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ORIGINAL PAPERS

A STORY ABOUT *Portulaca oleracea*: DESCRIPTION, METHODOLOGY OF OBTAINING BIOACTIVE EXTRACTS, AND THEIR POSSIBLE USE IN MEDICINE AND COSMETICS

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Abstract. *Portulaca oleracea, or purslane, is a spontaneous plant from the succulent family with an extensive history and rich possibilities for exploitation in the nutrition, medicine, and cosmetic industries. Written historical sources attest to the plant's use as a remedy for gum parodontal injuries and as a topical antimicrobial in the healing of wounds, but also with psychoactive sedative effect. In traditional medicine, purslane is used as a source of nutrients and as a good remedy against diarrhea and gastrointestinal infections. This paper aims to present more details about this potential of the well-known Portulaca oleracea, as*

reported in the literature in recent years, and to explore possible future directions for exploiting its bioactive potential.

Keywords: *Portulaca*, purslane, medicinal plant, nutrition, cosmetic industry

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1. INTRODUCTION

Since the beginning of humankind, plants have been used for their nutritional and medicinal potentials. Significant evidence showed that in the Palaeolithic, human was specifically directed to care about their traumatic injuries and dental disorders, as they could be found by analysing human remains from archaeological sites [1-3]. Also, bags, pots, tools, and grinding stones found during excavations suggested auto-medication as often as feeding [1]. Moreover, evidence dating from the Neolithic period supported the hypothesis that pre-modern humans already had knowledge about and consistently used psychotropic plants, such as *Cannabis* and *Papaver* [1]. Despite these, written sources of evidence on the use of plants for medical purposes do not date to earlier than 5000 BC, i.e. to the Sumerian civilization, Antic Chinese Empire, and Indian, Egyptian, and Jewish civilizations [2].

Portulaca oleracea is a spontaneous annual flowering plant that can be found in both warm and cold climates throughout the globe. As a part of the succulent family, *Portulaca oleracea* is a small plant, whose decumbent stem often not reaches 30 cm in height [4]. The succulent-typical leaves are smooth and mostly rounded, while the flowers are 5-typed and yellow, with slight differences according to the geographical location. Due to being covered in a thick layer of wax, the aerial parts are resistant to pests. The tiny black seeds are found in capsules. Purslane could be easily cultivated on any type of soil, yet they are dependent on humidity, sunlight, and temperatures (above 25 ºC). Also, purslane is closely related to *Portulaca grandiflora*, often found as an ornamental plant in our country and in many parts of Europe, Asia, and America [4].

In many places, the presence of purslane is closely correlated to anthropic factors, being edible both wild and cultivated [5]. Due to this aspect and as part of the major plant family of succulents, *Portulaca oleracea* has an extensive history. Evidence dating to ancient period certifies the use of the seeds and leaves for food (both human and animal) and medicines [6]. Salads, soups, and stews were often prepared from purslane aerial parts, while bread could be obtained from ground seeds; teas and infusions were used for treating gastrointestinal disorders [7]. Modern times, however, allowed the development of valorising the potential of plants for their active compounds in medicine and other biotechnological branches, such as the cosmetic products industry.

Thus, in this current mini-review, we aimed to describe the possible uses of *Portulaca oleracea* in both medicine and cosmetics, as it could be found in the recent reports and to explore further opportunities in expanding their use according to their biochemical properties.

2. Cultivation and harvesting of *Portulaca oleracea*

The spontaneous growth of purslane is well adapted to any type of soil as long as it benefits from sunlight and a minimum temperature of 20 to 35 ºC (night/day) [4]. It has increased tolerance to drought and salinity stress and strong allelopathic potential [8]. As a consequence, *Portulaca oleracea* is considered an endemic invasive species that could affect agriculture.

On the other hand, the special metabolic characteristics of purslane could also be valorised by cultivation. In this regard, many purslane cultivars are described, including several transgenic variants. Despite the negative potential of *Portulaca oleracea* plants, the socioeconomic importance is well explained and significant. Thus, purslane cultivation could be used for cleaning soils and waste waters that were polluted with heavy metals and nitrates. Also, purslane could be successfully used to remediate excessive salinity and defective mineral contents. Consequently, the use of agricultural unavailable soils could be expanded: drylands, salt-affected areas, wastelands, and lands affected by defective agricultural practices [8].

Another important aspect of purslane cultivation and valorisation was extensively discussed by [8], as it was reported that it could offer substantial biomass production, by comparison to other vegetables and food plants [4]. As a consequence, purslane is also valorised in the nutrition of both humans and animals [9,10] as a potent source of vitamins, antioxidants, minerals, and omega-3 fatty acids [11]. The potential as a medicinal plant was also documented and it was shown that purslane could be effective in improving several symptoms of diabetes, gastric mucosal ulcerations, cancer [12], liver inflammation [13], headache [14], anxiety [15], and skin photoaging [16]. Moreover, it was reported that purslane could also be of biotechnological interest, in preserving fresh vegetables due to the antioxidant and antimicrobial effects, as described by [17] and [18], respectively, and even in preserving yoghurt [19] and chilled meat [20].

Studies have reported that the nutritional value of purslane varies by the stage of development and the properties of the soils. Mohamed and Hussein [21] reported that the highest protein content is reached during the third growth stage, while the highest content of soluble carbohydrates during the first and second growth stages. Also, the content of omega-3 fatty acids was the highest in the plants that were harvested during the 6-true-leaves stage, as shown by [22], all of which production could be modulated by different growth environments [22]. Similar to these, the content of oxalic acid in leaves and stems could be decreased by cultivation in ammonium-poor

soils [23,24]. Also, Petropoulous et al [25] suggested that early harvesting and the selective use of leaves could increase the nutritional value of purslane.

3. Chemical composition and bioactive compounds extraction

Increasing interest on the chemical composition of *Portulaca oleracea* have been shown. Most of the studies reported increased carbohydrate content, lipids, proteins, and low fibre content [26,27]. Also, increased mineral content was reported suggesting that purslane aerial parts are a potent source of sodium, potassium, calcium, magnesium, iron, and zinc [9,28]. Besides the nutrients for which purslane is known, its socioeconomic importance is also given by the special metabolic pathways and the production of several secondary metabolites, enumerated by [29]: alkaloids, saponins, tannins, flavonoids, cardiac glycosides, terpenoids, phenolic acids, and organic acids. Many studies have extensively described the structure and functions of most of the mentioned secondary products suggesting that the medicinal potential is mainly due to the content of alkaloids, flavonoids, catecholamines, vitamins, and antioxidants [9,12,27,29,30,31].

One particular case of purslane-originating compounds is the organic silicon. It was demonstrated as implicated in the regeneration of dermal tissues and vascular walls and the constitution of hair, teeth, bones, cartilage, and tendons [32]. The literature is rather scarce in this regard, as only one report was identified, in our best knowledge. Popescu et al [32] investigated the properties of the silicon mineral extracted from the dried aerial parts of purslane and other 5 plant sources by cold maceration in glycerine R 20%. They found that the macerate of *Portulaca oleracea* could offer the best quantity of organic silicon.

Considering the different physicochemical properties of each of those bioactive compound classes, the extraction method could greatly vary. In this context, Petropoulous et al [27] discussed the methods of obtaining omega-3 fatty acids-rich extracts and concluded that the most efficient extraction procedure is by using the chloroform: methanol mixture on purslane ground seeds, as described by Stroescu et al [33]. Also, they discussed that methanolic extraction could be the most efficient in obtaining phenolic compound-rich extracts, as described by Uddin et al [26], thus extracts with increased antioxidant activity. Despite these, the most common extraction solvent for leaves and stems of purslane is water, but it was argued that steaming could decrease the antioxidant content of the aerial parts [29]. Also, by the aid of hot water treatment, the polysaccharides content could be obtained by a complex protocol including steps of lipid degradation, ethanol precipitation, purification, and separation, as described by Wang et al. [34]. Ethanol or methanol in combination with increased temperatures and ultrasonic or microwave treatments were described as efficient for flavonoid content extraction [35-37].

4.Possible uses in medicine and cosmetic industry

4.1. Uses in dermatological treatments

An older study evaluating the emulsification properties of *Portulaca oleracea*-originating gum while searching for replacements for gum Arabic suggested that purslane leaves are rich in a non-toxic biopolymer with hydrocolloidal properties [38]. This constituent could be used not only as food stabilizers, but also as a potent stabilizer, anti-flocculant, and coalescent of oil-in-water emulsions.

Purslane fresh homogenized crude extract was reported as effective in acute, but not chronic, skin wounds with faster healing in a mice skin excision model [39]. The authors argued that the increased wound contraction and tensile strength that were similar to the *Aloe vera* and *Centella asiatica* extracts' effects could be caused by the increased collagen and fibre content of the crude extract. Skin lesions caused by insect and snake bites were also mentioned by traditional medicine written sources as improvable by purslane topical treatment [40].

Aqueous extracts and ultrasound-assisted ethanol extracts of purslane were tested in formalin-induced acute paw edema mice model and more than one 2,4-dinitrochlorobenzene-induced atopic dermatitis mice model [41]. Lv et al [42] described antihistaminic and anti-inflammatory effects, comparable to the 0.1% hydrocortisone butyrate atopic dermatitis typical treatment. Thus, the authors reported decreased density of nerve fibres on the lesioned skin and decreased number of lymphocytes, eosinophils, basophils, and decreased mast cell infiltration, as well as the inhibition of cytokines associated with proliferation of skin lesions and pruritus [42].

Similarly, traditional Persian standardized purslane extracts were evaluated for efficiency against mild or moderately severe chronic hand eczema by being administered as syrup in patients, in combination with topical vaseline, but no concluding results were reported due to the lack of comparison with commonly used treatments and the occurrence of side effects [43]. In this context, Radhakrishnan et al [44] suggested that purslane extracts could be used in topical treatments for common skin disorders, yet the phytoconstituents' pharmacokinetics and pharmacodynamics and their mechanisms of action are not fully understood, while nanocarriers use could induce toxicity and side effects. Another study using a similar 2,4-dinitrochlorobenzene-induced atopic dermatitis mice model reported that purslane and probiotic fermented purslane extracts had a significant effect against mast cell infiltration and skin lesions, reduced inflammatory cytokines, and modulated NF-κB signalling pathway [45].

The beneficial effect of *Portulaca oleracea* extracts was also reported in preventing photoaging in a mice model of UV radiation skin exposure by

inhibiting cellular apoptosis, oxidative damage, and inflammation through a mechanism that is associated with miR-138-5p/Sirt1 signalling modulation [16].

4.2. Uses in dental treatments

A recent study reported the potential of natural extracts to incorporate in oral mouthwashes performant in treating periodontal disease and dental caries due to antimicrobial effect [46]. By comparison to a commercial alcohol-based mouthwash, the herbal formulation consisting of more than 25 plant extracts was reported to decrease microbial growth in 13 of 18 oral microbial species. Moreover, *Portulaca oleracea* extracts have been reported to contain levanbiose, an oligosaccharide previously shown to be effective in preventing dental caries [47]. Yet another herbal mouthwash was formulated for treating plaque-induced gingivitis [48]. Five herbal extracts were used in the formulation (fresh plant parts of *Myrtus communis*, *Quercus brantii*, *Punica granatum*, *Portulaca oleracea*, and *Boswellia serrata* powdered and macerated separately in ethanol; the extracts were then mixed in water and 3% ethanol). The results revealed no significant differences in improvement of periodontal indices following 2-week care using herbal mouthwash, as compared to 0.2% chlorhexidine mouthwash. Similarly, oral gels consisting of 5-10 % purslane ethanolic extracts were evaluated for anti-inflammatory potential against oral lichen planus, by comparison to a well-known topical corticosteroid gel (0,1% triamcinolone acetonide) typically used in this chronic autoimmune mucocutaneous disorder and significant and comparable results were reported [49].

A rat periodontitis model was used to test the cell inflammatory responses when *Portulaca oleracea* extracts were administered orally [50] and reported that the severity of periodontitis was attenuated as well and the profile of immune cells was modified. However, the mechanism through which the effects were obtained were not due to the antimicrobial and anti-inflammatory potential of the extracts, as the S. mutans proliferation and gingival fibroblast inflammatory responses were not affected [50].

Another important effect of great interest in oral care is analgesia. In the case of *Portulaca oleracea* extracts, the analgesic properties were studied on rat models of mechanical and chemical injuries [51]. Following the *per os* administration of aqueous extracts, the analgesic activity was observed when the chemical injury was performed to the hind paws, while during tail flick test significant differences were not reported [51].

The most recent application of purslane in oral care is an innovative dental film based on carbon dioxide extract recommended for oral cavity diseases treatment due to antibacterial and anti-inflammatory potential of *Portulaca oleracea* [52]. According to the authors, a dental film is an effective dosage form of drugs, their release kinetics, and the prolonged effects of different

combinations. In this case, the dental film consisted of sodium alginate as a natural matrix of transdermal systems, carbon dioxide extract of *Portulaca oleracea*, glycerine, powdered sugar, and purified water.

4.3. Uses in gastrointestinal and hepatological treatments

Traditional medicine and folklore mention purslane as useful in treating various infections of the gastrointestinal tract, as well as inflammations of the intestines and liver. Also, there are several recent reviews addressing the hepatoprotective potential of *Portulaca oleracea*. Farkhondeh and Samarghandian [53] reported numerous clinical studies that demonstrated that purslane extracts could be effective in inhibiting ethanol-induced gastric lesions and preventing gastric ulcers due to antioxidant and antiacid properties. Similar effects were cited for the prevention of hepatocellular carcinoma, hepatic inflammation, hepatic insufficiency, hepatic fibrosis, hepatic steatosis, and chemically-induced liver toxicity [53]. Also, related to malignancies, Shao et al. [54] very recently demonstrated the potential of *Portulaca oleracea* to prevent and treat digestive inflammatory cancer transformation.

Liver inflammation caused by fat accumulation within the liver tissues (metabolic dysfunction-associated steatohepatitis) could also be alleviated by purslane extracts treatment, as it was shown in a mice model of liver injury due to myricetin that inhibited the expression of prostaglandin-endoperoxide synthase 2, of other lipid synthesis and homeostasis genes, and several key pro-inflammatory cytokines [13].

Inflammatory bowel disease patients could also benefit from purslane extracts treatments, as Kim et al [55] showed that ethyl acetate and ethanolic extracts could alleviate ulcerative colitis symptoms, such as colon mucosal injuries, by decreasing the production of anti-inflammatory cytokines, in a mice model of dextran sulphate sodium-induced intestinal injuries, similar to sulfasalazine at high concentrations. Zhang et al [56] inspected the potential mechanism of action through which purslane extract could improve inflammatory bowel disease-related inflammation and found it could be due to the regulatory effect on endoplasmic reticulum stress and autophagy. Zhu et al [57] even proposed an innovative treatment for ulcerative colitis using exosome-like nanoparticles extracted from *Portulaca oleracea* that was successful in a mice model of dextran-sodium sulphate-induced colitis. A porcine model of lipopolysaccharide-induced intestinal inflammation was used to evaluate the potential of *Portulaca oleracea*-originating polysaccharide fraction in reducing mucosal barrier damage and inflammatory response of the intestinal epithelial monolayer and was found that the mechanism of action is mainly residing in the modulation of TLR4/NF-κB and EGF/EGFR pathways [58].

The positive effect of *Portulaca oleracea* on the intestinal microbiota was previously documented in lambs, Chinese pond turtles, and rodent models [47, 59-63]. Furthermore, the purslane extracts were successfully used for alleviating bacterial diarrhoea symptoms [59].

Regarding the analgesic potential against gastrointestinal pain, the intraperitoneal administration of purslane extracts was demonstrated as efficient in decreasing abdominal pain and inhibiting pro-inflammatory cytokines, in a rat model of chronic constriction injury [41]. On the contrary, Chan et al [64] showed that the ethanolic extract of dried leaves and stems was not able to reduce pain and inflammation by oral administration, but only topical and intraperitoneal.

Moreover, the administration of purslane seed extracts to type-2 diabetes patients leads to lipid metabolism stabilisation, liver enzymes normalisation, and glycaemia and insulin resistance decrease, comparable to standard metformin treatment [65].

Despite that no report of side effects from consuming *Portulaca oleracea* by humans (except for the accumulation of oxalic acid in kidneys), there are mentions regarding purslane consumption by sheep and goats as being harmful due to poisoning with nitrite and nitrates [66].

4.4. Uses in neuroprotection

Surprisingly, several studies are reporting neuroprotective and neuroactive effects following purslane extracts administration in animal models and humans. Due to the content of catecholamines and catecholamine derivates, flavonoids, and alkaloids, extensively discussed by [29], but not limited to, the extracts of purslane were reported as potent modulators of the nervous system. Of these, dopamine, adrenaline, noradrenaline, oleraurea (with anticholinesterase activity), quercetin, and myricetin could be namely enumerated [29]. When neuroinflammation was induced using lipopolysaccharides in rats that previously received purslane extract treatments, an improvement in cognitive performance and brain inflammation was obtained [66].

The juice from the aerial parts of purslane obtained in aqueous solution was also reported as a potent neuroprotective agent, as it was demonstrated that it could inhibit oxidative stress, apoptosis, and inflammation, in the striatum of a rotenone-induced brain injury rat model [67]. Also, intraperitoneal administration of *Portulaca oleracea* extracts led to decreased locomotor activity, anti-nociceptive activity, anti-convulsant, and muscle relaxant activity, in a rat model evaluated by Radhakrishnan et al [68]. While arguing the possible mechanisms of action through which the positive effects were obtained, the authors proposed the implication of opioid receptors in the central and peripheral nervous system modulation.

Anxiolytic effects were also shown for an 70% ethanolic extract of purslane. While evaluating the anxiety-like behaviour in the elevated plus maze paradigm, Lee et al [15] reported that the extract could improve anxiety in a GABAergic-dependent manner, while locomotion and muscle tonus were not affected. Sedative and hypnotic effects were observed when mice models were intraperitoneally treated with hydro-alcoholic extract of *Portulaca oleracea* and pentobarbital, comparable to that induced by diazepam [69]. Furthermore, some recent reports also assigned to purslane extracts alleviating effects over headaches [70,71], traumatic brain injury [72], neuropathic pain [73], and joint inflammation [74].

CONCLUSIONS

Portulaca oleracea use in nutrition and medicine was previously attested by both written historical sources and scientific research. Purslane was demonstrated as a good vegetal source of fatty acids, as well as with great potential in preventing and treating microbial infections, wounds and injuries, gastrointestinal disorders, and to protect against various neurotoxic and hepatotoxic stimuli.

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