Food and Chemical Toxicology 114 (2018) 155–169

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Review

Halophytic herbs of the Mediterranean basin: An alternative approach to health

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ARTICLE INFO

Keywords:
Bioactive compounds
Halophytes
Health effects
Native herbs
Salinity
Secondary metabolites

ABSTRACT

Wild native species are usually grown under severe and stressful conditions, while a special category includes halophytic species that are tolerant to high salinity levels. Native halophytes are valuable sources of bioactive molecules whose content is higher in saline than normal conditions, since the adaptation to salinity mechanisms involve apart from changes in physiological functions the biosynthesis of protectant molecules. These compounds include secondary metabolites with several beneficial health effects which have been known since ancient times and used for medicinal purposes. Recent trends in pharmaceutical industry suggest the use of natural compounds as alternative to synthetic ones, with native herbs being strong candidates for this purpose due to their increased and variable content in health promoting compounds. In this review, an introductory section about the importance of native herbs and halophyte species for traditional and modern medicine will be presented. A list of the most important halophytes of the Mediterranean basin will follow, with special focus on their chemical composition and their reported by clinical and ethnopharmacological studies health effects. The review concludes by suggesting future requirements and perspectives for further exploitation of these valuable species within the context of sustainability and climate change.

1. Introduction

The Mediterranean basin is abundant with native plants that have adapted to various unfavorable conditions such as high salinity, especially when considering the extensive coastline and the great number of islands. The adaptation of halophytic species to high salinity levels includes both morphological and physiological acclimatization features, while of special importance are the various defense mechanisms that plants have developed which involve the enhanced biosynthesis of primary and secondary metabolites (Ksouri et al., 2008). Halophytes have been traditionally used for food and medicinal purposes throughout the centuries, while nowadays there is a great research interest for their health promoting effects. Considering the recent trends in pharmaceutical industry for new natural compounds and the consumers' concerns about consumption of synthetic compounds and the health effects that these might have, there is an imperative need for using native herbs not only as food but also for medicinal formulations and therapeutic purposes.

The application of native cultivated and non-cultivated species in traditional and folk medicine used to be very common in developing countries for people who do not have access to conventional drugs and modern medicine, while nowadays it is a common place in both developing and developed countries for the treatment of mild illnesses such as coughs, stomach aches, headaches, fatigue etc. and the overall well-being. However, there is the misconception that all natural remedies and food supplements are safe and people seem to ignore safety issues regarding toxic effects of specific species due to antinutrients content, the recommended daily intake of specific compounds as well counter effects and interactions with conventional drugs or other bioactive compounds that have not been studied under long-term clinical studies (Kristanc and Kreft, 2016). Moreover, bioactive compounds content of wild species is affected by several factors such as genotype, growing conditions, harvest time and growth stage among others that make general recommendations for safe consumption and daily intakes very complex and controversial (Mukherjee et al., 2011). Sánchez-Mata et al. (2012) have also demonstrated the great diversity in chemical composition among the species as well the various ecotypes of native species of the Mediterranean basin due to the variety of climate and soil conditions and terrain morphology.

Due to these concerns and the great surge and consumers' demand

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https://doi.org/10.1016/j.fct.2018.02.031
Received 5 January 2018; Received in revised form 13 February 2018; Accepted 14 February 2018
Available online 15 February 2018
0278-6915/

for these botanical medicines, there has been an inducement for many research studies where the *in vitro* and *in vivo* health effects and therapeutic properties against various chronic diseases have been evaluated (Simopoulos, 2008, 2004; Trichopoulou et al., 2000; Vardavas et al., 2006). Moreover, many ethnopharmacological and ethnobotanical studies validate properties and uses of medicinal herbs that have been described since the ancient times by the scholars and are being imparted from generation to generation (González-Tejero et al., 2008; Ksouri et al., 2012; Pieroni, 2017).

Considering the surge for natural products and remedies of herbal origin, the aim of this review was to record and briefly describe the most important halophytic herbs of the Mediterranean basin with well-known uses for medicinal and therapeutic purpose in traditional and folk medicine. Moreover focus will be given on their chemical composition and health effects with special interest in toxic effects and anti-nutrients compounds content. The most recent clinical and ethno-pharmacological studies that confirm the so far alleged health promoting effects will be also highlighted, while the involved mechanisms for these therapeutic effects will be described. The review concludes by suggesting future requirements and perspectives for further exploitation of these valuable species within the context of sustainability and halophyte agriculture under climate change conditions as well as bioconservation of wild medicinal halophytes.

2. Medicinal halophytes

In the following section the most common halophytes of the Mediterranean basin will be presented focusing on their medicinal uses. The reported species have multiple medicinal uses and therapeutic properties with various plant parts being used, as presented in Table 1. Moreover, in Tables 2 and 3 the phenolic compounds content and the confirmed bioactive properties for each species are presented, respectively.

2.1. *Asplenium ceterach* L.

2.1.1. Botanical aspects

Scale fern [*Asplenium ceterach* L. (syn. *Ceterach officinarum* Willd)] is a perennial rhizomatous herb that belongs to Aspleniaceae family (Durdević et al., 2007; Van Den Heede et al., 2004). Apart from its roots, the rest of the plant is used for medicinal purposes in several Mediterranean countries (González-Tejero et al., 2008; Pieroni et al., 2004), while according to Bogdanović et al. (2011) plants grown in half-strength MS media are able to tolerate 50 and 100 mM of NaCl. In order to adapt to saline conditions plants increased the synthesis of phenolic compounds which serve as protectants against oxidative stress (Bogdanović et al., 2011).

2.1.2. Chemical composition

Scale fern presents a wide variety of chemical constituents, among them volatile organic compounds, such as lipid derivatives (77.4%): nonanal, (E)-2-nonenal, (E)-2-heptenal, 1-octen-3-ol, tetradecanoic acid, hexahydrofarnesylacetone, (E)-2-tridecenoic acid); shikimic compounds (21.3%): 3,4-dihydroxybenzaldehyde, 3-methoxy-4-hydroxybenzoic acid, 4-hydroxybenzoic acid, benzoic acid, 2-amino-4-methoxyphenol; carotenoid derivatives (0.8%): 4-hydroxy-β-ionone, 3-hydroxy-5,6-epoxy-β-ionone (Froissard et al., 2015). Phenolic compounds, both flavonoids and phenolic acids are also present, but in lesser amounts, being chlorogenic and caffeic acids the most abundant ones. Kashyap et al. (2017) reported that *A. ceterach* is a good source of kaempferol derivatives, namely Kaempferol 3-(6-malonyl)-D-glucoside and Kaempferol 3-(6-malonyl)-D-galactoside, which are highly regarded as anticancer molecules. Moreover, according to Durdević et al. (2007) free and bound phenolics in leaves (11744.00 $\mu g\ g^{-1}$ and of 9135.00 $\mu g\ g^{-1}$, for free and bound phenolics, respectively) and rhizomes (2811.11 $\mu g\ g^{-1}$ and of 1962.74 $\mu g\ g^{-1}$, for free and bound

Table 1
Common salt-tolerant medicinal herbs of the Mediterranean basin.

Common name	Scientific name	Family	Plant part used	Uses[a]	References
Mediterranean saltbush	*Atriplex halimus* L.	Amaranthaceae	Aerial parts	F, M	El-Aasr et al. (2016); Kabbash and Shoeib (2012); Walker et al. (2014)
Scale fern	*Asplenium ceterach* L.	Aspleniaceae	Aerial parts	M	Berk et al. (2011); Guarrera et al. (2008); Pieroni et al. (2004)
European searocket	*Cakile maritima* Scop.	Brassicaceae	Leaves	M, I	Davy et al. (2006); Ksouri et al. (2008); Meot-Duros et al. (2008); Zarrouk et al. (2003)
Montpellier cistus	*Cistus monspeliensis* L.	Cistaceae	Aerial parts	M	Attaguile et al. (2000); Jemia et al. (2013); Shimoda et al. (2012); Sayah et al. (2017)
Centauries	*Centaurium* spp.	Gentianaceae	Aerial parts and roots	M	Hamza et al. (2011); Hanlidou et al. (2004); Šiler et al. (2014)
Spiny rush	*Juncus acutus* L.	Juncaceae	Rhizomes	M	Awwad (2006); Behery et al. (2013); Och et al. (2017); Rodrigues et al. (2014)
Yellow hornpoppy	*Glaucium flavum* Crantz.	Papaveraceae	Aerial parts and roots	M	Arafa et al. (2016), Bournine et al. (2013); Hadjiakhoondi et al. (2013);
Sea lavender	*Limonium sinuatum* (L.) Mill.	Plumbaginaceae	Flowers	M	Li et al. (2014); Xu et al. (2017)
Common reed	*Phragmites australis* (Cav.) Trin. ex Steud.)	Poaceae	Rhizomes	E, M	Kiviat and Hamilton (2001); Palombo and Semple (2001); Zhu et al. (2017)
Bermudagrass	*Cynodon dactylon* (L.) Pers.		Rhizomes	M, F	Passalacqua et al. (2007); Rai et al. (2010); Tuttolomondo et al. (2014)
Sea health	*Frankenia laevis* L.	Frankeniaceae	Aerial parts	M	Jdey et al. (2017); Mahjoub et al. (2010); Saïdana et al. (2010)
French tamarisk	*Tamarix gallica* L.	Tamaricaceae	Shoots, leaves and flowers	M	Bettaib et al. (2017); Boulaaba et al. (2013); Jdey et al. (2017); Ksouri et al. (2009)
Narrowleaf cattail	*Typha angustifolia* L.	Thyphaceae	Rhizomes and Leaves	E, M	Fruet et al. (2012); Londonkar et al. (2013); Varghese et al. (2009)
–	*Zygophyllum album* L.		Leaves and flowers	M	Kchaou et al. (2016); Mnafgui et al. (2014)

[a] E: edible; F: fodder; I: Industrial; M: medicinal.

Table 2
Total phenolics content[b] of various salt tolerant medicinal plants native in the Mediterranean region.

Scientific name	Plant parts	Total Phenolics[a] (mg GAE/g extract)	References
Asplenium ceterach L.	Leaves	11.74	Durdević et al. (2007)
	Rhizomes	2.81	
Atriplex halimus L.	Leaves	10.12	Benhammou et al. (2009)
	Stems	3.77	
Cakile maritima Scop.	Leaves	22.24	Meot-Duros et al. (2008)
		31.58–66.93	Ksouri et al. (2007)
Cynodon dactylon (L.) Pers.	Rhizomes	39.82	Soraya et al. (2015)
Frankenia laevis L.	Leaves	253	Lopes et al. (2016)
Juncus acutus L.	–	17–93	Rodrigues et al. (2014)
Limonium sinuatum (L.) Mill.	Flowers	34.17	Li et al. (2014)
Tamarix gallica L.	Leaves	3.91	Ksouri et al. (2009)
	Flowers	12.33	Ksouri et al. (2009)
Zygophyllum album L.	Leaves	78.0–403.4	Kchaou et al. (2016)

[a] Total phenolic content is expressed as gallic acid (GAE) equivalents (mg gallic acid g^{-1} dry weight (DW)).
[b] Total phenolic compounds as determined by LC-DAD-ESI/MS.

phenolics, respectively) of *A. ceterach* were significantly higher than other species of the genus. Also interesting to highlight is that a pronounced decrease in phenolic compounds content is observed during dehydration process due to increased activity of peroxidase (POD) and polyphenol oxidase (PPO) enzymes (Živković et al., 2010).

2.1.3. Health effects

Asplenium ceterach presents a very interesting antioxidant potential, namely acting as free radicals scavenger, reducing and chelating agent, and even DNA damage protector (Berk et al., 2011), while González-Tejero et al. (2008) reported its use for the treatment of disorders related to the respiratory system and intestinal. It also exhibits significant antimicrobial effects, namely against the most common Gram-positive microorganisms, among them *Shigella dysenteri*ae and *Staphylococcus aureus* species (Berk et al., 2011). Besides to these effects, very important demulcent, expectorant, laxative, diuretic, anticatarrhal, anthelmintic and even emmenagogue properties have been reported, being mostly of these effects directly attributed to its high content in phenolic compounds (Berk et al., 2011; Froissard et al., 2015; Guarrera et al., 2008; Pieroni, 2017), while ethnopharmacological studies have suggested the use of decoctions against menstrual pains, hypertension, joint aches, malaria, renal colics and kidney stone formation (Maria et al., 2005; Passalacqua et al., 2007).

Despite of the species belonging to the group of ferns which may exhibit toxic effects, no toxicity has been reported for *Asplenium caterach* L. so far.

2.2. Atriplex halimus L.

2.2.1. Botanical aspects

Also known as Mediterranean saltbush, *Atriplex halimus* L. is a euhalophyte native in the broad Mediterranean region usually used as a fodder or for medicinal purposes (Walker et al., 2014). According to Boughalleb et al. (2009) and Bendaly et al. (2016), low to moderate salinity had a stimulating effect on plant growth mainly due to promoting root and stem growth, while the salt tolerance could be attributed to compartmentalization of high amounts of Na^+, the

Table 3
Biological activity of the selected medicinal halophytes and their main bioactive compounds.

Scientific name	Biological activity	Bioactive compounds	References
Asplenium ceterach L.	Antioxidant; Antimicrobial; Demulcent; Expectorant; Laxative; Emmenagogue; Anticancer	Kaempferol 3-(6-malonyl)-D-glucoside; Kaempferol 3-(6-malonyl)-D-galactoside; Chlorogenic acid; Caffeic acid	Berk et al. (2011); Froissard et al. (2015); Guarrera et al. (2008); Passalacqua et al. (2007); Pieroni (2017)
Atriplex halimus L.	Antioxidant; Anti-leishmanial; Anti-multidrug resistance; Cytotoxic; Antimicrobial; Immunomodulatory; Anticancer	Syringetin derivatives; Atriplexoside A; Atriplexoside B;	El-Aasr et al. (2016); Kabbash and Shoeib (2012); Walker et al. (2014)
Cakile maritima Scop.	Antioxidant; Antibacterial; Antiscorbutic; Diuretic; Digestive; Molluscicidal	Glucosinolates; Isothiocyanates	Davy et al. (2006); Ksouri et al. (2012); Meot-Duros et al. (2008); Radwan et al. (2008)
Centaurium spp.	Antioxidant, Antidiabetic, Antiflatulent, Antipyretic, Antibacterial, Antifungal, Diuretic, Digestive	Secoiridoid glycosides; Xanthones	Đorđević et al. (2017); González-Tejero et al. (2008); Pieroni et al. (2004); Šiler et al. (2014); Valentão et al. (2002)
Cistus monspeliensis L.	Antioxidant, Anti-inflammatory, Antibacterial, Antiproliferative, Cytotoxic	Terpenes; Carvacrol; Eugenol; Apigenin diglucoside; Phenolic acid derivatives	Barrajón-Catalán et al. (2011); Jemia et al. (2013); Loizzo et al. (2013); Papaefthimiou et al. (2014)
Cynodon dactylon L.	Anti-inflammatory, Diuretic, Antiemetic, Antidiabetic, Angiogenic, Wound healing, Antibacterial	Flavonoids; Carotenoids; Phytostilbenes	Marasini et al. (2015); Rai et al. (2010); Soraya et al. (2015); Tuttolomondo et al. (2014);
Frankenia laevis L.	Antioxidant, Anti-tyrosinase, Antimicrobial	Chlorogenic acid; Catechin; Volatile compounds	Hussein (2004a,b); Jdey et al. (2017); Mahjoub et al. (2010)
Glaucium flavum Crantz.	Anti-inflammatory, Analgesic, Antibacterial, Antifungal, Anticancer, Cytotoxic	Alkaloids	Arafa et al. (2016); Bournine et al. (2013); Hadjiakhoondi et al. (2013); Och et al. (2017)
Juncus acutus L.	Antioxidant, Anti-acetylcholinesterase, Cytotoxic	Phenanthrenoids; Coumarines; Carotenoids; Juncunol	Awwad (2006); Behery et al. (2013); Rodrigues et al. (2017)
Limonium sinuatum (L.) Mill.	Antioxidant	Phenolic acids; Flavonoids	Li et al. (2014); Xu et al. (2017)
Phragmites australis (Cav.) Trin. ex Steud.	Antioxidant, Anti-melanogensis, Hepatoprotective	Phenolic compounds	Chen et al. (2013); Kiviat and Hamilton (2001); Sim et al. (2017); Zhu et al. (2017)
Tamarix gallica L.	Antioxidant, Anticancer, Anti-inflammatory, Hepatotonic, Antimicrobial, Stimulant, Anti-diarrheic; Antihyperlipidemic	Phenolic acids; Flavonoids; Coumarins; Tannins	Boulaaba et al. (2015); Hmidene et al. (2017); Ksouri et al. (2009); Lefahal et al. (2017); Tomas-Barberán et al. (1990)
Typha spp.	Antioxidant, Antibacterial, Immunosuppressive; Thrombolytic	Flavonoids; Cerebrosides; Non-structural carbohydrates	Fruet et al. (2012); Londoņkar et al. (2013); Qin and Sun (2005); Varghese et al. (2009)
Zyghophyllum album L.	Antioxidant, Antidiabetic, Antibacterial, Anticancer, Anti-inflammatory, Anti-acetylcholinesterase	Flavonoids; Volatile compounds	(Kchaou et al., 2016); Ksouri et al. (2013); Mnafgui et al. (2014)

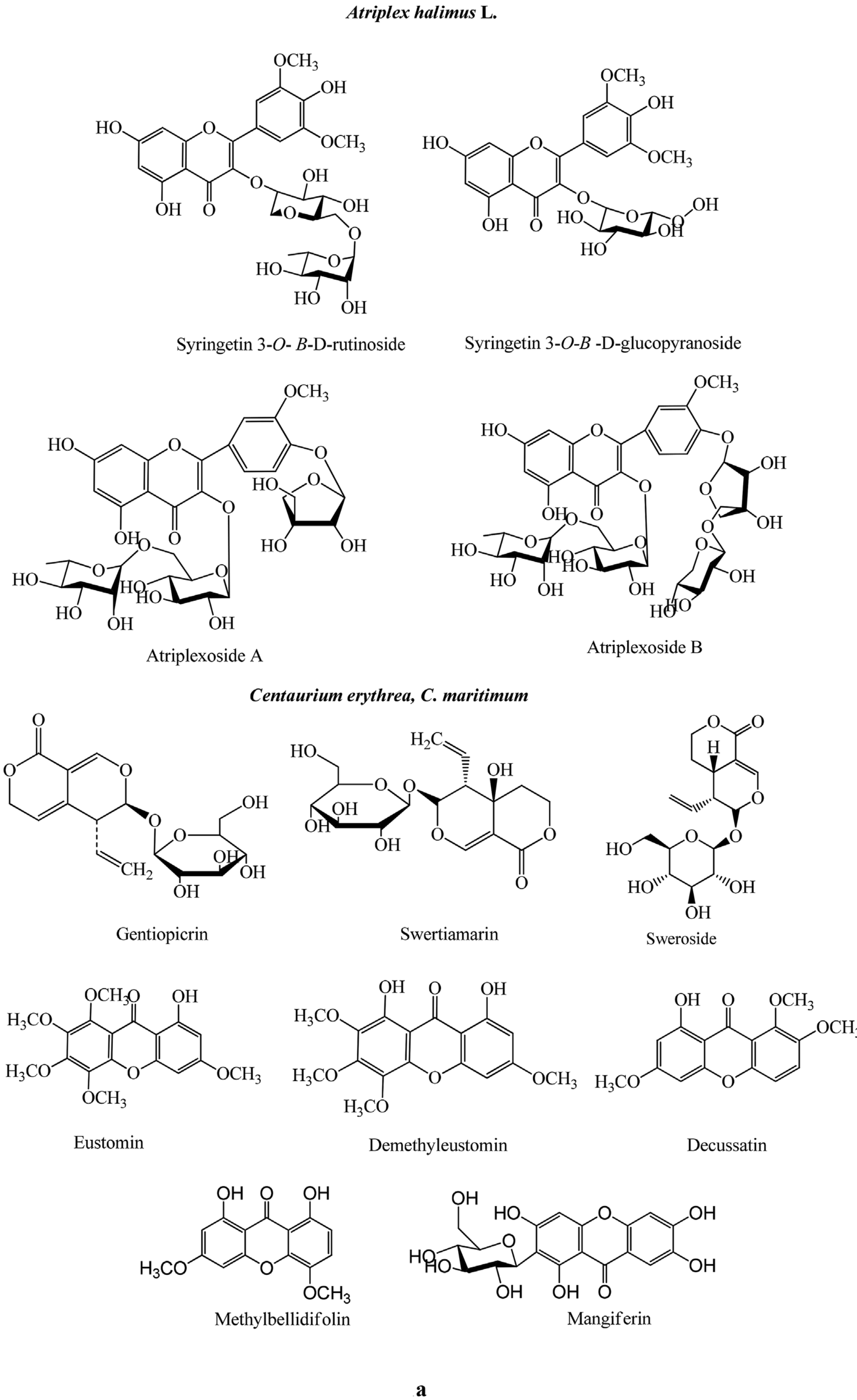
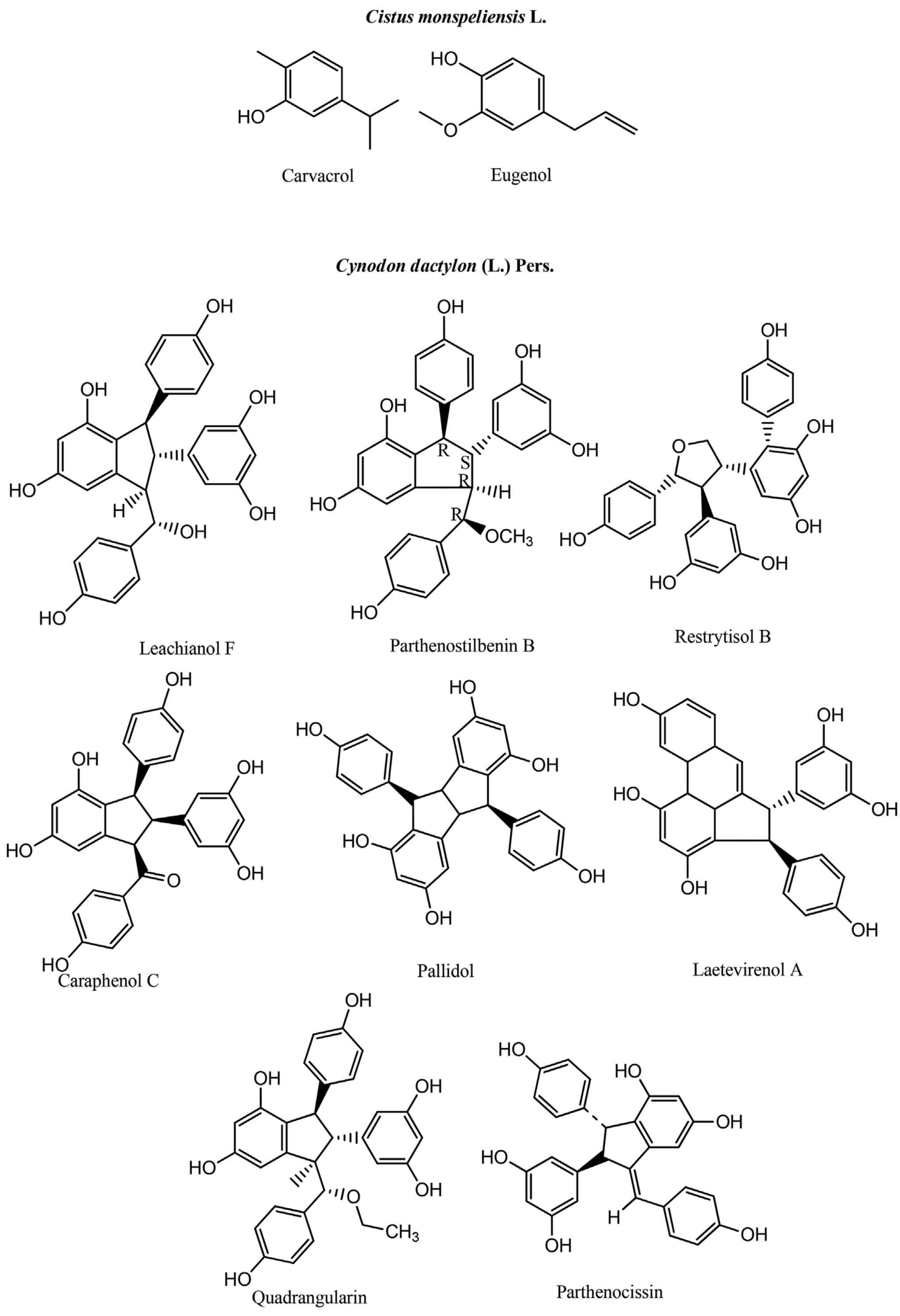


Fig. 1. a: Main compounds found in *Atriplex halimus* and in Centaurium species. b: Main compounds found in *Cistus monspeliensis* L. *and* in *Cynodon dactylon* (L.) Pers. c: Main compounds found in *Glaucium flavum* Crantz., *Juncus acutus* L. and in Typha spp.

succulent nature of leaves, as well as to high photosynthetic capacity and high content in photosynthetic pigments (Bendaly et al., 2016). However, according to the latter study (Bendaly et al., 2016), the decreased plant growth under high salinity levels may be due to high energy consumption for the biosynthesis of proline, glycinebetaine and sucrose for osmoregulatory purposes, while Panta et al. (2014) noted



b

Fig. 1. (*continued*)

that annual biomass production amounts to 14 ton ha^{-1} in plants irrigated with saline water (20 $dS\,m^{-1}$).

2.2.2. Chemical composition

Mediterranean saltbush (*Atriplex halimus* L.) shows a very interesting and varied chemical composition; it is a rich source of phenolic compounds, such as various flavonol glycosides, namely syringetin 3-*O*-β-D-rutinoside, syringetin 3-*O*-β-D-glucopyranoside and isorhamnetin 3-*O*-β-D-rutinoside (narcissin) which have been isolated from a 60% methanolic fraction, as well as atriplexoside A (3′-*O*-methylquercetin-4′-*O*-β-D-apiofuranoside-3-*O*-(6″-*O*-α-L-rhamnopyranosyl-β-D-glucopyranoside) which has been detected in a 20% methanolic fraction of the aerial plant parts (El-Aasr et al., 2016) (Fig. 1a). Another two important phenolic compounds, namely two flavonol glycosides, designated as atriplexoside A [3′-*O*-methylquercetin-4′-*O*-β-apiofuranoside-3-*O*-(6″-*O*-α-rhamnopyranosyl-β glucospyranoside)] and atriplexoside B [3′-*O*-

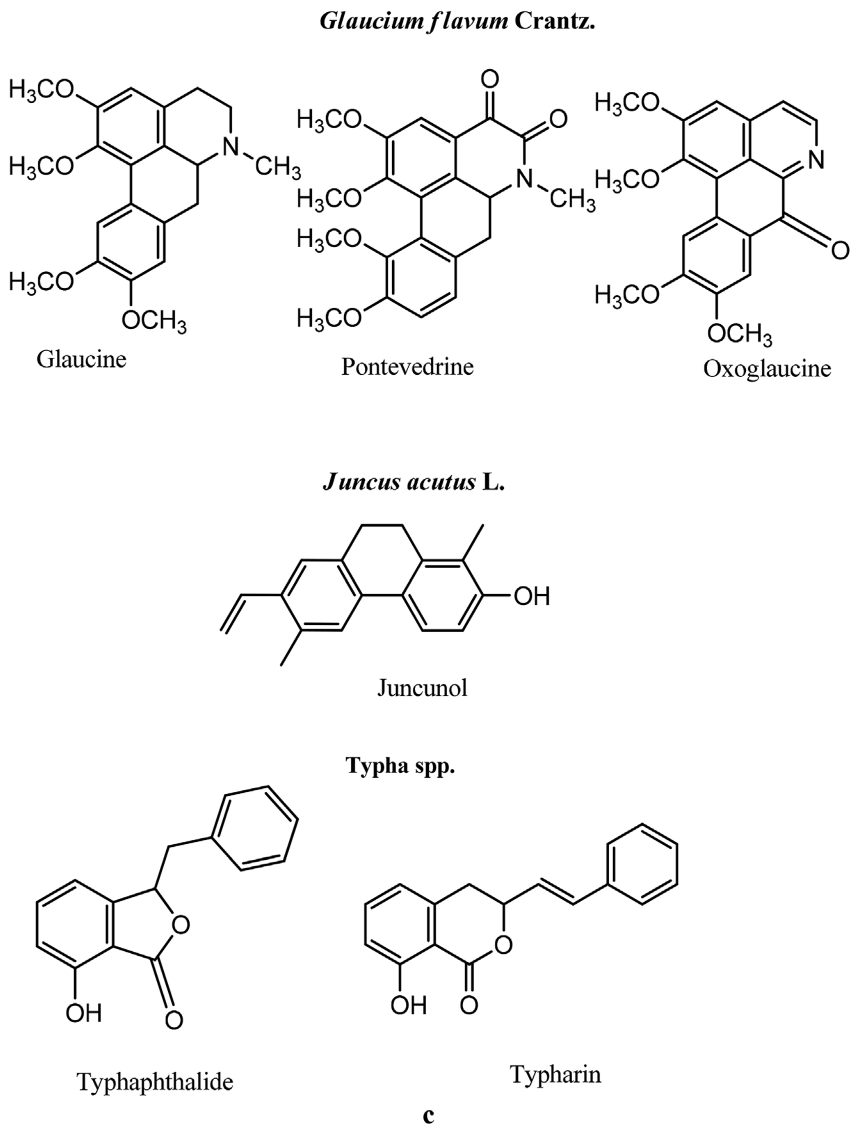


Fig. 1. (*continued*)

methylquercetin-4′-*O*-(5″-*O*-β-xylopyranosyl-β-apiofuranoside)-3-*O*-(6″-*O*-α-rhamnopyranosyl-β-glucopyranoside)] were also identified by Kabbash and Shoeib (2012), as also two phenolic glycosides, one ecdysteroid, one megastigmane and two methoxylated flavonoid glycosides. Tannin, alkaloid, saponin, lignin and fiber contents were relatively low, while proteins were detected in moderately high levels and were associated with high digestibility (Benhammou et al., 2009; Bouazza et al., 2012). Also interesting to point out is that the concentrations of bioactive constituents vary within the growing season, reaching high protein and low fiber levels during February to April and low protein and high fiber levels during August and October (El-Shatnawi and Mohawesh, 2000).

2.2.3. Health effects

Atriplex halimus exhibits interesting antioxidant effects, mainly by acting as a free radicals scavenger, while it has been reported to being able to reduce elevated blood glucose and hepatic levels in streptozotocin-induced diabetic rats (El-Aasr et al., 2016; Kabbash and Shoeib, 2012). Anti-leishmanial and anti-multidrug resistance activity were also observed, with these effects being directly attributed to its high content in phenolic compounds (Kabbash and Shoeib, 2012). The cytotoxic activity of the species has been also reported by El-Aasr et al. (2016) who observed a high selectivity against breast (MCF-7) and prostate (PC3) carcinoma cells. Interestingly, in a deepen study carried out by El-Aasr et al. (2016) the antimicrobial activity of the isolated compounds from *A. halimus* was assessed, where a broad spectrum of antibacterial activity against both Gram-negative (*E. coli* and *Acinetobacter baumanii*) and Gram-positive (*S. aureus, Streptococcus pyogenes* and *Enterococcus feacalis*), and even antifungal activity against *Candida* species was detected. The immunomodulatory effect of phenolic compounds was also carried out, and a pronounced reduction of the induced IL-6, IL-1β, TNF-α and COX-2 to normal levels was observed in LPS-inflammation models, which suggests their role as immunomodulators (El-Aasr et al., 2016). Other health effects of the species include the use of decoctions against rheumatism, heart diseases, diabetes (Pieroni, 2017; Walker et al., 2014).

No signs of toxicity have been reported for *Atriplex halimus* L. so far. However, considering that the species is a heavy metal hyper-accumulator, there should be great concerns regarding human toxicity from consumption of wild plants gathered in degraded soils due to heavy metal pollution (Mateos-Naranjo et al., 2013; Pérez-Esteban et al., 2013).

2.3. Cakile maritima Scop.

2.3.1. Botanical aspects

European searocket (*Cakile maritima* Scop., Brassicaceae) is a facultative halophyte distributed along the Mediterranean seashores (Megdiche et al., 2009). According to Megdiche et al. (2009) the salt tolerance of this species is based on the expression of a cystatin gene which is involved in plant development and defense against abiotic constraints, while Amor et al. (2006) reported that salt tolerance is associated with high antioxidative enzymes activities and the capacity to limit oxidative damage through increased antioxidant compounds content. One of the suggested protection mechanisms of *C. maritima* against salt stress is the increased endogenous level of compatible osmolytes such as proline which protect membrane stability (Megdiche et al., 2009), as well as the increased leaf thickness and succulence (Debez et al., 2006).

2.3.2. Chemical composition

Cakile genus contains 16 distinct glucosinolates which mainly consist of isopropylglucosinolate, allylglucosinolate and s-butylglucosinolate (Davy et al., 2006), while Iranshahi (2012) reported various isothiocyanates or mustard oils. Radwan et al. (2008) identified β-sitosterol and oleic and linoleic fatty acid methyl esters in the aerial part extracts, while the isolated four new glucosinolates for the species, namely glucotropaelin, 2- methyl butyle glucosinolates, ethyl glucosinolate and 4- pentyl glucosinolates. Moreover, *C. maritima* is very rich in phenolic choline esters, while flowering shoots contain flavonol glucosides and shoots phenolic compounds consist of benzoic and cinnamic phenolic acids (Davy et al., 2006). Seeds of *C. maritima* contain high amounts of oil (42% on a d.w. basis) which consist mostly of triacylglycerols, while the most abundant fatty acid was erucic acid (> 25%) which makes it unsuitable for human or animal consumption due to negative effects on cardiac muscles (Zarrouk et al., 2003). However, other uses of seed oil have been proposed such as the production of erucamide for industrial purposes, considering the high oil content of seeds, as well as for pharmaceutical purposes (Zarrouk et al., 2003). The leaves extracts of the species are also a valuable source of antioxidant compounds, while its potency depends on plant part and growth stage, as well as on environmental conditions (Ksouri et al., 2008).

2.3.3. Health effects

Sea rocket is attributed with diuretic, digestive, antiscorbutic and purgative properties, as well as with activities against jaundice, lympatic and nervous system disorders and lung viscid phlegm and scrofulous infections (Davy et al., 2006; Ksouri et al., 2012). Moreover, Meot-Duros et al. (2008) reported a strong antioxidant activity and inhibitory effects against *Pseudomonas marginalis, P. aeruginosa* and *Candida albicans*, while Radwan et al. (2008) noted significant molluscicidal activity.

No toxicity effects have been reported for *Cakile maritime* so far.

2.4. Centaurium erythrea L., C. maritimum Rafn.

2.4.1. Botanical aspects

Sea centaury (*Centaurium maritimum* (L.) Fritsch) and common centaury (*C. erythrea* Rafn) are widely distributed in the Mediterranean region, while they can also be found in saline soils (Mišić et al., 2009; Šiler et al., 2014). According to Mišić et al. (2012) *C. maritimum* responds to salinity and water deficit through osmoregulatory mechanisms by synthesizing trehalose and polyols which are the main components of plant defense against salt stress.

2.4.2. Chemical composition

Centaurium species contain a wide variety of bioactive compounds, among them secoiridoid glycosides (gentiopicrin, swertiamarin, and sweroside) and xanthones (eustomin, demethyleustomin, decussatin, methylbellidifolin, and mangiferin) (Šiler et al., 2014) (Fig. 1a). Furthermore, Mišić et al. (2013) reported that hairy roots of *C. maritimum* produces secoiridoid glycosides that are natural compounds with great importance for the food and pharmaceutical industry. Phenolic compounds such as esters of hydroxycinnamic acids, namely p-coumaric, ferulic, and sinapic acids were also identified in *C. erythraea* extracts (Valentão et al., 2002).

2.4.3. Health effects

Regarding their medicinal properties, *Centaurium* species exhibit antidiabetic, digestive, antipyretic, spasmolytic, antiflatulent, and antioxidant activities, as well as beneficial effects against cardiovascular, kidney, muscular and muscular-sceletical disorders (Đorđević et al., 2017; González-Tejero et al., 2008; Pieroni et al., 2004; Šiler et al., 2014). Other therapeutic properties include the use of leaves decoctions and ingestions against constipation, obesity, arthritis and dismenorrhya (Hanlidou et al., 2004), while Polat and Satil (2012) has been also reported the use of leaf infusions in oil or honey against stomach ache, ulcers, enteritis and waist pain. Antioxidant properties are also evidenced by *C. erythraea* plants, namely acting as superoxide radical scavenger or as inhibitor of xanthine oxidase (Valentão et al., 2002). It is also interesting to highlight that *C. erythrea* has been used in traditional medicine for treatment of diabetes, since according to Hamza et al. (2011) a significant decrease in fasting blood glucose levels in mice was detected comparing to control group; total cholesterol and serum insulin concentrations also decreased in a significant manner. Besides, the extracts of aerial parts and roots of several centaury species (*Centaurium erythraea, C. tenuiflorum*, *C. littorale* ssp. *uliginosum*, and *C. pulchellum*) exhibited considerable antibacterial and high antifungal activity suggesting their use in food industry as additives for food safety and preservation (Šiler et al., 2014). In addition, oral administration of 10 ml kg^{-1} of aqueous extracts of *C. erythraea* exhibited a diuretic effect on rats (Haloui et al., 2000).

No toxicity effects have been reported for *Centaurium* species so far. However, according to Tahraoui et al. (2010) oral administration of aqueous extracts of *C. erythraea* in mice at doses of 0–15 g kg^{-1} BW or administration via the intraperitoneal route at doses of 0–14 g kg^{-1} BW showed no acute or sub-chronic toxicity. In addition, a commercial pharmaceutical product that contains extracts of *C. erythrae* and is usually administered against dyspepsia showed no toxicity effects and has been called as safe for human consumption (Tagliati et al., 2008). Another plant mixture extract (P-9801091) which is used against hyperglycemia and contains extracts of *C. umbellatum* showed no biochemical and histological changes comparing to control treatment when administered in mice at a dose of 20 mg kg^{-1} (Petlevski et al., 2008).

2.5. Cistus monspeliensis L.

2.5.1. Botanical aspects

Montpellier cistus (*Cistus monspeliensis* L.) is a salt tolerant species of the Cistaceae family (Li Rosi et al., 2010; Torrecillas et al., 2003). According to Torrecillas et al. (2003) the osmotic adjustment through the inclusion of Na and Cl and the reduction of the canopy area for regulation of water losses are the main salt tolerance mechanisms of the species. The resin (ladano), produced by the glandular trichomes of *Cistus* species contains a wide variety of compounds (Papaefthimiou et al., 2014), while the essential oils of several *Cistus* species can be used in the food industry as additives (Loizzo et al., 2013).

2.5.2. Chemical composition

Monpellier cistus contains a wide variety of compounds, among them terpenes: limonene, p-cymene, 1,8-cineole, linalyl acetate, viridiflorol, manoyloxide, 13-epi-manoyl oxide, neophytadeine, terpineol-4, α-terpineol, safranal, cyclosativene, β-caryophyllene, α- and βcadinol; fatty acids and their derivatives: (Z,Z,Z)-9,12-15-octadecatrienoic acid, (Z,Z)-9,12-octadecadienoic acid, tetradecanoic acid, eicosanoic acid, docosanoic acid, tetracosanoic acid, hexacosanoic acid; and phenolic compounds: carvacrol, eugenol, methylisoeugenol (Jemia et al., 2013; Loizzo et al., 2013; Papaefthimiou et al., 2014) (Fig. 1b). According to Nicoletti et al. (2015), *Cistus* sp. shows strong *in vitro* antioxidant activity due to its high content in phenolics, flavonoids and tannins, while they suggested a discrimination between the various species of the genus depending on the presence of diterpenes which are usually detected in *C. mospeliensis* and *C. libanotis*. Barrajón-Catalán et al. (2011) also isolated from the aerial parts of plants the flavonoid apigenin diglucoside and four phenolic acids derivatives (uralenneoside, gentisoyl glucoside, 3,4′-dihydroxypropiofenone-3-β-D-glucoside, hydroxyl-ferulic acid hexoside). The labdane diterpene (+)-19-acetoxy-cis-clerodan-3-en-15-oic acid was also identified in C. *monspeliensis* leaves, while among hydrocarbons isolated from leaves of *C. monspeliensis* collected from Tunisia, were pentacosane, heptacosane, octacosane, nonacosane, and hentriacontane (Jemia et al., 2013). Diurnal and seasonal variation in composition of essential oil from the leaves of *C. monspeliensis* have also been reported (Angelopoulou et al., 2002).

2.5.3. Health effects

Several species of the Cistaceae family are reported to have medicinal properties and are used as ingredients in traditional medicine formulations (Bedoya et al., 2009; Sayah et al., 2017). In a previous study, Attaguile et al. (2000) reported that extracts from aerial parts of *C. monspeliensis* exhibit antioxidant capacity and protective activities against DNA cleavage. Similarly, Shimoda et al. (2012) reported that leaf extracts display antioxidant activity and promote the energy metabolism pathways in human intestinal cells, while Sayah et al. (2017) reported *in vivo* and *in vitro* anti-inflammatory and analgesic capacity, as well as activities against key enzymes associated with hyperglycemia, for aerial plant parts extracts in animal studies. The extracts from leaves and flowers of C. *monspeliensis* also exhibited considerable antibacterial activity against Gram-positive bacteria such as *Staphylococcus aureus* and *S. epidermidis* (Papaefthimiou et al., 2014; Sassi et al., 2017). Finally, and not least important to point out is the *in vitro* antiproliferative and cytotoxic activity of the species against the human epithelial prostate cells and human melanoma cell line A-375 (Jemia et al., 2013; Vitali et al., 2011), as well as the activity of leaves essential oils against neurogenerative disorders (Loizzo et al., 2013).

No toxicity effects have been reported for *Cistus monspeliensis* so far.

2.6. Cynodon dactylon (L.) Pers.

2.6.1. Botanical aspects

Bermudagrass or Scotch grass (*Cynodon dactylon* (L.) Pers.) is a perennial omnipresent and difficult to control weed which is reproduced vegetatively with stolones and rhizomes (Horowitz, 1996). The aerial parts of the plant are good cattle forage, however they are also used for medicinal purposes as well as in landscaping (Pessarakli, 2015). The salt tolerance of this species is based on its ability to accumulate proline for osmoregulatory purposes, while some ecotypes of *C. dactylon* exhibited lower uptake rates of Na^{+} and Cl^{-} and increased uptake of Ca^{2+} and K^{+} (Hameed and Ashraf, 2008).

2.6.2. Chemical composition

Bermudagrass contains a wide variety of chemical constituents such as eachianol G, leachianol F, parthenostilbenin B, parthenostilbenin A, restrytisol B, caraphenol C, pallidol, laetevirenol A, quadrangularin B, quadrangularin C, quadrangularin A, and parthenocissine A (Li et al., 2017) (Fig. 1b). According to (Muthukrishnan et al., 2015), ethyl acetate extracts of leaves contain several flavonoids (catechin, rutin, quercetin, kaempferol and myricetin), carotenoids (violaxanthin, lutein, zeaxanthin and β-carotene) and chlorophyll-b, while Biswas et al. (2017) detected significant amounts of ascorbic acid, caffeic acid and syringic acid. Other detected compounds in ethanolic extracts of leaves include glycerin, 9,12-Octadecadienoyl chloride, (Z,Z), hexadecanoic acid, ethyl ester, ethyl α-d-glucopyranoside, linoleic acid and phytol (Jananie et al., 2011).

2.6.3. Health effects

Bermudagrass presents very interesting medicinal properties. The extracts and decoctions of rhizomes from this species exhibit several anti-inflammatory, diuretic and antiemetic activities (Rai et al., 2010; Tuttolomondo et al., 2014). Besides to these effects, Singh et al. (2007) reported that the aqueous extracts of the species possess high antidiabetic activity, while (Soraya et al., 2015) found that the extracts from rhizomes possess angiogenic activity due to their increasing effects on the expression of VEGF (vascular endothelial growth factor). The wound healing activity in animal models was also reported by (Biswas et al., 2017), who attributed the effect of aqueous extracts ointments to its content in phenolic acids and flavonoids which exhibits anti-oxidative activity and help in collagenesis. Furthermore, ethanolic extracts of the whole plant exerted moderated antibacterial activity against Gram positive and Gram negative bacteria, while chloroform extracts had a pronounced antibacterial effect against *Staphylococcus aureus* (Marasini et al., 2015). Ethnopharmacological studies have also confirmed the use of Bermudagrass as digestive and against kidney disorders (González-Tejero et al., 2008), while Neves et al. (2009) and Passalacqua et al. (2007) reported various medicinal effects for dry roots and aerial parts, including detoxifying, gastroprotective, anti-inflammatory, mild laxative, antirheumatic and diuretic properties.

Regarding toxicity effects of *C. dactylon*, Yadav and Nath (2017) reported that the administration of plant extracts at doses of 200–800 mg kg^{-1} in mice showed no acute toxicity effects.

2.7. Frankenia laevis L.

2.7.1. Botanical aspects

Sea health (*Frankenia laevis* L.) is a halophyte species that can be found in coastal areas of Southern Europe (Lopes et al., 2016). It is a scabrid puberulent shrub with a height of 0.1–0.3 m (Hussein, 2004a). The species which belongs to Frankeniaceae family exhibited a significant salt and gypsum tolerance, with sunken salt glands on their leaves (Manning and Helme, 2014).

2.7.2. Chemical composition

Sea health have a pronounced content of phenolic compounds, being chlorogenic acid and catechin the major compounds (Jdey et al., 2017). Phenolic anionic conjugates were also isolated and identified as gallic acid-3-methylether-5-sodium sulphate, acetophenone-4-methyl ether-2-sodium sulphate, ellagic acid-3,3′-dimethylether-4,4′-di-sodium sulphate and ellagic acid-3-methyl ether-4-sodium sulphate (Hussein, 2004a). In the study of Hussein (2004b) two new flavonol di-sodium sulphates and an ellagic acid methyl ether mono-sodium sulphate were also characterized and identified as 3,7-di-sodium sulphate of kaempferol, 3,7-di-sodium sulphates of quercetin and 4′-mono-sodium sulphate of ellagic acid-3-methylether. Apart from this class of chemical compounds, a pronounced content of volatile compounds is also present, namely hexadecanoic acid, the major compound identified in *F. laevis*, followed by methyl linoleate, (*E, E*)-farnesyl acetate, (*E*)-nerolidol and benzyl benzoate. In smaller amounts, are also present dodecanoic acid, benzyl benzoate, methyl hexadecanoate, benzyl cinnamate, tricosane, pentacosane, hexacosane, heptacosane, octacosane, nonacosane and 1-docosene (Mahjoub et al., 2010). Therefore, fatty acids and their esters, hydrocarbons and their derivatives (alkanes, alkenes, alcohols and aldehydes), terpenoids (oxygenated monoterpenes, sesquiterpene hydrocarbons and oxygenated sesquiterpenes) and aromatic compounds are the main classes present on sea health essential oil composition (Mahjoub et al., 2010). However, the quantitative composition and the relative proportions of oil components are widely influenced by the genotype, ontogenic development and even environmental and growing conditions.

2.7.3. Health effects

Frankenia laevis is a halophyte that has been widely recognized for its prominent antimicrobial effects, namely as antibacterial against both Gram-positive (*S. aureus, S. epidermidis* and *Micrococcus luteus*) and Gram-negative (*E. coli* and *Salmonella typhimurium*) bacteria (Saïdana et al., 2010). Interestingly to highlight is that this significant potential is reached by using both the aerial plant parts extract and essential oils (Jdey et al., 2017; Mahjoub et al., 2010). Nevertheless, at the tested concentrations, no positive antifungal effects were noted against different fungi species, namely *Fusarium oxysporum, Aspergillus niger, Alternaria* spp. and *Penicillium* spp. These results may be explained by the different levels of complexity existent between bacteria and fungi. On the other hand, pronounced antioxidant effects were also noted for *F. laevis*, mainly acting as a free radical's scavenger, reducing power agent and lipid peroxidation inhibitor (Jdey et al., 2017). In the same line, the same authors reported a high potential of diphenolase activity inhibition. This data suggests an upcoming and effective use of this plant as a new natural skin-whitening agents.

No toxicity effects have been reported for *F. laevis* so far.

2.8. Glaucium flavum Crantz.

2.8.1. Botanical aspects

Yellow hornpoppy (*Glaucium flavum* Crantz., Papaveraceae) is a common herb of the Mediterranean region, usually found at areas with a wide range of soil salinity levels (Arafa et al., 2016; Cambrollé et al., 2011). The species has the ability to tolerate up to 300 mM NaCl salinity levels, mostly due to plant's ability to maintain a particularly low assimilation of CO_2 and the little effects of salinity on photosystem PSII (Cambrollé et al., 2011).

2.8.2. Chemical composition

Studies on chemical composition of *G. flavium* have identified several isoquinoline alkaloids of the aporphine class such as glaucine, pontevedrine, oxoglaucine, and catalane which were isolated from the aerial plant parts (Arafa et al., 2016). In an earlier study of Daskalova et al. (1988), ethanolic extracts of aerial parts at full blossom, revealed the presence of some minor alkaloids, namely dihydropontevedrine, dihydrosanguinarine, dihydrochelerythrine and dihydrochelirubine, while Petitto et al. (2010) identified apart from glaucine, talikmidine, isocorydine and norisocorydine (Fig. 1c). Moreover, Bournine et al. (2013) studied the chemical composition of roots and isolated two new alkaloids, namely protopine and bocconoline. Two more alkaloids were also isolated and identified in aerial parts as N,N-dimethyl-hernovine and sanguinarine (Och et al., 2017). However, according to Doncheva et al. (2016) alkaloid profile of the species is highly depended on genotype, with three chemotypes being suggested in terms of aporphines, protopines and morpinanes content. Seeds are rich in oils (33.64%) which consist of linoleic, oleic, palmitic and stearic acid (Ozcan, 2014).

2.8.3. Health effects

Glaucium flavum is considered a rich source of alkaloids which although they are associated with toxic effects, they also show strong pharmacological activity, especially as anticancer agents (Och et al., 2017). For example, Lidder et al. (2008) have reported that the combined use of diphenylprolinol and glaucine may result in cardiovascular toxicity. Moreover, Arafa et al. (2016) reported that ethanol extracts from the aerial parts of the plant possessed analgesic, antibacterial, anti-inflammatory, antifungal and cytotoxic activities. Similarly, Hadjiakhoondi et al. (2013) observed that the aerial parts alkaloid extracts exhibited cytotoxic effects against colon adenocarcinoma cell lines (HT-29, Caco-2), while Bournine et al. (2013) reported that the root methanolic extracts displayed anticancer effects against breast cancer cells. Other health effects include depressive effects of various plant parts extracts on the central nervous system (CNS) and blood glucose levels (Cabo et al., 1988, 1987), while the main bioactive compound of the species (glaucine) has been associated with various pharmacological properties, such as antitussive, antiparkinsonic, hypotensive, antiviral, cardiovascular and cytotoxic effects (Orallo et al., 1995; Spasova et al., 2008).

Considering that the species belongs to Papaveraceae family which includes plants with high amounts of alkaloids, any toxic effects of *G. flavum* could be associated with ingestion of excessive amounts of alkaloids and their side effects. Therefore, it is considered as a poisonus plant and is registered as such in FDA (Cooper and Johnson, 1998).

2.9. Juncus acutus L.

2.9.1. Botanical aspects

Spiny rush (*Juncus acutus* L. Juncaceae) is a salt tolerant species found at coastal marshes in the Mediterranean basin (Batriu et al., 2015; Fountoulakis et al., 2017). The salt tolerance of the species is associated with proline and Ca^{2+} and Mg^{2+} accumulation which contribute to plant defense mechanisms against salinity stress through osmoregulation (Boscaiu et al., 2011; Hassan et al., 2017b). Hassan et al. (2017a) observed an increase of total phenolic compounds and flavonoids in the aerial parts of the species under high salinity levels (400 mM NaCl), whereas photosynthetic pigments were sensitive to salt-induced oxidative stress and decreased at levels higher than 100 mM NaCl.

2.9.2. Chemical composition

The wetland plants of *Juncus* genus such as *J. acutus*, are considered rich sources of nitrogen-free alkylated phenanthrenoids, while they also contain secondary metabolites of various classes, such as coumarins, sterols, terpenes, stelbenes, carotenoids and so forth (Behery et al., 2013; El-Shamy et al., 2015). In the study of Behery et al. (2013) several compounds with antioxidant activity were isolated from *J. acutus* rhizomes, namely 8,8′-bidehydrojuncusol, juncunol, 5,7-dihydroxychromone and flavone derivatives (apigenin, luteolin, chrysoeriol, luteolin-7-O-β-glucoside and hydnocarpin (Fig. 1c). Plant culms are rich in soluble carbohydrates (myo-inositol, clicerol, sorbitol, fructose, glucose and sucrose) which are used in salt tolerance mechanisms (Gil et al., 2011).

2.9.3. Health effects

Juncus acutus constituents, especially nitrogen-free alkylated phenanthrenoids, exert a pronounced antioxidant activity and biological activities, including anti-inflammatory, cytotoxicity, anti-leukaemic, anti-algal and cognitive-enhancing properties (Behery et al., 2013; Rodrigues et al., 2017). Moreover, Rodrigues et al. (2014) reported significant *in vitro* cytotoxicity of juncunol against HepG2, MDA-MB-468 and HeLa human cancer cells, which is probably associated with radical scavenging activity of the species. Ethanolic extracts of the aerial parts of the plants showed significant anti-eczematic activity in animal studies, with compounds markhamioside F and as canthoside B having the highest potency (Awwad, 2006).

No toxicity effects have been reorted for *J. acutus* so far.

2.10. Limonium sinuatum (L.) Mill.

2.10.1. Botanical aspects

Sea lavender or statice (*Limonium sinuatum* (L.) Mill.) is a salt tolerant flower crop and member of the Plumbaginaceae family (Grieve et al., 2005; Rivoal and Hanson, 1994). *Limonium* species belongs to recretohalophytes and they have the ability to secrete salts from their leaves as a means to tolerate salinity stress (Hassan et al., 2017b). Moreover, according to Rivoal and Hanson (1994) *Limonium* plants tend to accumulate choline-O-sulphate under saline conditions for osmoregulatory purposes, while Raman and Rathinasabapathi (2003) associated salinity tolerance with β-alanine betaine accumulation which serves as an osmoprotectant and is usually detected in plants of Plumbaginaceae family.

2.10.2. Chemical composition

The flowers of *Limonium sinuatum* contain gallic acid, ferulic acid, quercetin, rutin and epigallocatechin (Xu et al., 2017). One phenolic acid; homogentisic acid and two flavonoids; catechin and epicatechin were also isolated in flower extracts of the species (Li et al., 2014), while Ross (1984) identified myricetin-3′- methyl ether-7-O-B-D-glucopyranoside and isorhamnetin-7-0-B-D-glucopyranoside.

2.10.3. Health effects

Although no reports regarding the health effects of the species are available, its potential health effects could be associated with the antioxidant potential of flower extracts (Li et al., 2014; Xu et al., 2017). Moreover, according to Xu et al. (2017), flower decoctions have been used for their anti-aging properties. However, Wiszniewska et al. (2011) have reported a case of occupational asthma and rhinitis induced by pollen grains and leaves of *L. sinuatum*.

No toxicity effects have been reorted for *L. sinuatum* so far.

2.11. *Phragmites australis (Cav.) Trin. ex Steud.*

2.11.1. Botanical aspects

Common reed or reed (*Phragmites australis* (Cav.) Trin. ex Steud.; synonym. *Phragmites communis* Trin.) is a perennial weed which develops an extensive root system (Mal and Narine, 2004). This species is considered as a salt tolerant species through the adjustment of osmotically active solutes levels in leaves (Lissner and Schierup, 1997). Plant parts such as culm and rhizomes have been traditionally used for human consumption, while raw leaves can reduce horse stomach flatulence (Menale and Muoio, 2014).

2.11.2. Chemical composition

Common reed presents a varied chemical composition. The compounds aurantiamide acetate, 2,3-dihydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone, ferulic acid, p-coumaric acid, syringic acid, vanillic acid, p-hydroxy benzoic acid, p-hydroxybenzaldenhyde, palmitic acid, heptadecanoic acid, β-sitosterol, stigmasterol, α-D-glucose and β-D-glucose were isolated and identified from the rhizomes of this species (Gao et al., 2009). Moreover, Choi et al. (2009) identified methyl gallate, (+)-lyoniresinol, and (+)-lyoniresinol-3α-*O*-β-D-glucopyranoside from reed rhizomes.

2.11.3. Health effects

Regarding the medicinal properties of common reed, Kiviat and Hamilton (2001) reported that this species is used in traditional medicine for the treatment of various diseases, while Chen et al. (2013) found that aqueous extracts from the rhizomes of *P. australis* exhibited antioxidant and hepatoprotective activities. Furthermore, it is important to point out that extracts from leaves possess anti-melanogenesis and antioxidant activities (Sim et al., 2017), while González-Tejero et al. (2008) referred to its traditional uses against nutritional disorders. Moreover, Zhu et al. (2017) reported *in vitro* inhibition of inflammatory mediators and pro-inflammatory cytokines, as well antiviral effects of water soluble crude extracts, while (Borer et al., 2012) noted significant *in vivo* beneficial effects on lipid metabolism and erythrocyte antioxidant defense system in rats. Other therapeutic effects reported in ethnopharmacological studies include its uses in folk medicine against sore throat (Palombo and Semple, 2001), while Viegi et al. (2003) described its uses in folk veterinary medicine.

No toxicity effects have been reorted for *P. australis* so far.

2.12. *Tamarix gallica L.*

2.12.1. Botanical aspects

French tamarisk (*Tamarix gallica* L., Tamaricaceae) is a deciduous, herbaceous shrub or tree, which naturally grows in arid and semiarid areas of the Mediterranean basin (Molina et al., 2012; Terrones et al., 2016). It has been used in traditional medicine for many centuries, while it is also commonly used as an ornamental plant or as a fuel wood (Ksouri et al., 2012; Panta et al., 2014). According to Borer et al. (2012) apart from salt tolerant, the species also exhibits tolerance in high calcium environments through foliar partitioning and secretion mechanisms.

2.12.2. Chemical composition

French tamarisk contains a wide variety of chemical constituents, among them phenolic acids (gallic, synnapic, chlorogenic, syringic, vanillic, *p*-coumaric, and *trans*-cinnamic acids), flavonoids (catechin, (-)-epicatechin, quercetin, quercetin-3-*O*-glucuronide, isoquercetin, apigenin, kaempferol, kaempferol-3-*O*-β-*D*-glucuronide, rhamnocitrin, amentoflavone, flavone, resveratrol-3-*O*-glucoside), coumarins and tannins (Boulaaba et al., 2015; Jdey et al., 2017; Ksouri et al., 2009), with significant differences in their relative contents according to plant parts used, harvesting stage and growing and extraction conditions (Ksouri et al., 2008). According to the latter study, polyphenols content was higher in flowers than leaves, hence the higher antioxidant potency of leaves, while significant differences were observed between different ecotypes of the species. Stem bark contains coniferyl alcohol 4-sulphate and other phenolic and flavonoid sulphates, such as kaempferol 4′-methyl ether 3-sulphate, and tamarixetin 3-sulphate were also identified (Tomas-Barberán et al., 1990). Other reported flavonoids include 3,5,3′-trihydroxy-7,4′-dimethoxyflavone, 3,5,7-trihydroxy-4′-methoxyflavone and 5-hydroxy-3,7,4′-trimethoxyflavon, O-Methylated and glucuronosylated flavonoids, as well as rhamnetin, tamarixetin, rhamnazin, KGlcA, KGlcA-Me, QGlcA, and QGlcA-Me (Hmidene et al., 2017; Lefahal et al., 2017). Also, pronounced levels of carnosol, capsaicin, 6-shogaol, 6-gingerol and their corresponding derivatives, and even vitamins, terpenoids (carotenoids and essential oils) have been identified (Boulaaba et al., 2013; Ksouri et al., 2009), which makes this plant a potential source of bioactive compounds for multiple applications.

2.12.3. Health effects

Tamarix gallica exhibits prominent free radical's scavenging, reducing power and lipid peroxidation inhibition effects (Jdey et al., 2017; Ksouri et al., 2009). Besides, the effectiveness varied depending from the plant part used, i.e. flowers exhibited a higher biological activity as compared to the leaves (Ksouri et al., 2009). Appreciable antimicrobial effects were also stated, namely antibacterial and antifungal properties against human pathogen strains, while silver nanoparticles synthesized with *Tamarix gallica* extract exhibited significant antibacterial activity against *Escherichia coli* (Ksouri et al., 2009; López-Miranda et al., 2016). Jdey et al. (2017) observed a prominent *in vitro* antibacterial activity of this halophyte against the pathogenic bacteria, *S. aureus* and *S. enterica* strains, while Ksouri et al. (2009) found an appreciable effect against *Staphylococcus epidermidis, Micrococcus luteus, E. coli* and *P. aeruginosa* strains. A weak to moderate antifungal activity was also noted against the *Candida* species: *Candida albicans, C. glabrata, C. kefyr, C. holmii* and *C. sake* strains (Boulaaba et al., 2013; Ksouri et al., 2009). On the other hand, and taking into account that oxidative stress is among the factors causing cancer-related deaths, the abundance in bioactive molecules with antioxidant capacity of *T. gallica*, motivated the investigation of the anticancer potential of the species. Boulaaba et al. (2015) stated that is halophyte not only prevents cancer formation but also the proliferation of cancer cells. The authors found that *T. gallica* extract significantly inhibited Caco-2 cell growth as also decreased DNA synthesis, which confirm their effect on Caco-2 cell proliferation, as also arrested cell mitosis at G2/M phase (Boulaaba et al., 2013). Taken these facts together and considering the changes occurred in the cell-cycle-associated proteins (cyclin B1, p38, Erk1/2, Chk1 and Chk2), the authors proposed *T. gallica* as a promising source of anticancer biomolecules (Boulaaba et al., 2013). Bettaib et al. (2017) have also reported the protective effects of hydroethanolic extracts of shoots against oxidative stress of intestine epithelial cells (IEC-6), while Sehrawat and Sultana (2006) suggested significant protective effects of methanolic extracts of *T. gallica* aerial parts against liver carcinogenesis. Bensatal and Ouahrani (2008) have also observed inhibitory effects of aerial parts extracts against crystallization of calcium oxalate which results in stone formation in kidneys and the urinary tract. Moreover, *T. gallica* extracts are one of the ingredients of Liv.52, a herbal hepatoprotective medicine which has been used against alcohol induced liver diseases (de Silva et al., 2003; Huseini et al., 2005). Finally, it is also important to highlight the widespread use of *T. gallica* in traditional medicine as hepatotonic, expectorant, stimulant, as well as in the treatment of several liver disorders, an anti-inflammatory and even anti-diarrheic (Ksouri et al., 2009). Phenolic extracts of *T. gallica* also displayed antihyperlipidemic activity, since they decreased the levels of cholesterol, triglycerides, LDL-C and VLDL-C and increased the HDL-C level (Naveed et al., 2015). Other uses include its application in folk veterinary medicine (Viegi et al., 2003), cicatrizing and antiseptic effects (Ksouri et al., 2012), the use of decoctions against eye diseases, colds, tonsillitis and as a sudorific agent (Hammiche and Maiza, 2006), as well as its use in warts healing (Montesano et al., 2012).

Regarding toxicity effects, the administration of methanolic and ethyl acetate extracts of *T. gallica* at doses up to 3000 mg kg^{-1} BW in rats showed no acute toxicity symptoms (Urfi et al., 2016).

2.13. *Typha spp.*

2.13.1. *Botanical aspects*

Common cattail (*Typha latifolia* L.,Thyphaceae) and narrowleaf cattail (*Typha angustifolia* L.) are perennial species commonly found in wet or saturated soils in marshes, fens and other areas in the Mediterranean basin (Grace and Harrison, 1986), while *Typha latifolia* shows lower salt tolerance than *T. angustifolia* (McMillan, 1959).

2.13.2. *Chemical composition*

Typha rhizomes present a wide variety of chemical compounds, among them saponins, coumarins and flavonoids (Fruet et al., 2012). The compounds typhaphthalide, typharin, sitosterol, afzelechin, epiafzelechin, (+)-catechin, and (-)-epicatechin were also isolated and identified from rhizomes of *Typha capensis* Rohrb. (Shode et al., 2002), nonacosanol and lupeol acetate were detected in dry flowers and leaves of *T. angustifolia* (Varghese et al., 2009) (Fig. 1c). Moreover, the cerebrosides, 1-O-(beta-d-glucopyranosyloxy)-(2S,3S,4R,8Z)-2-[(2′R)-2′-hydroxytricosanoylamino]-8-nonadecene-3,4-diol and 1-O-(beta-D-glucopyranosyloxy)-(2S,3R,4E,8Z)-2-[(2′R)-2′-hydroxynonadecanoylamino]-4,13-nonadecene-3-diol, were identified in *Typha angustifolia* pollen grains (Tao et al., 2010). The rhizomes of *T. angustifolia* also accumulate considerable amounts of non-structural carbohydrates. According to Kausch et al. (1981) the rhizomes and roots which were collected at early winter contained high amounts of starch (45.03 and 22.80% in rhizomes and roots, respectively), while from late winter to spring a decrease in starch content was observed.

2.13.3. *Health effects*

Typha species are widely used as medicinal plants (Fruet et al., 2012). In a recent study, Fruet et al. (2012) reported that rhizome flour from *T. angustifolia* displays significant antioxidant activity. Moreover, Londonkar et al. (2013) observed that the leaves extracts exhibited strong antimicrobial activity against *Salmonella typhimurium*, *Pseudomonas aeruginosa* and *Escherichia coli*. Similarly, Varghese et al. (2009) reported that the extracts from dry flowers and leaves exhibited antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. In addition, silver nanoparticles synthesized using *T. angustifolia* leaf extract enhanced the antibiotic activity against the Gram-negative bacteria *Escherichia coli* and *Klebsiella pneumonia* (Gurunathan, 2015). Besides, extracts from aerial parts of. *T. angustifolia* exhibited thrombolytic and cytotoxicity activities (Umesh et al., 2014), while Qin and Sun (2005) reported that the extracts from pollen grains of *T. angustifolia* possessed immunosuppressive activity.

No toxicity effects have been reported for *Typha* species so far. Moreover, according to Grace and Harrison (1986) although *T. angustifolia* was suspected for cattle poisoning, no toxic effects were confirmed, while Patankar et al. (2015) evaluated acute and sub-acute toxicity and mucus membrane irritation of formulations derived from *T. angustifolia* flower extracts and reported no such effects.

2.14. *Zygophyllum album L.*

2.14.1. *Botanical aspects*

Zygophyllum species are salt tolerant plants native in the Mediterranean region (Hammad and Qari, 2010), while the species *Zygophyllum album* L. in particular has been used in traditional medicine to treat several diseases (Mnafgui et al., 2014).

2.14.2. *Chemical composition*

Ksouri et al. (2013) isolated from *Z. album* shoots three flavonoids; isorhamnetin-3-O-rutinoside, malvidin 3-rhamnoside and quercitin-3-sulphate (flavonoids), four triterpenoid saponins; 3-O-[b-D-Glucuronic acid pyranosyl]-29-hydroxyoleanolic acid-28-O-[b-Dglucopyranosyl] ester (zygophyloside K), 3-O-[b-D-2-O-Sulphonylglucopyranosyl]-quinovic acid-28-O-[b-Dglucopyranosyl] ester (Zygophyloside G), 3-O-b-D-Quinovopyranosyl-quinovic acid 28-b-D-glucopyranosyl ester, 3-O-[b-D-2-O-Sulphonylquinovopyranosyl]-quinovic acid-27-O-[b-Dglucopyranosyl] ester (zygophyloside F), one phenylopropanoid; p-Hydroxyphenethyl trans-ferulate, and one sterol; b-Sitosterol-b-D-glucoside or 3-O-[b-D-glucopyranosyl]-b-sitosterol. Several volatile compounds, such as (E)-β-damascenone, delta-decalactone, 3-Nonen-2-one, safranal, Butylated hydroxytoluene, tricosane, and heneicosane were also identified in the essential oil of the aerial parts (Tigrine-Kordjani et al., 2006).

2.14.3. *Health effects*

Zyghophyllum album is also an important medicinal species. According to Mnafgui et al. (2014) the extract from leaves and flowers of Z. *album* exhibited antidiabetic properties through delaying carbohydrates and lipids digestion and absorption, while Ksouri et al. (2013) reported that the shoot extracts displayed appreciable antioxidant, anti-inflammatory and anticancer activities. Extracts from the same species also showed a considerable antiacetylcholinesterase activity (IC_{50} values = 40–58 μg/mL), and thus can be suggested in pharmaceutical formulations against Alzheimer's disease (Kchaou et al., 2016). Furthermore, according to the same study (Kchaou et al., 2016), the essential oil of this plant exerts high anti-bacterial activity against Gram-positive bacteria.

However, Moustafa et al. (2007) observed highly toxic effects of ethanol extracts of *Z. album* aerial parts on rats and sheep and they suggested a slight toxicity to human at high doses.

3. Conclusions

The Mediterranean basin is considered an important reservoir of medicinal plants and halophytes in particular. These species have been used throughout the centuries for their therapeutic properties, while there is a recent increase in global demand for herbal medicines and food supplements. Considering the great diversity in chemical composition and bioactive compounds content among the various species and the great amount of ecotypes, it is of major importance to record and describe chemical composition and health effects of these species, while a special focus should be given on possible toxic effects and anti-nutrients compounds content. Although several *in vitro* and *in vivo* animal model studies are available regarding the health effects for most of these species, there is a great lack of knowledge about their long-term effects and toxicity symptoms in clinical studies as well as the involved mechanisms of action. Therefore, although most of the studied halophytes have confirmed medicinal properties further studies are required in order to elucidate the mechanisms of action and pharmacokinetics and the involved bioactive compounds and their bioavailability in clinical studies, while official regulations about the safe consumption, recommended dose, toxicity effects and possible interactions with conventional drugs and formulations have to be established.

Transparency document

Transparency document related to this article can be found online at http://dx.doi.org/10.1016/j.fct.2018.02.031.

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