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**REVIEW ARTICLE**

# Phytochemical composition of some common coastal halophytes of the United Arab Emirates

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## Abstract

Halophyte species of United Arab Emirates are a source of unique active phytochemicals, potentially due to the extreme environmental conditions under which the plants grow in the UAE. These phytochemicals make the native halophytes possibly interesting crops for biorefining, where biofuel production is combined with the production of value added chemicals, improving the economic feasibility of both process. Phytochemicals found in these species are widely recognized and researched as potential pharmaceutical and nutraceutical products. We reviewed the literature for secondary metabolites from species from the following halophyte families: Aizoaceae, Amaranthaceae (incl. Chenopodiaceae), Avicenniaceae, Zygophyllaceae. The review revealed that plant species belonging to these families contain valuable phytochemicals, such as fatty acids, terpenoids, flavonoids, alkaloids, steroids, tannins, saponins, quinones and coumarins, many of which have been reported to have therapeutic effects in humans.

*Key words*: Halophytes, Phytochemicals, Biorefining

## Introduction

Currently, efforts are underway to develop halophytes as crops for seawater irrigation in the United Arab Emirates. One of the potential uses of halophytes is as feedstocks for biofuels (Abideen et al., 2012; Abideen et al., 2011). However, as the main component of the halophyte biomass is lignocellulose, significant processing (high temperature pretreatment and enzymatic hydrolysis) is needed to release the fermentable sugars needed for biofuel production. The processing of halophytes for biofuels is further complicated by their high ash content. In order to achieve feasible biofuels processes from most lignocellulosic biomasses and even more so from halophyte lignocellulose, biorefinery concepts need to be applied, where value added chemicals are extracted prior to the conversion of the biomass to biofuels (Wyman, 1996). In other words, the latest trend in biofuel research entails searching for biomasses that contain extractable active components or phytochemicals, which can be sold as food and cosmetics additives, nutraceuticals, and even pharmaceuticals. These plant-based chemicals may be attractive to consumers due to their natural origin.

In this paper we review the phytochemicals found in the coastal halophytes of the United Arab Emirates (UAE). Due to the extreme environmental conditions in the UAE, i.e., high temperatures and high salinity of the seawater of the Persian Gulf, it is possible that plants here may have unique compounds not found in other species or in higher concentrations found in other species.

Stress response mechanisms in halophytes have been reviewed by Jithesh et al. (2006). They note that salt stress, which affects cellular membranes, enzyme activities and the photosyntethic system, is largely caused by the damage from the production of reactive oxygen species (ROS) (Jithesh et al., 2006). Plants have evolved two antioxidative pathways to combat damage from ROS: an enzymatic pathway, which involves enzymes such as super oxide dismutase, and catalase, and a non-enzymatic pathway which includes antioxidants such as tocopherol, carotenoids, ascorbate, phenolic compounds, alkaloids, glutathione and non-protein

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amino acids that scavenge free radicals (Gill and Tuteja, 2010). Jithesh et al. (2006) also noted that osmolytes, such as glycine betaine and proline, which are produced by halophytes to adjust osmotically to saline conditions, may also provide protection against free radicals, but that the mechanism by which they confer protection is mostly unknown.

Halophyte metabolites are a combination of components typical for lignocellulosic biomass and components unique for a family or species. The most commonly found components include primary metabolites such as amino acids, protein, carbohydrates and lignin (Bandaranayake, 2002). Secondary metabolites or phytochemicals include compounds of pharmacological and biological importance, such as alkaloids (A), fatty acids and lipids (FA, L), flavonoids (Fl), phenolics (Ph), quinines (Q), tannins (Tan), terpenoids (Ter), steroids (St) and saponins (Sap), coumarins (Co) to name a few (Bandaranayake, 2002). Content of the secondary metabolites can vary depending on the particular habitat where the plant grows.

Waterlogging, which affect halophytes such as mangroves and other intertidal halophytes has also been shown to increase the concentration of antioxidants. *Suaeda maritima* was cultivated in saline conditions under flooded and drained conditions, and under saline-flooded conditions plants produced higher concentrations of antioxidants than under drained conditions (Alhdad et al., 2013). Finally heat stress is also known to trigger ROS production in plants (Gill & Tuteja, 2010; Pucciariello et al., 2012).

Thus, it appears as though the multiple severe environmental stresses such as extreme salinity, extreme heat and flooding that coastal plants in the UAE experience should likely provide for the evolution of multiple antioxidant compounds that the plants can employ to combat the deleterious effects of increased ROS production.

## 2. Review of the phytochemicals found in halophyte species of the UAE

We reviewed the literature on species that were indicated as common coastal halophytes in the UAE by Böer (2002) and Böer and Saenger (2006). We examined Aizoaceae family members *Sesuvium portulacastrum* (L.) L.; *Sesuvium sesuvioides* (Fenzl) Verdc.; *Sesuvium verrucosum* Raf.; Amaranthaceae s.l. (incl. Chenopodiaceae) family members *Arthrocnemum macrostachyum* (Moric.) C. Koch, *Halocnenum strobilaceum* (Pall.) M. Bieb., *Halopeplis perfoliata* (Forssk.) Schweinf. & Aschers., *Salsola annua* (Bunge) Akhani (Synonym *Anabasis setifera* DC.) (Akhani et al., 2012); *Salsola rosmarinus* (Ehrenb. ex Boiss.) Akhani (Basionym: *Seidlitzia rosmarinus* Ehrenb. ex Boiss.) (Akhani et al., 2007); *Salsola drummondii* Ulbr.; *Caroxylon imbricatum* (Forssk.) Akhani and E. H. Roalson (Basionym: Salsola imbricata Forssk.) (Akhani et al., 2012); *Bienertia sinuspersici* Akhani, a new species, formerly combined into *Bienertia cycloptera* Bunge ex Boiss. (Akhani et al., 2005); *Salicornia sinus-persica* Akhani, a new species formerly combined into *Salicornia europea* L. (Akhani, 2008); *Suaeda iranshahrii* Akhani & Freitag; a new species formerly combined into *Suaeda maritima* (Freitag et al., 2013); *Suaeda vermiculata* Forssk. ex J. F. Gmel. (synonymous with *Suaeda fruticosa* Forssk. ex J. F. Gmel.Bolous); the mangrove *Avicennia marina* (Forssk.) Vierh. from the Avicenniaceae family; and Zygophyllaceae member *Tetraena qatarense* (Hadidi) Beier & Thulin (Basionym: *Zygophyllum qatarense* Hadidid) (Beier et al., 2003).

### Aizoaceae

#### *Sesuvium portulacastrum*

*S. portulacastrum* is a long known medicinal plant traditionally used by healers in South Africa to treat infections (Magwa et al., 2006), where it was used as a remedy for fever, kidney disorders and scurvy (Rojas et al., 1992). *Sesuvium* species containing secondary metabolites have shown a great potential to substitute some artificial raw materials applied in nutraceuticals, cosmetics and perfumery industries (Lis-Balchin & Deans, 1997; Lokhande et al., 2013). Essential oil extracted from the leaves by hydrodistillation have been found to contain active phytochemicals (mostly terpenoids), which included (in descending order of amount in the essential oil): o-cymene, alpha- and beta-pinene, *trans*-caryophyllene, 1,8-cineole (eucalyptol), limonene, alpha-terpinene and alpha-terpinolene, camphene, bornylacetate, tridecane and alpha-humulene. Due to the content of these compounds, essential oils of *S. portulacastrum* exhibit notable antioxidant, antibacterial and antifungal properties (Filipowicz et al., 2003; Magwa et al., 2006). *Trans*-caryophyllene, bornylacetate, tridecane and alpha-humulene have been claimed to be precursors of complex menthols and resins, which are the defense mechanism of trees against pathogens (Magwa et al., 2006). Sterols, flavonoids, alkaloids, organic acids and other phenolic compounds have also been isolated from ethanol extracts of *S. portulacastrum.* These include dihydrostigmasterol, capsaicin, epicatechin,

gallic acid and benzoic acid (Al-Azzawi et al., 2012). All of these compounds are known for their antimicrobial activities. Capsaicin and epicatechin are strong antioxidants, while benzoic acid has been recognized as anticancer and anti-HIV agent (Al-Azzawi et al., 2012). Suganthy et al. (2009) discussed the similarity of the inhibitory activity of the methanolic extracts of *S. portulacastrum* to the drug Donepezil, which is used for Alzheimer treatment.

***Sesuvium verrucosum***

No detailed characteristic of *S. verrucosum* could be found in the literature available to us; however this species has been tested for its cytotoxicity and compared with a few other halophyte species. According to Taha & Alsayed, (2000), ethanol extracts obtained from the plant were found to be the most potent in the brine shrimp assay for cytotoxicity. This assay is a simple test for detecting the potential anti-tumor properties of a plant extract. Even though the active component responsible for the alleged cytotoxicity of the ethanol extract of *S. verrucosum* has not been identified, its properties are similar to those of the extracts of *Myrsine africana,* which contains 2-hydroxychrysophanol (Li & McLaughlin, 1989). This compound belongs to anthraquinones, which is a group of compounds that are currently used as anticancer medicines (Cichewicz et al., 2004; Smith et al., 1990).

**Amaranthaceae (incl. Chenopodiaceae)**

***Arthrocnemum macrostachyum***

*A. macrostachyum* has been reported to be a medicinal plant (El-Wahab et al., 2008). Screening for phytochemicals in *A. macrostachyum* revealed content of secondary metabolites, fatty acids and fatty acid methyl esters (FAME). Secondary metabolites present in *A. macrostachyum* include phenolic compounds, alkaloids, flavonoids and tannins. *A. macrostachyum* possess antioxidant and reductive activities which are attributable to the high phenolic content (55%). Also high radical scavenging activity (RSA) indicates that *A. macrostachyum* can be a potential source of antioxidant compounds (Custódio et al., 2012). *A. macrostachyum* contains significant amounts of edible oils, having high content of unsaturated fatty acid (70-80%), which can be an alternative for commercial sources of vegetable oil (Qasim et al., 2011). High content of polyunsaturated fatty acids (PUFA) (46.5%) was reported for *A. macrostachyum* dominated by α-linolenic and linoleic acids (Custódio et al., 2012). FAME and PUFA's were reported to possess high antioxidant activity and are potential radical scavengers (Plaza et al., 2009). FAME and PUFA's are considered to be important nutritional supplements for people with Alzheimer's disease, coronary heart disease, tumors, arteriosclerosis and inflammation. *A. macrostachyum* methanol extracts possess iron reducing and copper chelating activities, which can help in prevention of oxidative stress-related diseases and Alzheimer's disease (Custódio et al., 2012).

***Caroxylon imbricatum***

High protein content was found in the *C. imbricatum* species (40% dry weight), when compared to other *Salsola* species. Lipids were detected in the amount of 3% dry weight, and the identified fatty acids included mainly oleic, linolenic and palmitic acids (Turki, 1999). Oleic acid (monosaturated fatty acid) and linolenic acid (an omega-3-acid, falling into poly-unsaturated fatty acids category) have been associated with reducing risks of cardiovascular and heart disease in humans (Ramadan et al., 2009). Methanol extracts obtained from the *C. imbricatum* roots were found to contain four identified triterpenoids, namely triterpene saponins, which included glycosides: pseudoginsenoside and silphioside as well as two newly discovered akebonic acid glucopyranoside and hydroxyoleanolic acid glucopyranoside (Hamed et al., 2011).

***Halocnemum strobilaceum***

*H. strobilaceum* extracts have been identified to possess medically and pharmaceutically interesting properties due to being a source of fatty acids, triterpenoids and flavonoids. The most abundant fatty acid found in the unsaponifiable plant fraction was palmitic acid (comprising 40% of all the fatty acid content). Campesterol, stigmasterol, beta-sitosterol (phytosterols) and alpha-amyrin were the triterpenoids identified in the same fraction (Radwan and Shams, 2007). Phytosterols have been proven to reduce cholesterol levels in blood (Brauner et al., 2012) and are precursors for production of synthetic human progesterone (Janeczko, 2012). Alpha-amyrin was found to act as an antihyperglycemic (hypoglycemic) and hypolipidemic agent in mice and rats (Narender et al., 2009; Santos et al., 2012). Flavonoids, widely known for their antioxidant properties were isolated from chloroform and ethyl acetate fractions and included chrysoeriol, luteolin galactoside, quercetin rhamnoside and luteolin, and the ethyl acetate extract from *H. strobilaceum* was observed to

exhibit antioxidant activity (Radwan and Shams, 2007). Additionally, luteolin is an anti-inflammatory compound and has been examined as an alternative treatment for multiple sclerosis (Theoharides, 2009). Scopoletin, a coumaric derivative was also detected in these fractions (Radwan and Shams, 2007). Scopoletin has been also found to possess antioxidant activity (Shaw et al., 2003).

***Salsola annua***

Current research performed on *S. annua* resulted in the identification of four triterpenoids. Identified triterpenoids included: alpha-amyrin glucopyranoside, patuletin glucopyranoside, myricitrin and a newly discovered oleanane triterpene saponin derivative – sophradiol glucopyranoside (Abdou et al., 2013). All of these compounds were found to inhibit acute and chronic inflammatory agents in rats, and thus were concluded to exhibit anti-inflammatory properties (Abdou et al., 2013). *S. annua* has been previously described as being highly defensive towards insects, fungi and grazing animals due to emitting fragrant essential oils. Active components present in the steam distillate obtained from the aerial parts of the plant were identified as carvacol and thymol, and were observed to work as effective insecticides (Saleh, 1986). Both carvacol and thymol are commonly used as germicides and antiseptics in oral disinfectants and anesthetics as well as in cosmetics (Botelho et al., 2007). However, both compounds show bactericidal activities against other pathogenic bacteria (Nostro et al., 2012; Wattanasatcha et al., 2012). *S. annua* was found to contain alkaloid (1.25%) and saponin (1.30%), where the saponin at extract concentration of 5 mg/kg resulted in maintaining normal blood-glucose levels when orally administered to diabetic mice. Sub-acute administration showed no toxic effects compared to oral administration, which becomes toxic at extract concentration  1,000 mg/kg (Kambouche et al., 2009) .

***Salsola rosmarinus***

Traditionally, *S. rosmarinus* was used in soap and detergent-making due to its alkalinity and antiseptic properties (Hadi, 2009; Younos et al., 1987). The plant has been found to have high nutritional value and was found highly palatable for camels (Towhidi and Zhandi, 2007). Newer studies report on the content of polyphenolics (flavonoids and tannins) and terpenoids in aerial parts of *S. rosmarinus,* however no information has been found on the specific compounds. Antibacterial activity of the chloroform extracts from the aerial parts of the plant against *Bacillus subtilis* has been observed (Akbar and Yahya, 2011).

***Salicornia sinus-persica***

*Salicornia sinus-persica* was formerly included with *Salicornia europea* until Akhani (2008) identified the populations in the Persian Gulf region as a separate species. No studies have been performed on the phytochemical composition of *S. sinus-persica* to date, but *S. europaea* was found to contain alkaloids, saponins, flavonoids and other phenolic compounds (Lellau and Liebezeit, 2001). Four triterpenoid saponins extracted from *S. europaea* have been identified in a new study (Yin et al., 2012). These include oleanolic acid glucoside, chikusetsusaponin methyl ester, calenduloside E and calenduloside E 6'-methyl ester, in addition to a newly discovered dihydroxy-oleanenoic acid glucopyranosyl ester. Oleanolic acid glucoside has been characterized to possess antidiabetogenic properties on rats (Yoshikawa & Matsuda, 2000), while chikusetsusaponin methyl ester was found to work as an anti-obesity agent (Han et al., 2005). Calenduloside E 6'-methyl ester has been recently analyzed for cytotoxicity against colon cancer cells in mice with positive outcome (Lee et al., 2012). Betacyanines, chromomes and isoflavones have also been detected in *S. europaea* L. extracts (Arakawa et al., 1982). Betacyanines and isoflavones are known for their high potential in free radical scavenging and anti-inflammatory properties (Siow and Mann, 2010; Tesoriere et al., 2009), while some chromones have been found to work as anti-HIV agents (Yu et al., 2004). Additionally, flavonoid compounds found in *S. europaea* were suspected to be responsible for the antimicrobial effect of ethanol extract from this plant (Lellau and Liebezeit, 2003).

***Suaeda iranshahrii***

Similar to *Salicornia sinus-persica*, *Suaeda iranshahrii* was formerly included *with Suaeda maritima* until Freitag et al. (In Press) identified the populations in the Persian Gulf region as a separate species. No studies have been performed on the phytochemical composition of *Suaeda iranshahrii* to date, but phytochemicals have been identified in *S. maritima*. Ethanol extracts of *S. maritima* leaves have been reported to have hepatoprotective properties when administered to Wistar albino rats. Triterpenoids were identified in the plant extracts, suggesting their involvement in the liver tissue protection from stress agents (Ravikumar et al., 2011; Tamai et al., 2007). A polysaccharide detected in the leaves of *S. maritima* has been reported to have activity against human HIV

(Bandaranayake, 2002). Flavonoid sulfates, alkaloids, tannins and steroids were also found in *S. maritima* extracts (Bandaranayake, 2002; Patra et al., 2011). Ethanol extracts obtained from *S. maritima* leaves have been reported to exhibit antibacterial properties comparable with standard antibiotics as well as free radical scavenging activity confirmed using seven different assays (Patra et al., 2011).

***Suaeda vermiculata***

*S. vermiculata,* an edible halophyte, has been recognized for its hypoglycemic and hypolipidemic properties and is claimed to possess components active against cancer, the effects of free radicals and tissue inflammation (Oueslati et al., 2012). According to Benwahhoud et al. (2001), flavonoids are the group of compounds that act as hypoglycemic and hypolipidemic agents in water extracts of *S. vermiculata* when applied to rats. Shoot extracts of this plant were found to contain relatively high (higher than other halophyte species) content of polyphenolics (including flavonoids), which were responsible for their free radical-scavenging properties (Oueslati et al., 2012). These compounds, along with triterpenoids, can be useful in preventing cardiovascular diseases and even cancer (Chong et al., 2010; Stagos et al., 2012).

**Avicenniaceae**

***Avicennia marina***

Grey mangrove tree (*Avicennia marina)* extracts have been found to contain many valuable components (Alizadeh Behbahani et al., 2012; Bandaranayake, 2002). In addition to primary metabolites including higher polysaccharides (representing up to 50% plant weight (Ramadan et al., 2009)), such as cellulose, a valuable product for paper, polymer, food, and biofuel industry, *A. marina* contains a range of phytochemicals. These are found in bark, leaves, roots, stems and seeds and include the following groups of compounds: fatty acids, carboxylic acids, steroids, tannins and triterpenoids (Bandaranayake, 2002). Palmitic and oleic acids were the major fatty acids detected in *A. marina.* Furthermore, the plant contains relatively high amounts of poly-unsaturated fatty acids (PUFA), which have been proven to show activity against cardiovascular diseases, atherosclerosis, autoimmune disorder, diabetes (Ramadan et al., 2009). Lauric acid is one of the fatty acids that have been extracted from *A. marina* leaves (Chandrasekaran et al., 2010; Hogg and Gillan, 1984). This compound is widely used in cosmetics as an antimicrobial agent for treatment of inflammatory acne vulgaris (Higaki, 2003; Nakatsuji et al., 2009). Triterpenoids, hydrocarbons comprised of six isoprene units (i.e. betulinic acid, taraxerol and taraxerone) have been isolated from *A. marina* bark (Zhu et al., 2009). Due to their aromatic properties, these compounds are used as flavors, perfumes, soaps, but also as antimicrobial and antifungal agents (Bandaranayake, 2002; Chandrasekaran et al., 2009). Betulinic acid has been discovered to possess strong antitumor and anticancer properties against human melanoma and breast cancer cells (Mertens-Talcott et al., 2012; Pisha et al., 1995), while taraxerol is an anti-inflammatory agent (Yao et al., 2013). Unusual naphtoquinone derivatives have been isolated from stems of *A. marina*, including avicequinone A, avicequinone C and stenocarproquinone B, all exhibiting antiproliferative, cytotoxic and antibacterial effects (Zhu et al., 2009).

**Zygophyllaceae**

***Tetraena qatarense***

High antimicrobial activity was observed in butanol and ethanol extracts from *T. qatarense* against pathogens such as *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and *Candida albicans.* The activity has been found to be similar to that of the currently used standard antibiotics (Mahasneh, 2002). Water extracts of *T. qatarense* have been subjected to a test of antispasmodic properties on rabbit jejunum and showed medium activity compared to other medicinal plants of the UAE (Tanira et al., 1996). Active components responsible for the antimicrobial and antispasmodic effects have not been described in detail in the available literature to date, however the plant tested positively for alkaloids, sterols and coumarins (Taha and Alsayed, 2000).

**Discussion**

Findings from this review are summarized in Table 1. Halophyte species found in United Arab Emirates appear to represent a valuable source of phytochemicals with proven medicinal relevance. Harsh environment (saline soil, heat and flooding) induces production of both enzymes and phytochemicals in response to reactive oxygen species (ROS). The latter includes production of compounds possessing radical scavenging properties (antioxidants). The most commonly found phytochemicals include fatty acids (e.g. oleic, linolenic and palmitic acids), polyphenols (e.g. hydroxycinnamic acids), terpenoids (e.g. fatty

acid glycosides), flavonoids (e.g. quercetin and luteolin), alkaloids, sterols (e.g. stigmasterol and beta-sitosterol), tannins, saponins, quinones and coumarins, with reported effects such as prevention of cardiovascular diseases, as well as having anti-inflammatory, anti-carcinogenic, antioxidant, anti-microbial, anti-viral, anti-fungal, and anti-diabetic properties. Furthermore, valuable components that are used in cosmetic and food industry have been identified, *e.g.* lauric acid and aromatic compounds from the bark of grey mangrove tree (*Avicennia marina)* and different terpenoids from essential oils of *S. portulacastrum* and *S. annua*, which are known as effective antiseptic compounds.

Table 1. Characteristics of the researched halophyte species of United Arab Emirates coastline.

| Name | Life Form | Eco/morphotype | C3/C4 | Phytochemicals Found (y/n) | References |
|---|---|---|---|---|---|
| Aizoaceae | | | | | |
| *Sesuvium portulacastrum* | H | PSH/LS | C3 | Fl, Ph, Ter, Ph, Al | (Al-Azzawi et al., 2012; Magwa et al., 2006) |
| *Sesuvium sesuvioides* | An | PSH/LS | C4 | No studies | |
| *Sesuvium verrucosum* | Ch | PSH/LS | C3 | Q (possibly) | (Li and McLaughlin, 1989; Taha and Alsayed, 2000) |
| Amaranthaceae | | | | | |
| *Arthrocnemum macrostachyum* | Ch | HG/SS | C3 | FA, Fl, Tan, Ph, Al | (Custódio et al., 2012; Qasim et al., 2011) |
| *Bienertia sinuspersici* | An | H/LS | C4 | No studies | |
| *Caroxylon imbricatum* | Ch | XH/LS | C4 | FA, L, triTer-Sap | (Hamed et al., 2011; Turki, 1999) |
| *Halocnenum strobilaceum* | Ch | HG/SS | C3 | FA, Fl, triTer | (Radwan and Shams, 2007) |
| *Halopeplis perfoliata* | Ch | HG/SS | C3 | No studies | |
| *Salsola annua* | An/H/Ch | XH/SS | C4 | Ph, triTer-Sap | (Abdou et al., 2013; Saleh, 1986) |
| *Salsola drummondii* | Ch | H/LS | C4 | No studies | |
| *Salsola rosmarinus* | Ch | H/LS | C4 | Fl, Ph, Tan, Ter | (Akbar and Yahya, 2011) |
| *Salicornia sinus-persica* | An | HG/SS | C3 | No studies, but phytochemicals found in *Salicornia europea* | |
| *Suaeda iranshahrii* | An | HG/LS | ? | No studies, but phytochemicals found in *Suaeda maritma* | |
| *Suaeda vermiculata* | Ch | H/LS | C4 | Fl, Ph, triTer | (Benwahhoud et al., 2001; Oueslati et al., 2012) |
| Avicenniaceae | | | | | |
| *Avicennia marina* | Ph | HG | C3 | FA, Tan, triTer, Q | (Bandaranayake, 2002; Chandrasekaran et al., 2009; Ramadan et al., 2009; Hogg and Gillan, 1984; Zhu et al., 2009) |
| Zygophyllaceae | | | | | |
| *Tetraena qatarense* | Ch | H/LS | C3 | Al, St, Co | (Taha and Alsayed, 2000) |

Life form: An=annual; Ch=chamaephyte; H= Hemicryoptophyte; Ph=phranerophyte; Eco/morphotype Ecological type: PSH=psammohalophyte; H=halophyte; HG=Hygrohalophyte; XH=xerohalophyte; Morphological type; LS=Leaf succulent; SS=Stem Succulent. Data on Amaranthaceae species from (Akhani et al., 2005; Akhani et al., 1997); Aizoaceae from (Kocacinar and Sage, 2003; Lonard and Judd, 1997; Sikolia, 2009); Avicenniaceae from (Ball, 2009); Zygophyllaceae from (Sage, 2005).

Several of the halophytes are edible and contain important free radical scavenging anti-inflammatory compounds e.g. *S. vermiculata*, which indicate possible use in nutraceuticals. Phytochemicals found in the halophyte species local to the UAE have also been reported to be present in halophyte species in other regions of the world, which includes antioxidants (e.g. hydroxycinnamic acids and their derivatives) found in *Salicornia spp.* growing in Europe or Korea (Chung et al., 2005; Lellau and Liebezeit, 2001).

**Conclusion**

The findings in the reviewed papers show great potential for coastal halophytes of the United Arab Emirates to be used as raw material in biorefinery processes where biofuels production from the plants macronutrients (carbohydrates) is combined with production of value added products such as additives for food and feed industry and/or nutra- and pharmaceuticals. Also of interest is the fact that there have been several new halophyte species described recently in the Gulf region, and as of yet there have been no studies on the phytochemical content of these species. Phytochemicals have been found in closely related species, indicating that these new species may also be a source of useful compounds.

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