JAP&T
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Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2022, *28*(2), 187-198

Journal of Agroalimentary Processes and Technologies

Bioactive components of purslane seed and oil and its effects on human health

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Abstract

Purslane is a widely distributed vegetable that has been consumed since ancient times. Purslane, which has many uses as raw as well as consumed cooked, contains many bioactive components as well as primary metabolites. However, this vegetable, which has high antioxidant properties and is one of the richest green plant sources of omega-3 fatty acids, has high nutritional properties. Considering these nutritional properties of purslane, it has the potential to be a very useful food source for changing dietary habits.

In this review, brief information is given about the bioactive components of purslane seed and oil and their effects on human health.

Keywords: Purslane, bioactive components, human health

1.Introduction

Portulaca oleracea L. is a warm climate, herbaceous, succulent one-year plant belonging to the *Portulacaceae* family with a cosmopolitan distribution [22]. It is widely distributed in tropical and subtropical regions of the world, including many regions of the United States, and has many different uses [81]. It is added to soups and salads in Mediterranean and tropical Asian countries, Americans and Australian natives grind the seeds of this plant into flour for use in porridge and bread [70]. *Portulaca oleracea* is consumed both raw and cooked. It is an important component of green salad and the leaves and stems are used uncooked, alone or in combination with other vegetables [27]. Despite its genetic diversity, purslane is one of the most abundant terrestrial vegetables [26]. It has been used as an important traditional medicinal plant and has been named “Global panacea” by WHO [24].

Purslane is rich in polyunsaturated fatty acids (PUFA), including omega-3 (α-linolenic acid; C18:3) and omega-6 (linoleic acid; C18:2) fatty acids. However, the highest omega-3 fatty acid content was found in purslane compared to other vegetables [6]. Other components of the plant include glutathione, terpenoids, alkaloids, phenolic compounds (especially flavonoids) [56-13].

Among green leafy vegetables, it has the highest content of vitamin A, a natural antioxidant that plays an important role in eye health and protection against lung cancer. This herb also contains ascorbic acid, α-tocopherol and vitamin B complexes (eg niacin, pyridoxine and riboflavin) [114]. Purslane has traditional medicinal benefits. It can be used to treat intestinal, liver, stomach, cough, shortness of breath, headaches and various diseases [114]. It has important applications in various treatments such as laxative, cardiac stimulant, muscle relaxant, anti-inflammatory and diuretic in herbal medicine [114].

Purslane plant has remarkable nutritional, medicinal and pharmacological properties. It is extremely nutritious and contains many vitamins and minerals necessary for human nutrition. It can be easily grown in tropical, subtropical and underdeveloped regions of the world with high productivity [101]. Considering these nutritious properties of purslane, it has a great potential to be very beneficial in constantly changing nutritional habits.

2. Purslane

2.1. Origin

Purslane (*Portulaca oleracea* L.) is an annual herbaceous plant with fleshy leaves belonging to the *Portulacacea* family [29]. The term portulaca is derived from the Latin word "Portare" meaning to carry and "lac" meaning milk, referring to the milky

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sap of this plant. The name of the *Oleracea* species is of Latin origin and means "related to kitchen gardens" [46]. Purslane, a member of the *Portulacaceae* family, is very common as a weed and is among the eight most common plants in the world. It mainly grows in tropical and subtropical climates and its origin is South America and Africa [75]. It is known that purslane was a vegetable widely consumed in the Roman Empire. However, purslane has a long history of use as human food, animal feed, and for medicinal purposes [59]. Although its worldwide spread is thought to have originated from post-Columbian humans, archaeological evidence (pollen analysis) indicates that purslane arrived in the New World in pre-Columbian times [62].

Table 2.1. Classification of *P. oleracea* [111]**.**

Regnum	Tracheobionta
Phylum	Magnoliophyta
Classis	Magnoliopsida
Ordo	Caryophyllales
Familia	Portulacaceae
Genus	*Portulaca L*
Species	*Portulaca oleracea L.*

2.2. Morphology

Purslane has reddish, almost touching and fleshy stems; to aqueous plant sap; It is a plant with round, fleshy leaves and small yellow flowers that expand towards the tip [38]. The stems of the plant, which has a thick root and many secondary roots, can spread like a cover up to 60 cm in diameter. The fleshy stems are 10 to 30 cm long and have stems that are hairless, thick, rounded, smooth, juicy and radiating from the central root. The leaves are alternate, obovate (egg-shaped tapering downwards) or spatulate (spoon-shaped expanding smoothly towards the tip), rounded-tip, glabrous, thick and juicy, 2.8 cm long [48]. Both stems and leaves often have a reddish tint. The flowers appear at the ends of the stems as a single or two to five clusters. The flowers are orange, yellow, purple, or white-pink, singly or in clusters [14]. The seeds are brownish-black and brightly colored, 0.5 to 0.8 mm in diameter, with a white streak on one end. Seeds are spread by wind, water. Up to 10,000 seeds were counted in a single plant and it was stated that purslane could produce 101.625- 242.540 seeds per plant during the whole season [122].

Figure 2.1. Purslane plant [53].

2.3. Habitat

Purslane is found all over India, in the Himalaya and in all temperate countries up to 1524 meters (5,000 ft) [105]. It is the eighth most common grass worldwide, growing in temperate, subtropical and tropical regions at an altitude of 2.6 km above sea level. It is reported to be found from 45° north latitude to 40° south latitude. It is easily grown in warm humid places in summer and spring, and can produce flowers, fruits and seeds rapidly after forty days of germination.

2.4. Growing conditions

Purslane grows rapidly from a typical, large, degraded habitat, producing flowers, fruits and seeds within 6 weeks of germination. It has a wide tolerance for photoperiod, light intensity, temperature, humidity and soil type. Seeds germinate under conditions that increase seedling survival [20].

Purslane reproduces primarily from seed. After the first appearance of flowers (5-6 weeks of growth), more than 6000 seeds can be produced. Light is required for germination, but the temperature requirement is variable. Purslane seeds germinate in the range of 10-40°C, but germination stops when the temperature rises above 50°C [103]. After germination, purslane branches immediately. Purslane flowers are open for an average of 4 hours a day. Flowers are sensitive to both low light intensity and temperatures below 21°C [121].

3. Bioactive components of Purslane seed and oil

3.1 Bioactive components

Bioactive components are secondary metabolites found in small amounts in various plants [49]. These are mostly hydrophobic and sparingly soluble compounds.

Bioactive components are found in small amounts in foods, especially fruits, vegetables and whole grains, and have positive effects on health [30]. Bioactive components of foods and antioxidant activity are of great importance in terms of nutrition because of their effects on the prevention of diseases due to free radicals [86]. However, bioactive components are essential for human health due to their multiple biological effects such as reducing the risk factors of cardiovascular diseases and antioxidant, antimutagenic, anticarcinogenic, antiallergic, anti-inflammatory and antimicrobial activities [35, 81].

To date, a large number of bioactive components have been discovered. These compounds show great differences in chemical structure and function and are classified according to these differences. Some examples of bioactive ingredients are carotenoids, flavonoids, lignans, plant sterols, glucosinolates. Bioactive components of plant origin, also called phytochemicals; terpenes and terpenoids are alkaloids and phenolic compounds [72-16]. Vitamins and minerals can also be classified as bioactive components due to their various pharmacological effects [83].

Table 3.1. Classification of bioactive components **[**49-50]

Bioactive components	**Samples**	**Food sources**	**Biological effects**
Carotenoids	Lycopene, Lutein, α-carotene, β carotene, β-cryptoxanthin, Zeaxanthin	Yellow, red, green and orange fruits and vegetables	Antioxidant activity, preventing DNA damage.
Flavonoids	Flavone, Flavonone, Isoflavone, Flavonone, Catechin (Flavanol), Anthocyanidin	Fruit and vegetables, soya and legumes, tea, cacao	Antioxidant activity.
Phenolic acids	caffeic acid, chlorogenic acid, coumaric acid, ferrulic acid	Cereals, coffee, fruits and vegetables, olive oil	Reducing low-density lipoprotein (LDL) oxidation.
Glucosinolates	Sulforaphane, Benzyl (BITC), Phenethyl (PEITC)	Four-leaf plants with flowers such as broccoli, brussels sprouts, watercress	Suppression of tumor formation and development, anticarcinogenic activity.
Lignans	Enterolactone, Enterodiol, Kumestrol	Linseed, linseed oil, rye	LDL-cholesterol lowering, estrogenic activity, prooxidant activity.
Phytosterols	Campesterol, sitosterol, stigmasterol	Rice oil, soybean oil	Reducing LDL oxidation, reducing cholesterol absorption.

3.2. Bioactive components found in purslane seeds and oil

Purslane is a vegetable commonly found in various parts of the world due to its high adaptability under various climates and harsh conditions [108]. Recently, purslane has been described as a "functional food" due to its high nutritional value [96].

Phytochemical studies have shown that purslane is one of the richest terrestrial sources of ω-3 and ω-6 fatty acids, ascorbic acid, tocopherols, glutathione and β-carotene [95]. In addition to being a source of primary metabolites, purslane contains varying amounts of specialized substances.

These; metabolites such as alkaloids, saponins, tannins, flavonoids, cardiac glycosides, terpenoids, phenolics. Bioactive components, which are found in large numbers in purslane, are responsible for many biological activities [72-75].

3.2.1. Flavonoids

In 1930, a new substance was isolated from oranges and was thought to be a member of a new class of vitamins. This vitamin was named as vitamin P, but in later years, it was revealed that this substance is a flavonoid, and more than 4000 flavonoid types have been defined so far [66].

Flavonoids are secondary metabolites with a polyphenolic structure commonly found in fruits, vegetables and various beverages.

Flavonoids are an indispensable component in nutraceutical, pharmaceutical, medical and cosmetic applications due to their health-promoting effects [65]. Flavonoids are a large group with variable structures found in almost all growing parts of plants, reported as the most abundant plant pigment, along with chlorophyll and carotenoids, giving fragrance and flavor to fruits, flowers and seeds and beautifying them [101].

Chemically, flavonoids consist of a fifteen-carbon skeleton consisting of two benzene rings linked by a heterocyclic pyran ring. Flavonoids; There are 6 main subgroups: flavones, flavonones, flavanones, catechins (flavanols), isoflavones and anthocyanidins. Other flavonoid classes are biflavones, chalcones and coumarins [42].

Flavonoids are one of the most abundant and effective components in purslane. Flavonoid levels in purslane plant differ in parts of the plant. The highest level of flavonoids is found in the root, followed by the stem and leaves, respectively. According to the studies of Zhu et al., the flavonoid content was recorded as 11.36 mg/g in the root, 5.12 mg/g in the stem and 1.76 mg/g in the leaves. There are seven different types of flavonoids in this herb, including kaempferol, myricetin, luteolin, apigenin, quercetin, genistein, and genistin [119]. However, only kaempferol and apigenin were found in extracts from leaves and stems [113]. Flavonoids in purslane plant; They are biologically active ingredients that have been reported to have anti-oxidation, anti-bacterial, anti-virus, anti-ulcerogenic, anti-inflammatory, cough control and expectoration functions [38].

3.2.2. Alkaloids

Alkaloids are a large group of naturally occurring organic compounds that contain a nitrogen atom or atoms (in some cases amino or amido) in their structure. The nitrogen atoms in its structure cause the alkalinity of these compounds. Alkaloids are produced by a wide variety of organisms, including bacteria, fungi, plants and animals. Many alkaloids generally have pharmacological effects and are included in the components of drugs [113]. In pure form, alkaloids are usually colorless and odorless, but sometimes they can be yellowish liquids. Alkaloids have a bitter taste.

Today, more than 3000 alkaloids are known in more than 4000 plant species [53]. Another important chemical found in the purslane plant are alkaloids such as dopa, dopamine, and noradrenaline. According to the studies of Yue et al., dopamine and noradrenaline content in leaves is higher than in stems and seeds. The noradrenaline content obtained from the root, leaves and seeds was recorded as 0.011%, 0.084% and 0.014%, respectively [115]. Various alkaloids such as oleraceins, oleracins, trollisine, scopoletin, and oleraisoindole have also been reported in the purslane plant [30]. Three phenolic alkaloids isolated from purslane, namely oleracein A, oleracein B and oleracein E, show antioxidant activities [114]. However, purslane-derived Oleracein E and oleracein L were found to exhibit hypoglycemic and antidiabetic activities [87]. Xiu et al. reported a new alkaloid called oleraurea from purslane, and interestingly, this alkaloid has been reported to have anticholinesterase activity, which is thought to have an important role in Alzheimer's disease as a cholinesterase inhibitor [112].

3.2.3. Phenolic acids

Phenolic acids, in general, are phenolic compounds that have a carboxylic acid group [14]. Phenolic acids form one of the largest groups of phenolic compounds and are distinguished from other phenolics by their structures that typically contain a carboxyl group and one or more hydroxyl groups attached to the aromatic ring [7]. Found in plant-based foods, seeds, skins of fruits and leaves of vegetables contain the highest concentrations of phenolic acids [81]. Phenolic acids are obtained from benzoic and cinnamic acids; and although their basic structure remains the same, the number of hydroxyl groups and their position on the aromatic ring vary greatly, resulting in different varieties of phenolic acids. The most common phenolic acids derived from benzoic acid in vegetables; gallic, p-hydroxybenzoic, syringic and vanillic acids, while those derived from cinnamic acid; caffeic, chlorogenic, ferulic, p-coumaric and sinapic acids [30]. In general, the concentration of cinnamic acid derivatives in fruits and vegetables is higher than that of benzoic acid, with the exception of some red fruits and other herbal products [61]. Among the major groups of bioactive components of vegetables, phenolic acids are becoming the focus of attention of many researchers, considering their properties for human health and their relative abundance in vegetables [42].

Sicari et al. studied the phenolic acid composition of fresh and dried purslane leaves. According to this study, various phenolic acids such as caffeic acid, p-coumaric acid, ferulic acid were found in purslane plant and the amounts of caffeic acid, p-coumaric acid, ferulic acid in fresh purslane leaves were; It was recorded as 7.35 mg/kg, 20.53 mg/kg, 9.62 mg/kg [92]. Various derivatives of caffeic acid (caffeoyl glutaric acid, caffeic acid glucuronid acid isomer) and sinapic acid (38 mg/100 g) have also been identified in purslane [27].

Scientist's interest in phenolic acids is constantly increasing due to their antioxidant properties and promising health benefits. Phenolic compounds are known as direct antioxidants; however, they act as indirect antioxidant activity by inducing endogenous protective enzymes [103]. Epidemiological studies show that a diet high in antioxidant-rich fruits and vegetables significantly reduces the risk of many cancers. Among all the properties of phenolic acids, the best one is that it shows antidiabetic activity by inhibiting α-glucosidase and α-amylase, which are responsible for the conversion of dietary carbohydrates to glucose [35].

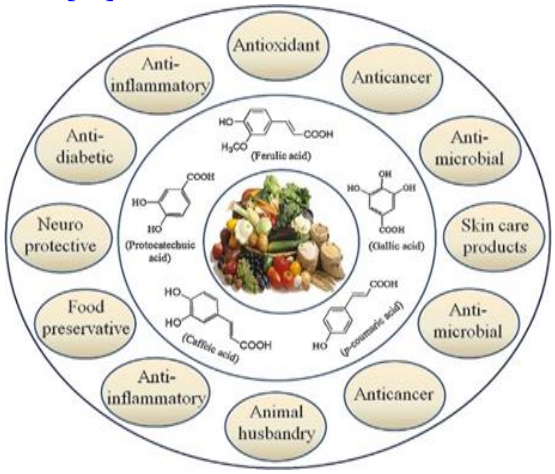

Figure 3.2. Effects of phenolic acids on health [50].

3.2.4. Carotenoids

Carotenoids are the most commonly found pigments in nature, displaying yellow, orange, red, and purple colors. Carotenoids are found in many plants and are fat-soluble. Most carotenoids are composed of eight isoprene units with a 40-carbon skeleton [8]. Carotenoids are divided into two classes, carotenes containing only carbon and hydrogen atoms, and xanthophylls, which contain at least one oxygen atom. The β-cryptoxanthins, cantaxanthin and astaxanthin are important xanthophylls [100]. Examples of carotenes are α-carotene, β-carotene, and lycopene [100]. A typical human diet contains only ~40 carotenoids, and about 20 carotenoids have been identified in human blood and tissues. These carotenoids in the diet and in the human body include β-carotene, α-carotene, lycopene, lutein and cryptoxanthin [86].

Among other important compounds, purslane also contains extremely important bioactive molecules such as carotenoids. Dias et al. examined the carotenoid content of purslane plant harvested in Portugal in July 2009. Carotenoid amounts in purslane harvested in this study; α-carotene (0.009 mg/ 100 g), β-carotene (3.5 mg/100 g), lutein (5.4 mg/100 g) and zeaxanthin (0.19 mg/100 g) were found [17]. Similarly, Rowley and colleagues performed a more detailed identification of major carotenoids found in purslane plants collected in Melbourne (Australia) in February. They concluded that the most abundant carotenoid (7.0 mg/100 g), followed by β-carotene (1.6 mg/100 g) [88].

There have been many studies showing that carotenoid-rich foods can have a positive role in human health and contribute to reducing the risks of various aging-related diseases such as certain cancers, cardiovascular diseases, bone, skin or eye disorders, and may be mentally beneficial. In addition to the coloring and bioactive compound roles of carotenoids, which have positive effects on human health, it has a defined role as a provitamin A compound, which is the key to combating vitamin A deficiency in regions where the consumption of animal foods is deficient [62-63].

3.2.5. Saponins

Saponins are a diverse group of compounds widely distributed in the plant kingdom, characterized by their structures containing a triterpene or steroid aglycone and one or more sugar chains [33]. Named for their ability to form stable, soap-like foams in aqueous solutions, saponins form a complex and chemically diverse group of compounds [91]. The combination of a hydrophobic aglycone backbone and hydrophilic sugar molecules makes saponins highly amphipathic (a chemical compound with both hydrophilic and hydrophobic properties) and concomitant foaming, emulsifying properties. These surfactant molecules have important roles in plant ecology and are also used for a wide variety of commercial applications in the food, cosmetic and pharmaceutical industries [90].

Triterpenoid and steroid saponins are mainly found in legume seeds, although many other foods and food raw materials contain small amounts of saponins [55].

The ability to synthesize saponins is quite common among plants belonging to the division Magnoliophyta, which includes both dicotyledons and monocotyledons [110]. Ezeabara et al. analyzed and described the leaf, stem and root of the purslane plant in terms of phytochemical components. The amount of saponin was found to be the highest (1.56%) in the ethanol extract of purslane leaf, and 1.32% and 1.24% in the stem and root, respectively. In the aqueous extract, saponin levels were determined as 1.5%, 1.27% and 1.17% in the leaf, stem and root, respectively. The results showed that all parts of purslane contained high concentrations of saponin in both aqueous and ethanol extracts [23].

Plants rich in saponins have been used for medicinal purposes since ancient times [26]. Saponins provide a wide variety of pharmacological activities, including expectorant, anti-inflammatory, hypocholesterolemic, immunomodulatory, hypoglycemic, antifungal, and antiparasitic effects [98-89]. It continues to play an important role as an emulsifier or sweetener not only in medicine but also in the food and cosmetic industry [33].

3.2.6. Fatty acids

Fatty acids consist of a hydrocarbon chain containing two to more than thirty carbon atoms and a methyl (CH_3) group at one end of the molecule and a carboxyl (COOH) group at the other end [9]. Fatty acids are among the most studied nutrients and bioactive components.

A number of fatty acids have been isolated and identified from various parts of purslane plants. Studies have shown that purslane contains higher total fatty acid content than commonly used vegetables such as spinach, red leaf lettuce, mustard and [96]. Purslane is a nutritious vegetable rich in polyunsaturated fatty acids (PUFA) and is known for its omega-3 (α-linolenic acid) and omega-6 (linoleic acid) fatty acids, which are essential for human health [80]. In addition to α-linolenic acid, which constitutes approximately 30% of purslane oil, other essential fatty acids such as palmitoleic (20.96%), palmitic (17.40%), linoleic (16.82%), oleic (5.89%) and stearic (3.46%) in plant tissues was also detected [31].

Purslane seeds are rich in both linoleic (34.1%) and α-linolenic acid (32.4%), as well as palmitic (16.4%) and oleic acid (11.0%) [18]. Omara-Alwala et al. reported that purslane also contains omega 3 fatty acids docosahexaenoic acid (DHA) and docosapentaenoic acid (DPA) in their studies [77]. The fatty acid percentage of purslane plant is shown in the table below.

Table 3.2. Percentage of fatty acids in edible parts of purslane [31].

Fatty acid	**Amount (%)**
α-linolenic acid	32.60
Palmitoleic acid	20.96
Palmitic acid	17.40
Linoleic acid	16.82
Oleic acid	5.89
Stearic acid	3.46
Behenic acid	3.33
ω-3/ ω-6	2.00

α-linolenic acid, an omega-3 fatty acid, is an essential fatty acid that cannot be synthesized by humans and must be taken with food. Omega-3 fatty acids have an important role in reducing the serum cholesterol level by suppressing the activity of the enzyme that provides cholesterol synthesis in the liver, thus preventing and delaying the formation of atherosclerosis [45]. Since they cannot be synthesized in the human body, it has been determined that increasing the consumption of omega-3 fatty acids, which must be taken from the outside through nutrition, lowers blood cholesterol levels, delays the formation of atherosclerosis, and significantly reduces the risk of heart attack by preventing thrombosis in the veins [93]. The true benefits of these bioactive compounds have been documented through clinical trials as well as both in vitro and in vivo studies. Therefore, purslane is a potentially valuable food source with a significant impact on human health, and therefore its daily consumption is highly recommended [83].

3.2.7. Terpenoids

Terpenoids, also known as isoprenoids, are a large class of naturally occurring compounds derived from the five-carbon isoprene unit. Terpenoids, also known as isoprenoids or terpenes, are a large class of natural products found in nearly all living organisms [76].

More than 60,000 terpenoid structures have been identified from natural sources, making them one of the largest known groups of natural compounds [47]. They contribute to the flavor, odor and color of the leaves, flowers and fruits of the plant. Terpenoids are also essential for plant growth and development [16].

There are various terpenoids in purslane plant. Elkhayat et al. defined portulene as a new diterpene from purslane [22]. Apart from this, purslane; A number of terpenoids have been identified, such as portuloside A, portuloside B, portulene, lupeol, Friedelane, taraxerol, portaraxeroic acid A, and portaexeroic acid B [14-67].

Terpenoids have been shown to be one of the secondary metabolites produced by various aromatic and medicinal plants that play a key role in the fight against diseases. For example, monoterpenoids are antibacterial in nature, interfering with their physiological and metabolic activities as well as inhibiting the proliferation and development of microbes [10]. In recent years, numerous studies have reported that terpenes and terpenoids are essential to support human health. Terpenes and terpenoids, which are among the bioactive components, have been reported in many studies to have a wide variety of biological activities, including anticancer, antimicrobial, anti-inflammatory, antioxidant and antiallergic [59].

4. Effects of purslane plant on human health

In many parts of the world, including Asian and Mediterranean countries, purslane is cultivated as a special plant valued for its nutritional and medicinal properties [74]. This plant has been used as a vegetable, spice and medicinal herb since ancient times in Egypt and England. The oldest use date is A.D. in China. It has been recorded as around 500 and has been called the "vegetable for longevity" in Chinese herbal culture. Purslane has also been used as a medicine substitute. In Unani medicine, it has been used as an antipyretic, diuretic, astringent, and dysentery reliever [104- 111]. It has been listed as one of the most used medicinal plants by the World Health Organization due to its various pharmacological effects, and the term “global panacea” has been given [111].

4.1. Anti-inflammatory effect

Inflammation is a fundamental protective response that ensures human survival when faced with a microbial condition or injury, and also maintains tissue homeostasis in a variety of harmful environments [105]. Substances that reduce inflammation and edema are called anti-inflammatory. In the study of Meng et al., a new alkaloid, oleracone, was first isolated from purslane, and it was determined that this alkaloid isolated from purslane showed remarkable anti-inflammatory effects [64]. In a study by Kaveh et al. in 2017, a significant decrease in PLA2 (phospholipase A2), TP (total protein) and IgE (immunoglobulin E) levels was observed in mice treated with purslane extract, which supported the anti-inflammatory and inhibitory effects of the studied plant on lung inflammation [43].

4.2. Antioxidant activity

The phytochemical composition of purslane provides information about its antioxidant properties and various studies prove this [1]. The antioxidant property of Portulaca oleracea depends on its components such as gallotannins, omega-3 fatty acids, ascorbic acid, α-tocopherols, kaempferol, quercetin and apigenin [11-118]. Lim and Quah tested their antioxidant activities using methanolic extracts of 6 different purslane cultivars in 2007. In particular, it was observed that one cultivar (with yellow flowers, red and soft juicy stems) had very high TPC (total phenol content) and antioxidant activities compared to other cultivars [56]. However, purslane leaves have been reported to exhibit more antioxidant activity due to their higher total phenol content and total phenolic acid content than other parts of the plant [97].

Various compounds have been isolated from purslane and their antioxidant activities have been proven. For example, phenolic alkaloids such as oleracein A, oleracein B and oleracein E show antioxidant activities [113]. It is reported that especially purslane seeds are more effective in antioxidation than those obtained from other plants [21]. Guo et al. conducted a study to determine the antioxidant activities of purslane seed oil, and the results showed that purslane seed oil has remarkable antioxidant activities and effectively prevents lipid oxidation of horse fat [32]. All these studies show that purslane has beneficial effects on health and provides protection against free radicals.

4.3. Antimicrobial potential

In the study of Zhou et al., it was determined that 70% methyl extract of *Portulaca oleracea* showed antifungal and antibacterial activity against *Candida albicans, Escherichia coli, Pseudomonas aeruginosa, Neisseria gonorrhoeae, Staphylococcus aureus, Bacillus subtilis* and *Streptococcus faecalis* [117]. Another study reported that apigenin, a flavonoid isolated from the ethanol extract of the aerial part of purslane, showed antibacterial activity in vitro on five pathogenic bacterial strains (*Pseudomonas aeruginosa, Salmonella typhimurium, Proteus mirabilis, Klebsiella pneumoniae and Enterobacter aerogenes*) [70]. It was also concluded that purslane has antifungal activity against Trichophyton genus dermatophytes [74].

4.4. Anticancer potential

Cancer is a life-threatening disease and is considered one of the leading causes of death worldwide. Therefore, the introduction of new therapeutic agents for cancer remains a priority to increase the diversity of effective treatments [41]. The purslane plant has been used in traditional treatments in different countries to treat different ailments in humans. *P. oleracea L.* polysaccharide (POL-P) extracted from purslane has been found to have bioactivities such as hypoglycemic and hypolipidemic, antioxidant and antitumor activities [116]. Huan et al. (2013) reported that *Portulaca oleracea* has anti-tumor effects by purifying a unique polysaccharide component (POP) in their study [39]. Purslane has shown promising results as an anticancer herb against various types of cancer. Purslane extract has been found to have an inhibitory effect on nodule formation in colon cancer stem cells [39]. It is also reported that purslane seed oil shows significant cytotoxicity against human liver cancer (HepG2) and human lung cancer (A-549) cell lines and inhibits cell growth [2]. The results show that the anticancer activity of this herb is promising against various types of cancer.

5. Result

As mentioned above, purslane is a plant with a wide variety of bioactive components. Besides being a source of primary metabolites, it contains many secondary metabolites such as alkaloids, saponins, tannins, flavonoids, cardiac glycosides, terpenoids, phenolic acids and organic acids.

Purslane is a nutritious vegetable with high antioxidant properties and has recently been recognized as the richest source of α-linolenic acid, essential omega-3 and 6 fatty acids, ascorbic acid, glutathione, α-tocopherol and β-carotene. The lack of vegetal sources of ω-3 fatty acids has resulted in an increased level of interest for this herb. Despite being a wonderful herb, it is underutilized around the world.

Purslane is becoming an important food due to its many benefits and is attracting attention by various scientists around the world. It is promising in providing both new biologically active substances and essential compounds for human nutrition. The abundance of high levels of these essential nutrients in purslane, which has high antioxidant properties and is one of the richest green plant sources of omega-3 fatty acids, indicates its potential as a new source of nutritious food for both humans and animals.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

References

1. Alam, M. A.; Nadirah, T. A.; Mohsin, G. M.; Saleh, M.; Moneruzzaman, K. M.; Aslani, F.,; Alam, M. Z., Antioxidant compounds, antioxidant activities, and mineral contents among underutilized vegetables. *International Journal of Vegetable Science*, **2021**, 27(2), 157-166.
2. Al-Sheddi, E. S.; Farshori, N. N.; Al-Oqail, M. M.; Musarrat, J.; Al-Khedhairy, A. A., Siddiqui, M. A., Portulaca oleracea seed oil exerts cytotoxic effects on human liver cancer (HepG2) and human lung cancer (A-549) cell lines. *Asian Pacific Journal of Cancer Prevention*, **2015,** 16(8), 3383-3387.
3. Alam, M.; Juraimi, A. S.; Rafii, M. Y.; Abdul Hamid, A.; Aslani, F.; Hasan, M. M.; Uddin, M., Evaluation of antioxidant compounds, antioxidant activities, and mineral composition of 13 collected purslane (Portulaca oleracea L.) accessions. *BioMed research international*, **2014.**
4. Alam, A.; Juraimi, A. S.; Rafii, M. Y.; Hamid, A. A.; Uddin, K.; Alam, M. Z.; Latif, M. A., , Genetic improvement of Purslane (Portulaca oleracea L.) and its future prospects. *Molecular biology reports*, **2014**, 41(11), 7395-7411.
5. Alam, M.; Juraimi, A. S.; Rafii, M. Y.; Hamid, A. A.; Aslani, F.; Hakim, M. A., Salinity-induced changes in the morphology and major mineral nutrient composition of purslane (Portulaca oleracea L.) accessions. *Biological research*, **2016**, 49, 1-19.

6. Berthelot, K.; Estevez, Y.; Deffieux, A.; Peruch, F., Isopentenyl diphosphate isomerase: a checkpoint to isoprenoid biosynthesis. *Biochimie*, **2012,**94(8), 1621-1634.
7. Bhattacharya, A.; Sood, P.; Citovsky, V., The roles of plant phenolics in defence and communication during Agrobacterium and Rhizobium infection. *Molecular plant pathology*, **2010**, 11(5), 705-719.
8. Britton, G.; Liaaen-Jensen, S.; Pfander, H., Carotenoids: handbook. *Springer Science & Business Media*, **2004**, 412-415.
9. Brossard, N.; Croset, M.; Pachiaudi, C.; Riou, J. P.; Tayot, J. L.; Lagarde, M., **1996**, Retroconversion and metabolism of [13C] 22: 6n− 3 in humans and rats after intake of a single dose of [13C] 22: 6n− 3-triacylglycerols. *The American journal of clinical nutrition*, **1996**, 64(4), 577-586.
10. Burt, S., Essential oils: their antibacterial properties and potential applications in foods-a review, *International journal of food microbiology*, **2004**, 94(3), 223-253.
11. Chan, K.; Islam, M. W.; Kamil, M. A.; Radhakrishnan, R.; Zakaria, M. N. M.; Habibullah, M.; Attas, A., The analgesic and anti-inflammatory effects of Portulaca oleracea L. subsp. sativa (Haw.) Celak. *Journal of ethnopharmacology*, **2000**, 73(3), 445-451.
12. Chowdhary ve ark., A review on phytochemical and pharmacological profile of Portulaca oleracea (purslane), *International Journal of Research in Ayurveda and Pharmacy*, **2013,** 4(1), 34–37.
13. Chugh, V.; Mishra, V.; Dwivedi, S. V.; Sharma, K. D., **2019**, Purslane (Portulaca oleracea L.): An underutilized wonder plant with potential pharmacological value. *Pharm. Innov. J*, **2019**, 8, 236-246.
14. Clifford, M., Appendix 1. A Nomenclature for Phenols with Special Reference to Tea, *Boca Raton, Florida*, **1999**, 41(5), 393- 397.
15. Croteau, R.; Kutchan, T. M.; Lewis, N. G., Natural products (secondary metabolites). *Biochemistry and molecular biology of plants*, **2000**, 24, 1250-1319.
16. Devarenne, T.P., Terpenoids: Higher, *Encyclopedia of Life Sciences*, **2009,** 1-7.
17. Dias, M. G.; Camões, M. F. G.; Oliveira, L., , Carotenoids in traditional Portuguese fruits and vegetables, *Food Chemistry*, **2009**, 113(3), 808-815.
18. Dubois, V.; Breton, S.; Linder, M.; Fanni, J.; Parmentier, M., Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. *European Journal of Lipid Science and Technology*, **2007**, 109(7), 710-732.
19. El-Keblawy, A.; Al-Ansari, F., Effects of site of origin, time of seed maturation, and seed age on germination behavior of Portulaca oleracea from the Old and New Worlds. *Canadian Journal of Botany*, **2000**, 78(3), 279-287.
20. Elkhayat, E. S.; Ibrahim, S. R,; Aziz, M. A., Portulene, a new diterpene from Portulaca oleracea L. *Journal of Asian natural products research*, **2008**, 10(11), 1039-1043.
21. El-Sayed, MI., Effects of Portulaca oleracea L. seeds in treatment of type-2 diabetes mellitus patients as adjunctive and alternative therapy, *Journal of Ethnopharmacology*, **2011**, 137, 643–651.
22. Ercisli, S.; Coruh, I.; Gormez, A.; Sengul, M., Antioxidant and antibacterial activities of Portulaca oleracea L. Grown wild in Turkey, *Italian Journal of Food Science*, **2008,** 20, 533–542.
23. Ezeabara, C. A.; Ikeh, C. F.; Chinyere, V.; Bibian, O.; Ogochukwu, E.; Mbaekwe, E., Comparative determination of phytochemical, proximate and mineral compositions in various parts of Portulaca oleracea L. *Journal of Plant Sciences*, **2014**, 2(6), 294-298.
24. Ezekwe M.O.; Omara-Alwala T.R.; Membrahtu T., Nutritive characterization of purslane accessions as influenced by planting date, *Plant Foods for Human Nutrition*, **1999**, 54,183–191.
25. Fernández-Poyatos, M. D. P.; Llorent-Martínez, E. J.; Ruiz-Medina, A., Phytochemical composition and antioxidant activity of Portulaca oleracea: influence of the steaming cooking process. *Foods*, **2021**, 10(1), 94.
26. Fiore, C.; Eisenhut, M.; Ragazzi, E.; Zanchin, G.; Armanini, D., A history of the therapeutic use of liquorice in Europe. *Journal of ethnopharmacology*, **2005**, 99(3), 317-324.
27. Asadi Gharneh, H. A.; Reza Hassandokht, M., Chemical composition of some Iranian purslane (Portulaca oleracea) as a leafy vegetable in south parts of Iran. In International Symposium on Vegetable Production, *Quality and Process Standardization in Chain: a Worldwide Perspective*, **2008**, 944, 41-44.
28. Goleniowski A., 2013, Phenolic Acids. In: Ramawat K.G., Mérillon J.M., editors. Natural Products: Phytochemistry, *Botany and Metabolism of Alkaloids, Phenolics and Terpenes*, 1951–1973.
29. Gökmen V., Acrylamide in food: Analysis, content and potantial health effects, *Elsevier*, 355-376.
30. Gu, Y.; Leng, A.; Zhang, W.; Ying, X.; Stien, D., A novel alkaloid from Portulaca oleracea L. and its anti-inflammatory activity. *Natural Product Research*, **2022**, 36(2), 595-600.
31. Guil, J. L.; Torija, M. E.; Giménez, J. J.; Rodriguez, I., Identification of fatty acids in edible wild plants by gas chromatography, *Journal of Chromatography A*, **1996**, 719(1), 229-235.
32. Guo, G.; Yue, L.; Fan, S.; Jing, S.; Yan, L. J., Antioxidant and antiproliferative activities of purslane seed oil. *Journal of hypertension: open a*ccess, **2016**, 5(2).
33. Güçlü-Üstündağ, Ö.; Mazza, G., Saponins: properties, applications and processing. *Critical reviews in food science and nutrition*, **2007**, 47(3), 231-258.
34. Ham, S. S.; Kim, S. H.; Moon, S. Y.; Chung, M. J.; Cui, C. B.; Han, E. K.; Choe, M., Antimutagenic effects of subfractions of Chaga mushroom (Inonotus obliquus) extract, *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, **2009**, 672(1), 55-59.

35. Hanhineva, K.; Törrönen, R.; Bondia-Pons, I.; Pekkinen, J.; Kolehmainen, M.; Mykkänen, H.; Poutanen, K., Impact of dietary polyphenols on carbohydrate metabolism, *International Journal of Molecular Sciences*, **2010**, 11, 1365–1402.
36. Holm, L. G.; Plucknett, D. L.; Pancho, J. V.; Herberger, J. P., The World's Worst Weeds, Distribution and Biology, *Honolulu, HI: University Press of Hawaii*, **1977**, 609.
37. Shen, H.; Tang, G.; Zeng, G.; Yang, Y.; Cai, X.; Li, D.; Zhou, N.,Purification and characterization of an antitumor polysaccharide from Portulaca oleracea L, *Carbohydrate Polymers*, **2013**, 93(2), 395-400.
38. Jian, J.; Xiao, Q. X., Phytomedicine effective component book*, People's Hygiene Press,* **1986**.
39. Jin, H.; Chen, L.; Wang, S.; Chao, D., Portulaca oleracea extract can inhibit nodule formation of colon cancer stem cells by regulating gene expression of the Notch signal transduction pathway, *Tumor Biology*, **2017**, 39, 7.
40. Ross, J. A.; Kasum, C. M., Dietary flavonoids: Bioavalibility, metabolic effect and safety, *Annual Review of Nutrition*, **2002**, 22,19-34.
41. Kamran, S.; Sinniah, A.; Abdulghani, M. A.; Alshawsh, M. A.; Therapeutic Potential of Certain Terpenoids as Anticancer Agents: A Scoping Review, *Cancers*, **2022**, 14(5), 1100.
42. Kaushik, P.; Andújar, I.; Vilanova, S.; Plazas, M.; Gramazio, P.; Herraiz, F. J.; Prohens, J., Breeding Vegetables with Increased Content in Bioactive Phenolic Acids, *Molecules*, **2015**, 20(10):18464-18481.
43. Kaveh, M.; Eidi, A.; Nemati, A.; Boskabady, M. H., Modulation of lung inflammation and immune markers in asthmatic rats treated by Portulaca oleracea, *Avicenna journal of phytomedicine*, **2017**, 7(5), 409.
44. Khanam, B.; Begu, W.; Tipo, F., Pharmacological profile, phytoconstituents, and traditional uses of Khurfa (Portulaca oleracea L.): Unani perspective, *The Pharma Innovation Journal*, **2019**, 8(4), 367-372
45. Kinsella, J. E.; Lokesh, B.; Stone, R. A., Dietary n-3 Polyunsaturated Fatty Acids and Amelioration of Cardiovascular Disease: Possible Mechanisms, *The American Journal of Clinical Nutrition*, **1990,** 52, 1-28.
46. Mıyanıshı, K.; Cavers. P., The biology of Canadian weeds. 40. Portulaca oleracea L. Can. J. *Journal of Plant Sciences*, **1980**, 60, 953-963.
47. Köksal, M.; Hu, H.; Coates, R. M.; Peters, R. J.; Christianson, D. W., Structure and mechanism of the diterpene cyclase ent-copalyl diphosphate synthase, *Nature Chemical Biology*, **2011**, 7, 431–433.
48. Kris-Etherton, P. M.; Hecker, K. D.; Bonanome, A.; Coval, S. M.; Binkoski, A. E.; Hilpert, K. F.; Etherton, T. D., Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer, *The American Journal of Medicine*, **2002**, 113(9), 71-88.
49. Kris-Etherton, P. M.; Lefevre, M.; Beecher, G. R.; Gross, M. D.; Keen, C. L.; Etherton, T. D., Bioactive compounds in nutrition and health-research methodologies for establishing biological function: The antioxidant and antiinflammatory effects of flavonoids on atherosclerosis, *Annual Review of Nutrition* , **2004**, 24.
50. Kumar N.; Goel N., Phenolic acids: Natural versatile molecules with promising therapeutic applications, *Biotechnology Reports*, **2019**, 24.
51. Kumar, A.; Sreedharan, S.; Kashyap, A. K.; Singh, P.; Ramchiary, N., A review on bioactive phytochemicals, ethnomedicinal and pharmacological importance of Purslane (Portulaca oleracea L.), *Resarch Square*, **2021**, 2-5.
52. Kumar, A.; Sreedharan, S.; Kashyap, A. K.; Singh, P.; Ramchiary, N., A review on bioactive phytochemicals and ethnopharmacological potential of purslane (Portulaca oleracea L.), *Heliyon,* **2022**, 8(1), 5-12.
53. Kurek, J., 2019, Introductory Chapter: Alkaloids - Their Importance in Nature and for Human Life. Alkaloids - *Their Importance in Nature and Human Life*, 1-3.
54. Lalromawii.; Subhalakshmı Devi, A.; Dahamaraj Meetei, U.; Baharati Devi, R.K., Evaluation of Portulaca oleracea Linn. for hypoglycaemic effects, *International Journal of Pharmaceutical*, **2014**, 5(5), 1908–1913.
55. Lásztity, R.; Hidvégi, M.; Bata, Á.; Saponins in food, *Food Reviews International*, **1998**, 14(4), 371–390.
56. Lim, Y.; Quah, E. P., Antioxidant properties of different cultivars of Portulaca oleracea, *Food chemistry*, **2007**,103(3), 734-740.
57. Liu, L.; Howe, P.; Zhou, Y. F.; Xu, Z. Q.; Hocart, C.; Zhang, R., Fatty acids and β-carotene in Australian purslane (Portulaca oleracea) varieties, *Journal of Chromatography A*, **2000**, 893(1), 207–213.
58. Liu, L.; Howe, P.; Zhou, Y. F.; Xu, Z. Q.; Hocart, C.; Zhang, R, Fatty acids and b-carotene in Australian purslane (Portulaca oleracea) varieties, *Journal of Chromatograph*, **2000**, 893, 207-208.
59. Masyita, A.; Sari, R. M.; Astuti, A. D.; Yasir, B.; Rumata, N. R.; Emran, T. B.; Simal-Gandara, J., Terpenes and terpenoids as main bioactive compounds of essential oils, their roles in human health and potential application as natural food preservatives, *Food Chemistry: X*, **2022**, 13, 100217.
60. Matthews, J. F.; Ketron, D. W.; Zane, S. F., The biology and taxonomy of the Portulaca oleracea L. (Portulacaceae) complex in North America, *Rhodora*, **1993**, 95(882), 166- 183.
61. Mattila, P.; Hellström, J.; Törrönen, R., Phenolic acids in berries, fruits, and beverages, *J. of Agricultural and Food Chemistry*, **2006,** 54(19),7193 -99.
62. Meléndez-Martínez, A. J.; Mandić, A. I.; Bantis, F.; Böhm, V.; Borge, G. I. A.; Brnčić, M.; O'Brien, N.; A comprehensive review on carotenoids in foods and feeds: Status quo, applications, patents, and research needs, *Critical Reviews in Food Science and Nutrition*, **2021**,1–51.

63. Meléndez-Martínez, A. J.; Böhm, V.; Borge, G. I. A.; Cano, M. P.; Fikselová, M., Gruskiene, R.; O'Brien, N. M., Carotenoids: Considerations for Their Use in Functional Foods, Nutraceuticals, Nutricosmetics, Supplements, Botanicals, and Novel Foods in the Context of Sustainability, Circular Economy, and Climate Change, *Annual Review of Food Science and Technology*, **2021**,12, 433–460.
64. Meng, Y.; Ying, Z.; Xiang, Z.; Hao, D.; Zhang, W.; Zheng, Y.,; Ying, X., The anti-inflammation and pharmacokinetics of a novel alkaloid from Portulaca oleracea L, *Journal of Pharmacy and Pharmacology*, **2016**, 68(3), 397-405.
65. Metodiewa, D.; Kochman, A.; Karolczak, S., Evidence for antiradical and antioxidant properties of four biologically active N, N, diethylaminoethyl ethers of flavanone oximes: a comparison with natural polyphenolic flavonoid (rutin) action, *Biochemistry and Molecular Biology International*, **1997**, 41, 1067–1075.
66. Middleton, EJ.,. "Effect of plant flavonoids on immune and inflammatory cell function," *Advances in Experimental Medicine and Biology*, **1998,** 439,175–182.
67. Mir, S.; Ali, M.; Taraxerane-type triterpenoids from Portulaca oleracea Linn. seeds, *Indian Journal of Chemistry*, **2016**, 55B, 119-122.
68. Mohamed A. I.; Hussein A. S., Chemical composition of purslane (Portulaca oleracea), *Plant Foods for Human Nutrition*, **1994**, 45(1), 1–9.
69. Mohamed AI.; Hussein AS., Chemical composition of purslane (Portulaca oleracea), *Plant foods for human nutrition*, **1994**, 1-2.
70. Nayaka, H. B.; Londonkar, R. L.; Umesh, M. K.; Tukappa, A., Antibacterial attributes of apigenin, isolated from Portulaca oleracea L, *International journal of bacteriology*, **2014**.
71. Neilson, A. P.; Goodrich, K. M.; Ferruzzi, M. G., Bioavailability and metabolism of bioactive compounds from foods, *Nutrition in the Prevention and Treatment of Disease*, **2017**, 407-423.
72. Nemzer, B.; Al-Taher, F.; Abshiru, N., Phytochemical composition and nutritional value of different plant parts in two cultivated and wild Purslane genotypes, *Food Chemistry*, **2020**, 320.
73. Nyffeler, R.; Eggli, U., Disintegrating Portulacaceae: a new familial classification of the suborder Portulacineae (Caryophyllales) based on molecular and morphological data. *Taxon*, **2010**, 59(1), 227-229.
74. Oh, K. B.; Chang, I. M.; Hwang, K. J.; Mar, W.; Detection of antifungal activity in Portulaca oleracea by a single-cell bioassay system, *Phytotherapy Research*, **2000** 14(5), 329-332.
75. Okafor, I.A.; Ayalokunrin, M.B.; Orachu, L.A., A review on Portulaca oleracea (Purslane) plant nature and biomedical benets, *International Journal of Biomedical Imaging*, **2014**, 5, 75.
76. Oldfield, E.; Lin, F.Y., Terpene Biosynthesis: Modularity Rules, *Angewandte Chemie International Edition*, **2011**, 51(5), 1124–1137.
77. Omara-Alwala, T. R.; Mebrahtu, T.; Prior, D. E.; Ezekwe, M. O., Omega-three fatty acids in purslane (Portulaca oleracea) tissues. *Journal of the American Oil Chemists' Society*, **1991**, 68(3), 198-199.
78. Palaniswamy, U. R.; McAvoy, R. J.; Bible, B. B., Stage of harvest and polyunsaturated essential fatty acid concentrations in purslane (Portulaca oleraceae) leaves, *Journal of Agricultural and Food Chemistry*, **2001**, 49(7), 3490-3493.
79. Palaniswamy U.; Benard, B.; Mcavoy, R., Effect of nitrate: ammonium nitrogen ratio on oxalate levels of purslane. *Trends in New Crops and New Uses*, **2002**, 11(5), 453–455.
80. Parvathy, K. S.; Negi, P. S.; Srinivas, P., Antioxidant, antimutagenic and antibacterial activities of curcumin-β-diglucoside, *Food Chemistry*, **2009**,115(1), 265-271.
81. Pereira, D. M.; Valentão, P.; Pereira, J. A.; Andrade, P. B., Phenolics: From chemistry to biology, *Molecules*, **2009**, 14(6), 2202-2211.
82. Perez-Vizcaino F.; Duarte J., Flavonols and cardiovascular disease, *Molecular Aspects of Medicine*, **2010**, 31(6), 478–94.
83. Petropoulos, S.; Karkanis, A.; Martins, N.; Ferreira, I. C., Phytochemical composition and bioactive compounds of common purslane (Portulaca oleracea L.) as affected by crop management practices, *Trends in Food Science & Technology*, **2016**, 55, 1-10.
84. Podolak, I.; Galanty, A.; Sobolewska, D., Saponins as cytotoxic agents: a review, *Phytochemistry Reviews*, **2010**, 9(3), 425-474.
85. Pereira, C.; Barros, L.; Carvalho, A. M.; Ferreira, I. C., Nutritional composition and bioactive properties of commonly consumed wild greens: Potential sources for new trends in modern diets, *Food Research International*, **2011**, 44(9), 2634-2640.
86. Rao, A. V.; Rao, L. G., Carotenoids and human health, *Pharmacological research*, **2007**, 55(3), 207-216.
87. Roozi, H.; Bojar, M. A.; Eidi, V.; Ali, K. N. R., Effects of oleracein E and oleracein L from portulaca oleracea on cell survival, antioxidant and antidiabetic efficacy on beta-TC-6 pancreatic cell line, *Indian Journal of Pharmaceutical Sciences*, **2019**, 81(4), 681-689.
88. Su, Q.; Rowley, K. G.; Itsiopoulos, C.; O'Dea, K., Identification and quantitation of major carotenoids in selected components of the Mediterranean diet: green leafy vegetables, figs and olive oil, *European Journal of Clinical Nutrition*, **2002**,56(11), 1149-1154.
89. Sahu, N. P.; Banerjee, S.; Mondal, N. B.; Mandal, D., Steroidal saponins. In: Fortschritte der Chemie Organischer Naturstoffe/progress in the chemistry of organic natural products, fortschritte der chemie organischer naturstoffe/progress in the chemistry of organic natural products, *Springer*, **2008**, 89, 45-141.
90. San Martı´n R.; Briones R., Industrial uses and sustainable supply of Quillaja saponaria (Rosaceae) saponins, *Society for Economic Botany*, **1999**, 53, 302–311.

91. Shi, J.; Arunasalam, K.; Yeung, D.; Kakuda, Y.; Mittal, G.; Jiang, Y., Saponins from Edible Legumes: Chemistry, *Processing, and Health Benefits. Journal of Medicinal Food*, **2004**, 7(1), 67–78.
92. Sicari, V.; Loizzo, M. R.; Tundis, R.; Mincione, A.; Pellicano, T. M., Portulaca oleracea L.(Purslane) extracts display antioxidant and hypoglycaemic effects, *Journal of Applied Botany and Food Quality*, **2018**, 91(1), 39-46.
93. Simopoulos A., , Omega-3 fatty acids in health and disease and in growth and development. *The American Journal of Clinical Nutrition*, **1991,** 54, 438-463.
94. Simopoulos, A.; Norman, H.A.; Gillaspy, J.E., Purslane in human nutrition and its potential for world agriculture, *World Review of Nutrition and Dietetics* , **1995**, 77, 47–74.
95. Simopoulos, A., Omega-3 fatty acids and antioxidants in edible wild plants. *Biological Research*, **2004,** 37(2), 263-277.
96. Simopoulos, A.; Xian-Tan, D.; Manchester, L.C.; Reiter, R., Purslane: a plant source of omega-3 fatty acids and melatonin, *Journal of Pineal Research*, **2005**, 39(3), 331-332.
97. Siriamornpun, S.; Suttajit, M., Microchemical components and antioxidant activity of different morphological parts of Thai wild purslane (Portulaca oleracea), *Weed Science*, **2010**, 58(3), 182-188.
98. Sparg, S.G.; Light, M.E., Biological activities and distribution of plant saponins, *Journal of Ethnopharmacology*, **2004**, 94, 219–243.
99. Srivastava, R.; Srivastava, V.; Singh, A., Multipurpose Benefits of an Underexplored Species Purslane (Portulaca oleracea L.): A Critical Review, *Environmental Management, **2021***, 1-3.
100. Stahl, W.; Sies, H., Bioactivity and protective effects of natural carotenoids, *Biochimica et Biophysica Acta*, **2005**, 1740(2), 101–107.
101. Stalikas C. D., Extraction, separation, and detection methods for phenolic acids and flavonoids, *Journal of Separation Science*, **2007**, 30(18), 3268-3295.
102. Steinmaus, S. J.; Prather, T. S.; Holt, J. S., Estimation of base temperatures for nine weed species, *Journal of Experimental Botany*, **2000**, 51(343):275-286.
103. Stevenson D.E.; Hurst R.D., Polyphenolic phytochemicals-just antioxidant or much more? *Cellular and Molecular Life Sciences*, **2007,** 64, 2900–2916.
104. Sultana A.; Rahman K., Portulaca oleracea: A global panacea with ethanomedical and pharmacological properties, *International Journal of Pharmacy and Pharmaceutical Sciences*, **2013**, 5(2), 33-9.
105. Tracey, K.J., The inflammatory reflex, *Nature*, **2002**, 420, 853–859.
106. Uddin, M. K.; Juraimi, A. S.; Anwar, F.; Hossain, M. A.; Alam, M. A., Effect of salinity on proximate mineral composition of purslane (P. oleracea L.), *Australian J. of crop science*, **2012**, 6(12), 1732-36.
107. Uddin, M.; Juraimi, A. S.; Hossain, M. S.; Nahar, M.; Un, A., Ali, M.; Rahman, M. M., Purslane weed (Portulaca oleracea): a prospective plant source of nutrition, omega-3 fatty acid, and antioxidant attributes, *The Scientific World Journal*, **2014**, 6.
108. USDA, 2012, National resources conservation service, plants database- plant profile.
109. Vincken, J. P.; Heng, L.; de Groot, A.; Gruppen, H., Saponins, classification and occurence in the plant kingdom, *Phytochemistry*, **2007**, 68, 275–297.
110. Dara, M. A.; Mohammed, A. W.; Bnar, M. I., Antimicrobial and antioxidant activities of extracts from medicinal plant ginger (Zingiber officinale) and identification of components by gas chromatography. *African Journal of Plant Science*, **2015**, 9(10):412–420.
111. Xiu, F.; Ying, Z., Ying, X.; Yang, G., Pharmacokinetic studies of soyalkaloid A from Portulaca oleracea L. using ultra high-performance liquid chromatography electrospray ionization quadrupole–time of flight mass spectrometry and its antioxidant activity, *Biomedical Chromatography*, **2019**, 33(2).
112. Xu, X., Yu, L.; Chen, G.; Determination of flavonoids in Portulaca oleracea L. by capillary electrophoresis with electrochemical detection, *Journal of Pharmaceutical and Biomedical Analysis*, **2006**, 41(2), 493-499.
113. Yang, Z.; Liu, C.; Xiang, L.; Zheng, Y., Phenolic alkaloids as a new class of antioxidants in Portulaca oleracea. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, **2009**, 23(7), 1032-1035.
114. Yue, M. E.; Jiang, T. F.; Shi, Y. P., Simultaneous determination of noradrenaline and dopamine inPortulaca oleraceaL. by capillary zone electrophoresis, *Journal of Separation Science*, **2005**, 28(4), 360–364.
115. Zaman, S.; Bilal, M.; Du, H.; Che, S., Morphophysiological and comparative metabolic profiling of purslane genotypes (Portulaca oleracea L.) under salt stress, *BioMed research international*, **2020**.
116. Zhao, R.; Gao, X.; Cai, Y.,; Shao, X.; Jia, G.; Huang, Y.; Zheng, X., Antitumor activity of Portulaca oleracea L. polysaccharides against cervical carcinoma in vitro and in vivo, *Carbohydrate Polymers*, **2013**, 96(2), 376–383.
117. Zhou, Y. X.; Xin, H. L.; Rahman, K.; Wang, S. J.; Peng, C.; Zhang, H., Portulaca oleracea L.: a review of phytochemistry and pharmacological effects, *BioMed research international*, **2015**.
118. Zhu, H.; Wang, Y.; Liu, Y.; Xia, Y.; Tang, T., Analysis of flavonoids in Portulaca oleracea L. by UV-vis spectrophotometry with comparative study on different extraction technologies, *Food Analytical Methods*, **2010,** 3(2), 90–97.
119. Zimmerman C., The causes and characteristics of weediness in Portulaca oleracea L. Ph. D. Thesis, University of Michigan, **1970**, 22-23.
120. Zimmerman A., Growth characteristics of weediness in Portulaca oleracea L. *Ecology*, **1976**, 57, 964-974.