipidimea in adult wister rats was induced by the administration of dexamethasone (10 mg/kg. S.C) for 8 days. Hyperlipidimea was characterized by marked increase in serum cholesterol and triglyceride levels along with increase in atherogenic index. It was found that the ethanolic extract of leaves of *Portulaca oleracea* Linn. (200 and 400 mg/kg) treatment has showed significant inhibition against dexamethasone induced hyperlipidemia in rats by maintaining the serum levels of cholesterol, triglycerides and near to the normal levels [81]. In another study attempted to appraise the hypocholesteromic effect of purslane extract group of rats were fed on high cholesterol diet to induce hyperlipidemia. Selected rats were fed on aqueous extract of purslane (AEP) and lovastanin diet while others were treated as hyperlipidemic and normal controls. The results revealed a significant ($p<0.05$) reduction in serum TC, LDL-C, VLDL-C, TAG, increase in serum HDL-C level observed in AEP fed rats as compared to cholesterol induced hyperlipidemic control group. Samples treated with AEP and lovastatin also demonstrated considerable decrease in LDL-C: HDL-C ratios, levels of SGOT, SGPT, ALP activities and body weight in comparison to control. Therefore, administration of AEP concluded that 150 mg/kg body weight AEP is a potent cardio-protective agent having preventive and curative effect against hyperlipidemia [82]. An another researcher also reported the hypolipidemic effect of three *Portulaca oleracea* stems (POS) preparations: stem powder (POS-powder), stem infusion (POS-infusion) and stem 70% ethanolic extract (POS-ethanolic 70%) on dietary hyperlipidemic Wister Albino rats fed on hyperlipidemic diet [83]. Author reported that POS preparations significantly improved elevated weight, feed intake, total cholesterol (TC), total lipids (TL), triglycerides (TG), low density lipoprotein cholesterol (LDL-C), very low density lipoprotein cholesterol (VLDL-C) levels and risk ratio compared with hyperlipidemic control. The abnormalities, which was shown on liver status of hyperlipidemic rats were ameliorated by administration of POS preparations significantly. Liver histology showed significant improvement after treating hyperlipidemic rats by POS form compared with hyperlipidemic control.

4.8 Antiulcerogenic activity

Published evidences have demonstrated that the aqueous extract of *Portulaca oleracea* L. has anti-ulcer activity in aspirin plus pyloric ligation induced ulcer in albino rats and the anti-ulcer activity was attributed to the flavonoids namely, kaempferol, apigenin, myricetin, quercetin and luteolin identified in different parts of the this plant [84, 21]. Karimi *et al*, (2004) also reported that the aqueous and ethanolic extracts of *Portulaca oleracea* showed a dose-dependent reduction in severity of ulcers induced by HCl in mice and the results were found comparable to the effect observed with sucralfate 0.1 g/kg, hence supported the gastroprotective action *of Portulaca oleracea* [8]. Similar dose dependent inhibition of ulcer index in ethanol and acetic-acid induced ulcers in rats has also been reported [85]. Authors studied the gastroprotective effect of 50% ethanolic extract of *Portulaca oleracea*. Results indicated that *Portulaca oleracea* prevents the oxidative damage of gastric mucosa by blocking lipid peroxidation and by significant decrease in superoxide dismutase, and increase in catalase activity and established that *Portulaca oleracea* possesses significant gastroprotective activity which might be due to gastric defence factors.

4.9 Hepatoprotective activity

Purslane (*Portulaca oleracea* L, Portulacaceae) has been traditionally used in folk medicine to afford protection against liver injury, although its actual efficacy remains uncertain. The hepatoprotective effect of ethanol extract of Purslane

against carbon tetrachloride (CCl_4)-induced hepatic toxicity in rats was studied. Liver damage was indicated by increase in hepatic marker enzymes (ALT, AST, ALP, GGT, and SOD) and histopathological alterations. Administration of purslane extract (0.01, 0.05, 0.1, and 0.15 g/kg b.w.) significantly showed a marked tendency towards normalization of all measured biochemical parameters in CCl_4-treated rats. Histopathological changes also paralleled the detected alteration in markers of liver function which demonstrated that purslane exerts protective effects against CCl4-induced damage in rat liver and supports a potential therapeutic use of purslane as an alternative for patients with liver diseases [86]. Similarly, the hepatoprotective activity of the aqueous extract of the aerial parts of *Portulaca oleracea* in combination with lycopene against carbon tetrachloride induced hepatotoxicity in rats was investigated [87]. Both the treatment groups showed hepatoprotective effect against carbon tetrachloride induced hepatotoxicity by significantly restoring the levels of serum enzymes to normal which was comparable to that of silymarin group. The oral administration of *P. oleracea* in combination with lycopene significantly ameliorates CCl_4 hepatotoxicity in rats. Another group investigated the protective role of aqueous extract of aerial parts of *Portulaca oleracea* L. against cisplatin-induced hepatotoxicity in chick embryonic liver [88]. A dose-dependent increase in biochemical parameters, such as alanine transaminase, aspartate transaminase, alkaline phosphatase, lactate dehydrogenase, malondialdehyde levels and a decrease in antioxidant enzymes levels like superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, glutathione-s-transferase and reduced glutathione were observed in cisplatin-treated animals, indicating a definite damage to the liver tissue. Pre-treatment with *Portulaca oleracea* extract was found to provide significant protection against cisplatin-induced hepatotoxicity, as evident by the recovered levels of the altered changes in the measured biochemical parameters.

4.10 Nephroprotective activity

It has been reported that the aqueous extract of *Portulaca oleracea* possesses marked nephroprotective activity and could have a promising role in the treatment of acute renal injury induced by nephrotoxins, especially cisplatin [89]. In a study, a group of researchers studied the effect of oral administration of aqueous purslane (*Portulaca oleracea*) extract (400mg/kg BW/day) and fish oil (5mg/kg BW/day) in gentamicin (80 mg/kg Bw/day) administered adult male rats (80-120g) [90]. Gentamicin resulted in decrease in plasma levels concentration of urea, uric acid and creatinine, decreasing in activities of GSH, SOD and CAT as well as an increasing in MDA concentration in the kidney. Co-administration of aqueous purslane extract and fish oil was found to improve the adverse changes in the kidney functions with an increase in antioxidants activities and reduction of peroxidation. This proposes that dietary fish oil or purslane extract supplementation may provide a cushion for a prolonged therapeutic option against GM nephropathy without harmful side effects.

4.11 Neuroprotective activity

Neuropharmacological actions of the *P. oleracea* extracts were previously reported in rodent models. Effects included the reduction of the locomotor activity, the increase in the onset time of pentylenetetrazole-induced convulsions in mice, the opioid mediated anti-nociceptive and muscle relaxant activities in rats [91]. Moneim (2013) reported that *Portulaca oleracea* have the ability to scavenge free radicals and antagonize rotenone induced neurons apoptosis, dopamine depletion, and complex-I inhibition in striatum of rats, indicating that *Portulaca oleracea* may be a potential neuroprotective candidate against Parkinson's disease [92]. This was further supported by another study also which reported that aqueous and ethanolic extracts of *P. oleracea* were able to reverse the behavioral motor deficits and neuronal loss induced by 6-hydroxydopamine and thus suggested that the *P. oleracea* is an important target of study with therapeutic potential for the treatment of neurodegenerative diseases [93]. It has been shown that *P. oleracea* protects neurons against hypoxia injury [94] and D-galactose induced toxicity *in vivo* [95]. The treatment with betacyanins from *P. oleracea* improved cognitive deficits and attenuated oxidative damage induced by D-galactose in the brains of senescent mice [96]. Moreover, the *P. oleracea* extracts decreased apoptosis and oxidative-stress-induced neurodegeneration caused by the pesticide rotenone [97].

4.12 Other activities

Ten premenopausal women with Abnormal uterine bleeding (AUB) comprising menorrhagia, metrorrhagia, polymenorrhea and intermenstrual bleeding who had not responded to standard drugs were subjected to 5 g of purslane seeds powder in a glass of water every 4 h orally 48 h after the onset of menstruation for 3 days. Eight (80%) patients were reported to have reduced duration and volume of bleeding and normalized patterns of periods. No adverse effects were reported. AUB did not recur in the patients responding to treatment for the duration of a 3 months' follow-up. The results suggested that purslane seeds could be effective and safe in the treatment of AUB [98]. Using male albino swiss mice (*Mus musculus* JVI-1), Rashed *et al,* (2003) reported that *Portulaca oleracea* accelerates the wound healing process by decreasing the surface area of the wound and increasing the tensile strength [11]. In another study aiming to examine the bronchodilatory effect of the boiled extract of *Portulaca oleracea* in the airway of asthmatic patients reported that the extract of *Portulaca oleracea*has a relatively potent but transient bronchodilatory effect on asthmatic airways [99].

5. Conclusion

Keeping in view the significant potential of *Portulaca oleracea* in the pharmaceutical industry due to its wide spectrum of pharmacological properties as mentioned above, which are attributed to its diverse phytoconstituents one would not hesitate to conclude that this is indeed a wonder plant and will indeed be the life saving plant of the 21st century if well harnessed. The nature and benefits of this plant herein exposed is a wake- up call to researchers in pharmacognosy and traditional medicine to do more in its exploitation to decrease human decrepitude. Although bioactivities of extracts or compounds isolated from *Portulaca oleracea* are substantiated by using *in vitro* and *in vivo* studies including animal models and cell culture studies, the mechanisms of action need to be addressed through more mechanistic approaches are required before it can be considered for further clinical use. This review concludes that *Portulaca oleracea* has tremendous nutritional, functional and medicinal potential provided that adequate studies are conducted.

6. References

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