



# Halophytes as Food

## Gastroethnobotany of Halophytes

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## Abstract

The halophytes are a specialized group of plants among which there are some representatives that have been cultivated for millenia. Domesticated or wild lineages are also consumed as food, being chard and dates fruits a good example of it. Other species highly appreciated and consumed locally are collected from wild, like *Crithmum*, and form part of the traditional cuisine of various areas of the planet. Within this group, some are the object of global cultivation and are distributed by haute cuisine networks such as *Salicornia*, *Mertensia*, or *Tetragonia*. Finally, there are other wild halophytes that were only consumed in situations of extreme need such as famines. Generally, they have not been appreciated by the populations that collect them, such as *Halosarcia*, *Suaeda*, or *Arthrocnemum*. The case of *Tetragonia*, a species native to Australia, is very significant. The perception of the aborigines, who did not eat it, was different from that of the European settlers who did consume them and even sent their seeds to Europe for domestication and cultivation as new vegetable. Currently, the new gastronomy, sometimes based on tradition and others on experimentation itself, has incorporated into the kitchen many news halophytes and with them has developed numerous unpublished and novel recipes.

## Keywords

Ethnobiology · Edible halophytes · Modern gastronomy · Wild food plants · Famine diet

## 1 Introduction

### 1.1 History of Halophytes as Food

A halophyte is a salt-tolerant plant that grows in soil or waters of high salinity usually coastal ecosystems like beaches, seashores, rocky shores, estuaries, salt marshes, and lagoons. These plants are exposed to highly fluctuating abiotic constraints, namely, salinity, drought, light intensity, and temperature, among others (Guerreiro 2018). Halophytes are consumed for their organoleptic and/or medicinal properties (Barreira et al. 2017). Until today over 7000 species have been recorded to be edible (Shikov et al. 2017), but very few are strict halophytes. Among other works, the halophyte database (eHALOPH. 2019) was used to select the species that would support a salt concentration above 50 dS/m or maximum salinity. Species that support high salinity were studied.

Saline ecosystems are no good areas for crop production, which is why wild halophytes have not made a great contribution to human food except in times of famine (Bubenicek 2001; Low 1991; Tardío et al. 2018b). However, saline habitats are the place of origin of some important crops worldwide such as chard and dates fruits. Also other wild halophytes with a wide distribution around the world are well-known in the traditional cuisine in many countries, and today, they are part of some recipes in modern restaurants. Edible halophytes may be contained in any of the following categories:

- Old main cultivated halophytes (*Beta vulgaris* L. s.l. and *Phoenix dactylifera* L.)
- Wild gathered halophytes locally appreciated as food (*Crithmum maritimum* L., *Salicornia* sp.)
- Relatively modern and widely cultivated halophytes (*Tetragonia tetragonioides* (Pall.) Kuntze, *Mertensia maritima* (L.) S.F. Gray).
- Wild gathered halophytes only eaten in times of famine (*Sarcocornia*, *Halosarcia*, etc.)
- Wild gathered halophytes now used and introduced in the nouvelle cuisine (*Mesembryanthemum*, *Limonium*, *Suaeda*, etc.)

The main sources for this group of edible plants are the old treaties of gastronomy, medicine, and agriculture where information is found directly or indirectly. There are numerous compilations on edible plants with extensive listings, but usually only appears little information about it. Other relevant sources consulted are the ethnobotanical studies and also the publications or communiqués from Gourmets to include the modern uses.

Around the Mediterranean Sea the historical gastronomic sources, although some agricultural treaties also have food or dietary references, always refer to the kitchens of kings and aristocrats (Bottéro 1985; Bottéro 2005; Manniche 1989; Tallet 2005; Apicius 1995; Meana et al. 1998; Bolens 1981; Huici Miranda 1966; Badi 1985; Zabala 2007; Agustín 1722; Martínez Montañó 1763; Martínez Llopis 1998). Just some old cookbooks made by monks (Altamiras 1822; Hayward 2017; San Valentín



**Fig. 1** Wild halophytes gathered as food for modern dishes in nouvelle cuisine. (a) Iceplant (*Mesembryanthemum crystallinum*) in coastal areas of Alicante (Spain); (b) Iceplant (*M. crystallinum*), details of glands; (c) and (d) Slenderleaf iceplant (*M. nodiflorum*) in coastal areas of Alicante (Spain); (e) New Zealand spinach (*Tetragonia cristata*) in coastal sands of Pemberton,

2001; de Pardo 1913) and the modern ethnobotanical approach (Sánchez-Mata and Tardío 2016; Pardo de Santayana et al. 2014, 2018a, 2018b, 2018c; Tardío et al. 2018a) can illustrate us about the kitchen of the poor or the ordinary people.

In Western culture, the oldest gastronomic well preserved data back to the first century with *De Re Coquinaria* of Apicius (the original text consulted had modifications until the fourth century). Prior to this time, there is scattered information about the Egyptian and Mesopotamian kitchens. Of the latter, from around the seventh century BC (Bottéro 1985, 2005), some recipes are known and also many ingredients and cooking methods. Dates (*Phoenix dactylifera* L.) stand out as one of the most consumed fruits (Bottéro 1985, 2005; Rivera et al. 2012b; Obón et al. 2018) from halophyte plant and sometimes used as recipe ingredients (Apicius 1995; Meana et al. 1998; Bolens 1981; Huici Miranda 1966; Badi 1985).

Saline environments of the Mediterranean Basin were the origin of chard (*Beta vulgaris* L. var. *cicla* L.) and beets (*Beta vulgaris* L. var. *esculenta* L. and *B. vulgaris* L. var. *vulgaris*), and they are cultivated throughout the world (Wyk 2006; De Candolle 1883; Zohary and Hopf 2000; Heywood and Zohary 2005). Today it is still possible to find them in the wild or as a weed living together in the same orchards with others closely related (*Beta maritima* L., *B. macrocarpa* Guss.). All of them are collected now and consumed as excellent vegetables (Zohary and Hopf 2000; Brouk 1978).

Another great food resource linked to saline habitat is the palm tree (*Phoenix dactylifera* L.). Its fruits, sap, and tender shoots are consumed as food in the entire circummediterranean area since centuries (Wyk 2006; De Candolle 1883; Zohary and Hopf 2000; Heywood and Zohary 2005; Rivera et al. 2012b). In the fourth century, Casiano Baso recommends digging the palm trees every year (Rivera et al. 1996; Rivera et al. 2012a). Today, it is still a salt-tolerant crop in many countries of the world (De Candolle 1883; Brouk 1978; Zohary and Hopf 2000; Rivera et al. 2012a), adding salt to them to grow better (Meana et al. 1998). Although the fruits are the main product of the palm tree and were very appreciated by the Roman patrician tables, their roasted bones were used also as an adulterant of Liburnian oil (Apicius 1995). Other products, such as the sap or tender shoots called “palmito,” were appreciated in the old aristocratic tables of Spain (De Villena 1766), and today in a residual way it is eaten in the palm groves of the Southeast of Spain (Obón et al. 2018). In the Middle Ages in Al-Andalus they were an irreplaceable fruit as food (Bolens 1981; Huici Miranda 1966; Badi 1985), and in Spain until the seventeenth century (Martínez Montaña 1763), there is a food continuity with this product.

In other order of importance, the New Zealand Spinach [*Tetragonia tetragonioides* (Pall.) Kuntze], an Australian wild halophyte was domesticated as a vegetable in the late nineteenth century. It was discovered by Captain Cook and by



**Fig. 1** (continued) Western Australia; (f) *Aizoanthemum hispanicum* (= *Aizoon hispanicum*) in coastal areas of Alicante (Spain). (Authors of the photographs: a and c (D. Ariza); e (S. Ríos), b, d, and f (E. Laguna))



**Fig. 2** Wild halophytes gathered as food for traditional and modern dishes. (a) and (b) Sea fennel (*Crithmum maritimum*) wild in the sea cliffs habitats of Alicante and Valence provinces; (c) and (d) Sea rocket (*Cakile maritima*) colonized sandy beach of Rottneest Island (Western Australia, left) and from a sandy beach in El Saler, Valencia (Spain, right); (e) and (f) Wavyleaf sea (*Limonium sinuatum*), both wild and cultivated, showing the growth of its leaves or edible part under

Joseph Banks in 1770, who sent seeds to Kew Botanical Garden (Low 1991). Since its introduction in the botanical gardens, it is very popular in the Western countries (Hedrick 1972; Wyk 2006), but curiously it was never eaten by the Australian aborigines (Low 1991). However it is currently much appreciated there and appears in the menu of modern Australian restaurants with the name of “Warrigal greens” (Fig. 1e).

The oyster plant [*Mertensia maritima* (L.) Gray] is one of the rarest edible wild plants of North Europe really tastiest, with its bluish succulent leaves that remember the oysters taste (Milliken and Bridgwater 2006) and its use in modern cuisine become popular worldwide. Root and leaves are eaten also in North America (Bubenicek 2001). The glasswort or marsh samphire [*Sarcocornia perennis* (Mill.) A.J.Scott.] is gathered in the UK and sold for high price in smart fishmongers. Similar edible uses present the sea beet (*Beta maritima* L.) and sea kale (*Crambe maritima* L.) gathered wild and sometimes cultivated for news recipes (Bubenicek 2001; Milliken and Bridgwater 2006).

Another well-known edible halophyte, sea fennel (*Crithmum maritimum* L.), is frequently used as a local food or in special dishes popular in many Mediterranean countries (Tardío et al. 2018b; Peris et al. 2019; Orengo 2016; Pellicer 2000; Ariza 2019) and north European coast (Bubenicek 2001; Milliken and Bridgwater 2006). This plant is used to improve taste of prickled olives and also for aromatized flavor of herbal liquor (Pellicer 2000; Martínez Francés and Ríos 2005; Orengo 2016).

But apart from these exceptional cases, the most frequent among edible halophytes is their occasional consumption raw or pickled mainly in times of famine. In Australia the earliest settlers scoured the countryside for wild vegetables and plants, finding edible halophytes similar to Europeans (Low 1991). Many genera such as *Suaeda*, *Halosarcia*, *Sarcocornia*, and *Gunnera* belong to this range easily recognizable by Europeans (Fig. 3) and covering large areas in saline desert zones of the central part or the coastal side of Western Australia (Mitchell and Wilcox 1998; Gardner 1990). Curiously were rarely or never eaten by aborigines who considered these plants “made known by the white man” (Low 1991).

Concluding, only a few species of halophytes are worldwide eaten as fruit or vegetables raw, pickled, or cooked and used for traditional food (Hedrick 1972; Facciola 1998; Bubenicek 2001; Wyk 2006). A relatively high number of halophytes are locally consumed as food, but only known as emergency food in times of famine diet (Hedrick 1972; Facciola 1998; Bubenicek 2001). However, some of them are appreciated in traditional dishes (Tardío et al. 2018b; Peris et al. 2019; Orengo 2016; Pellicer 2000). Now, nouvelle cuisine experiments with several halophytes looking for new tastes, flavors, textures, and colors and incorporates them into their modern recipes on the menu of many important restaurants (Ariza 2019).



**Fig. 2** (continued) cultivation conditions (Alicante, Spain). (Authors of the photographs: a (D. Ariza); c (S. Ríos), b, d (E. Laguna), e, f (C. Obón))



**Fig. 3** Wild halophytes used as food or fodder in Western Australia. (a) Sweet samphire (*Gunnipopsis quadrifolia*); (b) Australian iceplant (*Aizoon* sp.); (c) Tidal mudflat or Australian samphire (*Halosarcia* gr. *doloiformis*); (d) Inland pigface (*Sarcocoma* gr. *praecox*); (e) Globose samphire (*Sarcocornia* gr. *globosa*); (f) *Atriplex* and *Halosarcia* salt dune plant community. Saline succulent's plants of Western Australia: (a, b, c and d) Kalgoorlie salt plains (e) and (f) coastal saline dunes of Rottnest Island. (Author of the photographs: S. Ríos)

## 2 Relevant Edible Halophytes

The main parts used of edibles halophytes are the leaves and young stems, eaten as vegetables. Second ones are fruits, flowers, roots, sap, or others which are used less frequently. It is possible to organize the most significant edible halophytes into categories of use according to the part of the plant consumed. This organization



also allows the identification of the species widely used, from those that could be considered as local food.

## 2.1 Rhizomes, Roots

***Cakile maritima* Scop.** [Sea rocket]. Brassicaceae.

Roots are grounded, mixed with flour, and eaten during times of scarcity (Facciola 1998; Bubenicek 2001). Used as a substitute for bread flour (Bubenicek 2001).

***Conicosia pugioniformis* (L.) N.E. Br.** [Pigroot, Narrow-leaved iceplant]. Aizoaceae.

The young rootstock is consumed in South Africa, often boiled (Phillips and Rix 1995; Hartmann 2001; Oliver 2019).

***Mertensia maritima* (L.) Gray** [Oyster plant, Sea bugloss]. Boraginaceae.

Rhizomes are consumed as food by the Eskimos of Alaska (Facciola 1998; Bubenicek 2001).

***Phragmites australis* (Cav.) Trin. ex Steud.** [Common reed grass, Wild broom-corn]. Poaceae.

The rhizomes are sometimes cooked like potatoes (Facciola 1998). Underground parts are a source of starch (Rivera et al. 2012b). Used as a substitutes for bread flour (Bubenicek 2001). The halophyte populations of this species are often included in *P. australis* subsp. *altissimus* (Benth.) Clayton [= *P. australis* subsp. *chrysanthus* (Mabille) Soják].

## 2.2 Stems and Leaves

***Apium prostratum* Labill. ex Vent.** [Sea celery]. Apiaceae.

The leaves and stems are eaten in Albany (Western Australia), and it was even cultivated as a vegetable (Low 1991).

***Asparagus prostratus* Dumort** [Atlantic wild asparagus]. Asparagaceae.

Young sprouts are like those of the cultivated asparagus *A. officinalis* L. and are eaten in the same way. This species mainly grows on the Atlantic coastal cliffs and dunes from Northern Spain to Great Britain and Germany (Phillips and Rix 1995; López Anido and Cointry 2008).

***Atriplex cinerea* Poir.** [Grey saltbush]. Amaranthaceae.

In Australia, its edible leaves, able to tolerate a maximum of 56 dSm salinity, should always be cooked before eating (Low 1991; Bubenicek 2001).

***Atriplex halimus* L.** [Sea orache, Sea purslane]. Amaranthaceae.

Young leaves and tips of branches are eaten raw in salads or used in soups, casseroles pastas, quiches, and vegetable dishes (Facciola 1998; Bubenicek 2001). In northern Europe they tend to season with this plant (Lagasca 1817). It was widely used in Egypt. The men of the Euphrates Expedition (1836) often used this species as a culinary vegetable (Hedrick 1972). Its cooked leaves are eaten as vegetables,

standing out for its salty and somewhat astringent taste. Most of its nature is warm and favorable, with a moisture that cannot be well digested and somewhat flatulent (López 2020).

***Atriplex glauca* L.** [Waxy saltbush]. Amaranthaceae.

This plant has been consumed in Spain often boiled (Lagasca 1817; Peris et al. 2019).

***Atriplex portulacoides* L. [= *Halimione portulacoides* (L.) Aellen]** [Sea purslane]. Amaranthaceae.

Leaves are eaten raw in salads or cooked as a potherb. They are thick and succulent and have a good crunchy texture and natural saltiness (Facciola 1998; Bubenicek 2001). The tender shoots are collected and preserved in vinegar in a similar way to capers (Lagasca 1817).

***Beta vulgaris* L. subsp. *maritima* (L.) Arcang.** [Wild sea beet, Sea spinach]. Amaranthaceae.

Young tender leaves are eaten in salads. In the famous recipe Apicius book of the first century (Apicius 1995), there are numerous recipes with chard, probably wild sea beet. Throughout Spanish history wild sea beet are present in the traditional diet (Columela 1959; Meana et al. 1998; Martínez Montiño 1763; Agustín 1722; De Aviñón 2000; Huici Miranda 1966; Herrera 1996; Bassal 1995; Altamiras 1822; Asin Placios 1943; Banqueri 1802; Badi 1985). Older leaves are boiled or steamed and used as a spinach substitute (Bubenicek 2001). The flavor is considered to be superior to the cultivated beets and chards (Seijo Alonso 1973; Facciola 1998; Pellicer 2000; Orengo 2016; Peris et al. 2019). In Murcia and Alicante (Spain), this plant is a highly appreciated food (García Abellán 1980) and appears in many traditional recipes (Seijo Alonso 1973). In Alicante, there is a traditional dish with wild vegetables called “minxos” or “cocas,” which remember a rustic pizza where wild sea beet is an important ingredient (Ríos et al. 2009). According to Rivera and Obón (2004), sea spinach has been eaten in Murcia since the Paleolithic times. Also, the wild sea beet contains less Na and more Mg and good polyphenols than cultivated one (Romojaro et al. 2013; Pretel and Obón 2009).

***Cakile maritima* Scop.** [Sea rocket]. Brassicaceae.

Young leaves and stems (Fig. 2c and d) are eaten raw in salads and sandwiches or mixed with milder greens for use as potherbs or seasoning (Facciola 1998). As the leaves have a unique, slightly alkaline, bitter mustard flavor, it should be eaten raw (Mears and Hillman 2007).

***Carpobrotus edulis* (L.) N. Br.** [Hottentot figs]. Aizoaceae.

Leaves can be eaten raw or boiled, added to salads or fried (Phillips and Rix 1995; Bubenicek 2001; Cordero et al. 2017).

***Crambe maritima* L.** [Sea kale, Scurvy grass]. Brassicaceae.

It appears to have been known by Romans, who gathered it in wild next to the North Sea and preserved it in barrels to be consumed afterward in long voyages (Hedrick 1972; Meana et al. 1998). At the end of the eighteenth century, the bleached leaves were prepared covering them with sand, and once boiled they constituted an exquisite dish (Rivera and Obón 1991). The bleached leafstalks are eaten raw in

salads, boiled, baked, and braised or otherwise prepared as asparagus (Bubenicek 2001; Phillips and Rix 1995). When properly cooked they retain their firmness and have a very agreeable flavor, somewhat like that of hazelnuts, with a very slight bitterness. The leaves can be boiled until soft, minced, and seasoned with garlic and served as spinach (Facciola 1998).

***Crithmum maritimum* L.** [Samphire, Rock samphire, Sea fennel, Criste marine]. Apiaceae.

It is traditionally used in many countries as vegetable with interesting sensory attributes (Rennan and Gonnella 2012). It was cultivated in the garden of John Gerard (1596–1599) in England. In France it has been cultivated since 1690, cited by Quintyne, for its leaves which are pickled in vinegar and are consumed in salads and as seasoning (Hedrick 1972). The whole plant has a spice taste with certain saltiness. It has been long held in great repute as ingredient of salad. The leaves are salty and slightly spicy. Leaves are pickled in vinegar and added to salads or used like capers for flavoring some foods. In Italy and Greece, the leaves are washed, cut in pieces, and mixed with lemon juice and olive oil to prepare a salad dressing (Facciola 1998). As a vegetable, tender stems have been consumed in salad in Spain, but its most widespread consumption is in brine or vinegar (Tardío et al. 2018b; Peris et al. 2019). It is used also as potherb by the poor people as well as a pickle (Hedrick 1972). It grows wild on maritime rocks, piers, break water, sands, and beaches and was used by sailors during food preparation as protection against scurvy (Cunsolo et al. 1993). But on longer voyages the leaves were apparently kept pickled in vinegar for better preservation (Atia et al. 2011). It is a potent source of minerals, vitamin, and other biomolecules (Rennan and Gonnella 2012).

***Cynomorium coccineum* L.** [General's root, Desert thumb, Maltese mushroom] Cynomoriaceae.

This edible plant is considered so sweet (Leonti et al. 2019; Sdiri et al. 2018; Verde et al. 2018; Dharmananda 2011).

***Enchylaena tomentosa* R.Br.** [Ruby saltbush, Barrier saltbush]. Amaranthaceae.

The leaves are eaten as a vegetable in Australia, after boiled (Low 1991; Bubenicek 2001).

***Halogeton sativus* (L.) Moq.** [Barrilla, Barrilla Fina]. Amaranthaceae.

This plant has been consumed in Spain (Lagasca 1817; Peris et al. 2019).

***Halosarcia indica* (Willd.) Paul G. Wilson** [Tidal mudflat]. Amaranthaceae.

The stems were pickled by New South Wales settlers in Australia (Low 1991; Bubenicek 2001).

***Limbarda crithmoides* (L.) Dumort (= *Inula crithmoides* L.)** [Golden samphire]. Compositae.

Young leaves are occasionally eaten as a potherb. The fleshy leaves and young shoots were formerly pickled in vinegar and added to salads as a relish. They were used as adulterant of true samphire (*Crithmum maritimum*) (Facciola 1998). The leaves are pickled and eaten as condiment (Hedrick 1972).

***Limonium sinuatum* (L.) Mill.** [Wavyleaf sea lavender, Sea pink]. Plumbaginaceae.

Green and tender stems and leaves have been consumed raw or cooked in Spain (Alcaraz et al. 2018). This plant is consumed raw as a food plant in Cyprus and Bodrum area of Turkey (Della et al. 2006).

***Lycium europaeum* L.** [European boxthorn]. Solanaceae.

Leaves have been consumed as a vegetable in China (Bubenicek 2001).

***Mertensia maritima* (L.) Gray** [Sea bugloss, Oyster plant]. Boraginaceae.

It was consumed by the Eskimos of Alaska (Bubenicek 2001). The fleshy leaves, whose taste has given the name of oyster plant, are eaten raw and cooked. They are especially good cooked with eggs (Facciola 1998).

***Mesembryanthemum crystallinum* L.** [Iceplant, Ficoide glaciale]. Aizoaceae.

This plant was introduced into Europe from Cape of Good Hope in 1727 (Fig. 1a and b). In America, it is advertised in a seed list of 1881 as a desirable vegetable for boiling like spinach or for garnishing. In France, Vilmorin cited that the slightly acid flavor of the fleshy parts of the leaves have made it to be used as a fresh summer table vegetable. This species is growing in southern California (Hedrick 1972). The acid, succulent, salty leaves are eaten raw in salads, boiled as potherbs, made into pickles like cucumbers or used as a garnish (Facciola 1998; Bubenicek 2001). The leaves are consumed raw, or they can be frozen (Couplan 2007). Young shoots are also picked through winter and spring in cold sites (Phillips and Rix 1995; Tembo-Phiri 2019).

***Mesembryanthemum nodiflorum* L.** [Slenderleaf iceplant, Ficoide glaciale]. Aizoaceae.

Consumed like *M. crystallinum* (Peris et al. 2019). In fact one of the authors (D. A.) uses this species in its recipes (Fig. 1c and d).

***Phoenix dactylifera* L.** [Date palm]. Arecaceae.

The eaten part is the palm hearts (Facciola 1998), the large and succulent head cut from among the mass of leaves (Hedrick 1972). During the fifteenth century, tender hearts of palm called “palmito” were a luxury food at the Spanish aristocratic tables (De Villena 1766).

***Phoenix reclinata* Jacq.** [Senegal date]. Arecaceae.

The terminal bud is used as a vegetable (Facciola 1998).

***Phragmites australis* (Cav.) Trin. ex Steud.** [Common reed grass, Wild broom-corn]. Poaceae.

The young shoots are eaten like bamboo sprouts or pickled. The dried stem was turned into a marshmallow candy by North American Indians. The partly unfolded leaves can be eaten as a potherb (Facciola 1998). Tender leaves and shoots are consumed in the Caucasus (Rivera et al. 2012b).

***Plantago maritima* L.** [Seaside plantain, Sea plantain]. Plantaginaceae.

Leaves are occasionally eaten in salads, cooked like spinach, boiled in broths, or pickled like samphire. In Alaska they are canned for winter use (Facciola 1998).

***Salicornia europaea* L.** [Saltwort, Glasswort, Marsh samphire, Pickle weed, Sea bean, Perce-pierre]. Amaranthaceae.

The genus *Salicornia* L. (Fig. 3), formed by annual plants, produce succulent shoots which are highly appreciated in gourmet cuisine due to its salty taste (Phillips

and Rix 1995; Barreira et al. 2017). Its young salty stems and leaves are eaten raw in salads, cooked as a potherb, pickled, added to soups, or used as a garnish (Bubenicek 2001). To pickle the tender stems and branches, it is necessary to boil them first in their own salted water before putting them in spiced oil or vinegar (Facciola 1998; Bubenicek 2001). In the UK, *Salicornia* has a long history of human consumption as a vegetable and in pickles (Davy et al. 2001), so it has long been collected for eating, as samphire (Chevalier 1922).

***Salicornia ramosissima* J.Woods** [Purple glasswort]. Amaranthaceae.

The sprouts are steamed and subsequently added to salads or other stews in Valencian region (Spain) (Peris et al. 2019). It is also used locally brined in vinegar (Bubenicek 2001). In the UK *Salicornia* has been highly consumed as samphire (Davy et al. 2001; Chevalier 1922).

***Salsola kali* L.** [Russian thistle, Tumbleweed]. Amaranthaceae.

Young shoots are eaten raw in salads, put in soups or boiled and eaten like spinach (Facciola 1998; Bubenicek 2001). They make an excellent vegetable when served with butter, vinegar or lemon juice, bacon strip, or hard-boiled egg slices, or a cream. Because of their mild flavor, it can be mixed with stronger flavored greens such as mustard (Facciola 1998).

***Salsola soda* L.** [Barilla plant, Agretti, Roscano, Riscolo, Almiros]. Amaranthaceae.

The succulent tender young shoots are boiled or steamed and then served with olive oil and lemon juice. It is much appreciated for its slightly sour flavor. In Umbria and other parts of central Italy, it is considered a delicacy, and it is sold in local markets in spring (Facciola 1998). Also it is grown in Japan as vegetable (Rivera and Obón 1991; Bubenicek 2001). Almiros is sold in markets of Greece for salads.

***Sarcocornia quinqueflora* (Bunge ex Ung.-Sternb.) A.J. Scott** [Australian samphire]. Amaranthaceae.

The genus *Sarcocornia* L. is formed by perennial plants, which produce succulent shoots with salty taste, highly appreciated in gourmet cuisine (Phillips and Rix 1995; Barreira et al. 2017). In Australia settlers and convicts used the stems as an emergency food (Low 1991).

***Sesuvium portulacastrum* (L.) L.** [Sea purslane, Gelang pasir]. Aizoaceae.

The leaves are eaten raw or cooked (Facciola 1998; Bubenicek 2001). Also they are pickled like samphire, in vinegar in the Antylles (Bubenicek 2001) and in North America (Fernald and Kinsey 1996). The leaves should be rinsed in water to remove some salty taste. It is a source of vitamin C (Facciola 1998). It is regularly sold in Chinese and Indonesian markets (Fernald and Kinsey 1996).

***Suaeda spicata* (Willd.) Moq.** [Seablite]. Amaranthaceae.

Leaves and stems are taken cooked in stews or simply boiled and consumed with a little olive oil (Rivera et al. 2008).

***Suaeda australis* (R. Br.) Moq.** [Seablite]. Amaranthaceae.

Settlers used the leaves as a vegetable and pickles in Australia (Low 1991).

***Suaeda maritima* (L.) Dumort** [Seablite]. Amaranthaceae.

In India and other countries, the leaves and tender growing tips are eaten as a cooked vegetable after some of its saltiness has been removed. The salty leaves can be added to other foods to season them (Rivera and Obón 1991). Young shoots are pickled in vinegar and eaten alone or used as a relish (Facciola 1998).

***Tetragonia decumbens* Mill.** [Dune Spinach]. Aizoaceae.

It is consumed, as *T. tetragonioides*, raw or cooked, in salads (Tembo-Phiri 2019). Its cultivation as a vegetable was developed in Britain, France, and the USA at the beginning of the nineteenth century. It is currently grown in various areas around the world (Couplan 2007).

***Tetragonia implexicoma* (Miq.) Hook. f.** [Bower spinach]. Aizoaceae.

This plant is used as *T. tetragonioides*, consumed in salads (Low 1991; Bubenicek 2001).

***Tetragonia tetragonioides* (Pall.) Kuntze** [New Zealand spinach, Summer spinach]. Aizoaceae.

During the nineteenth century, it became popular in England and North America as a spinach substitute (Phillips and Rix 1995). It is used in salads, cooked or raw (Bubenicek 2001). In Japan the young *Tetragonia* leaves are dried, ground, and mixed with cereal flour to make dumplings. It is naturalized in Eastern North America and used as a potherb (Fernald and Kinsey 1996).

***Thespesia populnea* (L.) Sol. ex Corrêa** [Portia tree, Seaside mahoe, Milo]. Malvaceae.

Young leaves are eaten raw, boiled, or put in soups (Facciola 1998).

## 2.3 Flowers

***Cakile maritima* Scop.** [Sea rocket]. Brassicaceae.

Flower buds and unripe pods are eaten raw in salads and sandwiches or mixed with milder greens for use as potherbs or seasoning (Facciola 1998).

***Crambe maritima* L.** [Sea kale]. Brassicaceae.

The inflorescences are the equivalent of the florets on sprouting broccoli, and they have a similar taste. It is necessary to pick them, while the flowers are still a bud (Mears and Hillman 2007), or cultivate under shaded covers (i.e., black plastics) in order to promote the production of sprouts (Phillips and Rix 1995; Vaughan and Geissler 1997).

***Crithmum maritimum* L.** [Samphire, Rock samphire, Sea fennel, Criste marine, Hinojo marino]. Apiaceae.

Its flowers are eaten in salads (Facciola 1998).

***Phoenix dactylifera* L.** [Date palm]. Arecaceae.

The male inflorescence is eaten as a delicacy. Its pollen is also eaten (Facciola 1998).

***Thespesia populnea* (L.) Sol. ex Corrêa** [Portia tree, Seaside mahoe, Milo]. Malvaceae.

Flowers and flower buds may be eaten raw, cooked, or dipped in batter and fried (Facciola 1998).

## 2.4 Fruits

***Atriplex semibaccata* R.Br.** [Ruby saltbush, Barrier saltbush]. Amaranthaceae.

Eaten as *Enchylaena tomentosa* by the Wiradjuri aborigines in Australia; the red berries are consumed in raw (Greenwood 2014).

***Cakile maritima* Scop.** [Sea rocket]. Brassicaceae.

The immature fruits are eaten, although they are exceedingly bitter (Mears and Hillman 2007).

***Carpobrotus edulis* (L.) N. Br.** [Hottentot figs]. Aizoaceae.

Fleshy fruits are sourish taste, but they are often eaten raw, dried, or made into jam or syrup (Phillips and Rix 1995; Hartmann 2001; Guillot et al. 2009; Cordero et al. 2017; Bubenicek 2001).

***Carpobrotus aggr. Acinaciformis* L. Bolus** [Hottentot figs]. Aizoaceae.

Fleshy fruits are sourish taste, as fruits of *C. edulis*, so they are consumed in the same way (Phillips and Rix 1995; Hartmann 2001; Guillot et al. 2009; Cordero et al. 2017; Bubenicek 2001).

***Carpobrotus glaucescens* (Haw.) Schwantes** [Pigface, Australian pigface]. Aizoaceae.

The fruits become red when mature and are eaten raw, having a fig-like flavor (Hartmann 2001; Leech 2012; Bubenicek 2001).

***Coccoloba uvifera* (L.) L.** [Sea grape]. Polygonaceae.

The fruits, commonly sold in markets, are eatable. They are reddish purple or occasionally off-white, pear-shaped, juicy, and sweetish acid flavor (Hedrick 1972). They can be eaten out of hand or used for juice, jams, jellies, drinks, soups, and syrups. Sea grape jelly has an attractive musky flavor and a distinctive light lavender color. A potent wine of good flavor can also be made from the fruits in Florida and Caribbean region (Facciola 1998).

***Enchylaena tomentosa* R.Br.** [Ruby saltbush, Barrier saltbush]. Amaranthaceae.

The fruits are eaten by the aborigine Australian people (Bubenicek 2001; Greenwood 2014).

***Nitraria billardierei* DC.** [Nitrate]. Nitrariaceae.

Its fruits are eaten and they have a taste like salty grapes in Australia (Low 1991).

***Phoenix dactylifera* L.** [Date palm]. Arecaceae.

The ripe fruits are eaten out of hand, in breads cakes, pastry confectionery, pickles, syrups. Also unripe fruits are pickled (Facciola 1998).

***Phoenix paludosa* Roxb.** [Bengal date palm]. Arecaceae.

Fruits are eaten in curries (Facciola 1998).

***Phoenix reclinata* Jacq.** [Senegal date]. Arecaceae.

Ripe fruits are sweet and tasty and are eaten raw (Facciola 1998).

***Sarcozona praecox* J.M. Black.** [Inland Pigface]. Aizoaceae.

Fruits are edibles in Australia (Bubenicek 2001). They were consumed in raw by Wiradjuri aborigines during the summer (Fig. 3d). The salty tasting leaves were consumed as vegetable, fresh, or cooked. The leaves were squeezed to drink their juice (Greenwood 2014).

***Tetragonia implexicoma* (Miq.) Hook. f.** [Bower spinach]. Aizoaceae.

Its fruits are edible in Australia (Low 1991).

*Thespesia populnea* (L.) Sol. ex Corrêa [Portia tree, Seaside mahoe, Milo]. Malvaceae.

The fruit are eaten preserved (Facciola 1998).

## 2.5 Seeds

*Atriplex canescens* (Pursh) Nutt. [Cenizo, Fourwing saltbush]. Amaranthaceae.

A species from the USA and Mexico, whose seed is ground into meal to be used as flour, or as a beverage (Fletcher 2016).

*Atriplex confertifolia* (Torr. & Frém.) S. Watson [Shadscale]. Amaranthaceae.

A bush with close distribution to *A. canescens*, whose seed is also converted into flour (Fletcher 2016).

*Atriplex hortensis* L. [Orache]. Amaranthaceae.

An ancient vegetable used in the Old World, whose seed has been reported as source of flour. According to Fletcher (2016), its flour is used in soups and muffins. It is also reported of its high content of vitamin A.

*Atriplex patula* L. [Halberd-leaved saltbush]. Amaranthaceae.

A short-lived circumboreal plant, reported by Fletcher (2016) as a source of flour obtained from their seeds, which the Zuni Indians of the USA mixed with corns and steamed as meat balls.

*Atriplex prostrata* Boucher ex DC. [Hastate saltplant]. Amaranthaceae.

Distributed mainly in the Old World, the seed is ground into flour for use in bakery (Fletcher 2016).

*Haloxylon salicornicum* (Moq.) Bunge ex Boiss. [Rimth saltbush]. Amaranthaceae.

A salt bush that grows from North Africa to Pakistan and India, whose seeds are mixed with other grains to make bread in India (Fletcher 2016), making special *chapatti* locally called *dhokla* (Singh et al. 2015).

*Phoenix dactylifera* L. [Date palm]. Arecaceae.

The seeds are occasionally eaten or pressed for the oil (Facciola 1998). In the historical gastronomy book of Apicius (first century), the bones of toasted dates appear in the formula of the wonderful wine with spices (Apicius 1995).

*Phoenix paludosa* Roxb. [Bengal date palm]. Arecaceae.

The seed is edible (Facciola 1998).

*Phragmites australis* (Cav.) Trin. ex Steud. [Common reed grass, Wild broom-corn]. Poaceae.

Although difficult to remove from its hull, the grain is said to be very nutritious (Facciola 1998).

*Phoenix reclinata* Jacq. [Senegal date]. Arecaceae.

Seeds are used as a coffee substitute (Facciola 1998; Bubenicek 2001).

*Salicornia europaea* L. [Saltwort, Glasswort, Marsh samphire, Pickle weed, Sea bean, Perce-pierre]. Amaranthaceae.

The protein-rich seeds are eaten and can be refined into high-quality edible oil similar to safflower oil (Facciola 1998).



***Scirpus maritimus* L.** [Saltmarsh bulrush, Chid, Dila]. Cyperaceae.

Fletcher (2016) reports that the seeds are eaten raw or crushed, turned into flour, and mixed with millet in India.

***Suaeda corniculata* (C.A. Mey.) Bunge** [Seepweed]. Amaranthaceae.

According to Fletcher (2016), the seeds are eaten raw in Manchuria. This use is also reported for the seeds of *Suaeda heteroptera* Pall.

***Tecticornia verrucosa* Paul G. Wilson.** [Mangil, Samphire]. Amaranthaceae.

Its small seeds were ground into flour and are used for making bread by the aborigines of Australia (Facciola 1998; Lourandos 1997; Laudine 2009).

## 2.6 Sap

***Atriplex halimus* L.** [Sea orache, Sea purslane]. Amaranthaceae.

It is one of the sources of an edible manna (Facciola 1998).

***Haloxylon salicornicum* (Moq.) Bunge ex Boiss.** [Rimth saltbush]. Amaranthaceae.

Its sweet exudate obtained during the summer in the Middle East is used as food sweetener (Singh et al. 2015).

***Phoenix dactylifera* L.** [Palm date]. Arecaceae.

The sap is sweet and may be used as a drink or distilled into a kind of spirit (Hedrick 1972; Bubenicek 2001).

***Phoenix reclinata* Jacq.** [Senegal date]. Arecaceae.

The sap is fermented into a palm wine (Facciola 1998).

***Phragmites australis* (Cav.) Trin. ex Steud.** [Common reed grass, Wild broom-corn]. Poaceae.

A sugary gum exuded from the stem is rolled into balls and eaten as a sweet (Hedrick 1972; Facciola 1998). The gum is a sweet, manna-like substance (Hedrick 1972). The tender young shoots of common reed grass are chewed like sugarcane in the near East (Rivera et al. 2012b).

***Salsola komarovii* Iljin** [Oka Hijiki]. Amaranthaceae.

It is said to be one of the oldest vegetables of Japan. It has a very crunchy texture and need to be slightly saline for a pleasant taste. It is cultivated in Japan as vegetable for traditional cuisine.

***Tamarix canariensis* Willd.** [Tamarisk, Manna plant]. Tamaricaceae.

The sweet manna-like substance exuded from the stems is collected and mixed with flour, sugar, or honey and sweet almonds making a sweet cake that is baked (Facciola 1998).

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## 3 Culinary Use of Halophytes (Gastroethnobotany)

Many wild halophytes are consumed raw in salads, such as soups, boiled, sometimes in mixtures, and in many other ways, like fried, in omelettes, etc.

### 3.1 Salad

*Beta maritima* have been consumed in salads in Spain (Peris et al. 2019).

*Crithmum maritimum* is used for seasoning fish or salads in Marche, Apulia, Sicily, Sardinia and Lucania, in Italy (Guarrera and Savo 2016). In Spain the leaves are used for seasoning olives, raw in salads or pickled (Tardío et al. 2006).

*Halogeton sativus* have been consumed in salads in Spain (Peris et al. 2019).

*Limbarda crithmoides* is used in salads in Lucania, Italy (Guarrera and Savo 2016), and other countries (Bubenicek 2001).

*Lycium europaeum* tender leaves and stems are used in Spain raw or in salads (Tardío et al. 2006).

*Mesembryanthemum crystallinum* have been consumed in salads in Spain (Peris et al. 2019).

### 3.2 Soup

*Beta vulgaris* subsp. *maritima* is prepared in a chickpea soup in Sardinia, Italy (Guarrera and Savo 2016).

*Eryngium maritimum* is consumed in soups in Apulia, Italy (Guarrera and Savo 2016).

*Lycium europaeum* is used for soups in Lucania, Italy (Guarrera and Savo 2016).

### 3.3 Boiled

*Atriplex halimus* is used as substitute of spinach in Tuscany and Sardinia, Italy (Guarrera and Savo 2016).

*Beta vulgaris* subsp. *maritima* has been consumed boiled in Emilia-Romagna. Ravioli, gnocchetti sardi, are prepared with this plant, spinach and cheese, in the Oristano area of Sardinia, Italy (Guarrera and Savo 2016). Also, this species is used boiled in Spain (Peris et al. 2019).

*Crithmum maritimum* has also been consumed in Alicante and Menorca, Spain (Tardío et al. 2018b).

*Eryngium maritimum* has been consumed boiled in Apulia, Italy (Guarrera and Savo 2016).

*Limbarda crithmoides* is used for cooking pasta in Lucania, Italy (Guarrera and Savo 2016).

*Limonium sinuatum* tender stems and leaves have been consumed in a traditional stew with chickpeas “potaje de garbanzos” in Cabo de Gata area, Spain (Alcaraz et al. 2018; Tardío et al. 2006).

*Lycium europaeum* has been consumed boiled in Lucania and Sicily, Italy (Guarrera and Savo 2016). Its tender leaves and stems are consumed stewed in Spain (Tardío et al. 2006).

*Mesembryanthemum nodiflorum* is often consumed in Sardinia and in Spain (Guarrera and Savo 2016; Tardío et al. 2006).

*Salicornia europaea* is called Mpaniccia in Molise, Italy, where it has been consumed boiled (Guarrera and Savo 2016).

*Salicornia patula* has been consumed boiled as substitute for spinach in Tuscany, Italy (Guarrera and Savo 2016).

*Salsola kali* has been consumed boiled in Apulia, Italy (Guarrera and Savo 2016).

*Salsola soda* has been consumed boiled as *S. kali* in Apulia, Italy (Guarrera and Savo 2016).

*Suaeda spicata* leaves and stems are consumed boiled seasoned with olive oil (Rivera et al. 2008).

### 3.4 Seasoning

*Atriplex portulacoides* is used for seasoning fish in Sardinia, Italy (Guarrera and Savo 2016).

### 3.5 Fried

*Lycium europaeum* is fried in Lucania, Italy (Guarrera and Savo 2016).

### 3.6 Omelettes

*Lycium europaeum* is used to make omelettes in Sicily, Italy (Guarrera and Savo 2016).

### 3.7 Pickled

*Limbarda crithmoides* tender shoots are used for pickled (Tardío et al. 2018b).

*Crithmum maritimum* young green leaves are collected, cut into pieces, boiled slightly, and then cooled slowly. Then, they are placed in a wide-mouth bowl and covered with brine made with five parts of water, one of vinegar, and a half of salt (Fig. 4a and b). This pickle was eaten with bread and vinegar and also used to accompany soups in Mallorca and Alicante, Spain (Tardío et al. 2018, Pellicer 2000).

### 3.8 Brined

*Atriplex halimus* leaves are prepared in brine and eaten in salads (Lagasca 1817).



**Fig. 4** Halophytes used in homemade traditional dishes and in modern cuisine in popular Mediterranean countries: (a) and (b) Sea fennel (*Crithmum maritimum*). Young stems of sea fennel brine with salt and vinegar aromatized with endemic thyme called “pebrella” (*Thymus piperella*) and lemon (*Citrus limon*); (c) and (d) Sea fennel sold in Greek and Italian markets, respectively; (e) and

## 4 Halophytes in the Nouvelle Cuisine

At present, people in cities are looking for new products in their meals. They need new colors, flavors, textures, and ingredients (Mlcek and Rop 2011), and therefore, many restaurant chefs are interested in finding and using plants that have been traditionally consumed (Łuczaj et al. 2012; Łuczaj and Pieroni 2016). The use of halophytes in modern gastronomy mainly seeks to obtain flavors that evoke or enhance sea foods, sometimes in completely vegetarian dishes without the participation of fish or shellfish (Ariza 2019). Other times combining plant products (including algae) and others of animal origin to enhance the final taste or get new flavors and textures. It also seeks to increase the color of these dishes using certain extracts of the halophytes stems, leaves, flowers, or fruits (Ariza 2019).

There are currently several prestigious restaurants that are promoting the use of wild plants. We can highlight the NOMA restaurant in Copenhagen that offers a cuisine that includes the following species: leaves and unripe fruits of grass-leaved orache (*Atriplex littoralis* L.) and sea arrowgrass (*Triglochin maritima* L.), tender leaves of sea aster (*Tripolium pannonicum* (Jacq.) Dobroc.), flowers and shoots of sea pea (*Lathyrus japonicus* Willd.), aerial parts of sea plantain (*Plantago maritima* L.), leaves and flowers of sea rocket (*Cakile maritima* Scop.), aerial parts of sea sandwort (*Honckenya peploides* (L.) Ehrh.), and leaves, flowers, buds, and fruits of sea kale (*Crambe maritima* L.) (Łuczaj and Pieroni 2016).

Wild halophytes in the Southeast of Spain, under semiarid climate and with abundant alkaline substrates, is very rich in saline environments, both in the coastal area (beaches, cliffs, saline lagoons) and inland, where salt marsh appear in endorheic basins and even saline rivers (Alcaraz et al. 2008). For this reason, the diversity of halophytes and their availability is greater in this area. Although this culinary trend is widespread among modern gourmets all over the world, are specially the chefs from the Mediterranean area who experiment more with these plants preparing new extracts, smoothies, emulsions, etc. The list of species increases every year, and it is extensive, so here we will show some examples of this new cuisine, by the hand of one of the authors. In some recipes, well-known halophytes are used, and in others, unusual wild species are used (Ariza 2019). Nowadays, some Spanish cooks use the leaves of *Mesembryanthemum nodiflorum* and *M. crystallinum*, because they are extremely tender, slightly salty, and sour (Romojaro et al. 2013). *Salicornia*, marsh samphire, sea bean (USA), and Deniz borulcesi (Turkey), is an ingredient of the popular *mezze* elaborated in the Aegean and Mediterranean coast of Turkey. This plant is sold in supermarkets and markets in many parts of the world (Fig. 3), also in Spain. At the moment, it is being a fashionable sea vegetable in the UK by its succulent taste (Ozlem 2020).



**Fig. 4** (continued) (f) Young stems of *Salicornia europaea* in Valencian market (Spain). (Authors of the photographs: a, b (V. Martínez-Francés), b, d (C. Obón), e, f (E. Laguna))

*Crithmum maritimum* is recently proposed as a dried ingredient for alternative culinary uses. It is an important aromatic plant characterized by lightly salty taste and some notes of celery, followed from light notes of common fennel (*Foeniculum vulgare*) and peel of green citrus with a pungency after taste. Two drying technologies were applied with the aim to obtain a new spice-colorant without chemical synthesis (Rennan and Gonnella 2012).

## 5 New Recipes with Halophytes Lesser Known as Edible: The Case of Alicante, Southern Spain

### 5.1 Recipe 1. Spanish Rice with Fresh Wild Halophytes (Fig. 5a)

#### 5.1.1 Ingredients

75 g of rice “Bomba” per person (Spanish variety of short rice: *Oryza sativa* var. *japonica* with high value of broth absorption)

1/2 dried tomato per person (*Lycopersicon esculentum*)

500 g of fresh tomato (*Lycopersicon esculentum*)

200 g of halophytes:

- Leaves and young stems of iceplant (*Mesembryanthemum crystallinum*)
- Leaves of slenderleaf iceplant (*M. nodiflorum*)

2 onions (*Allium cepa*)

Fresh water

Extra virgin olive oil (*Olea europaea*)

Algae: a mixture of wakame (*Undaria pinnatifida*), sea lettuce (*Ulva* sp. pl.), dulse (*Palmaria palmata*), and/or others.

#### 5.1.2 Elaboration

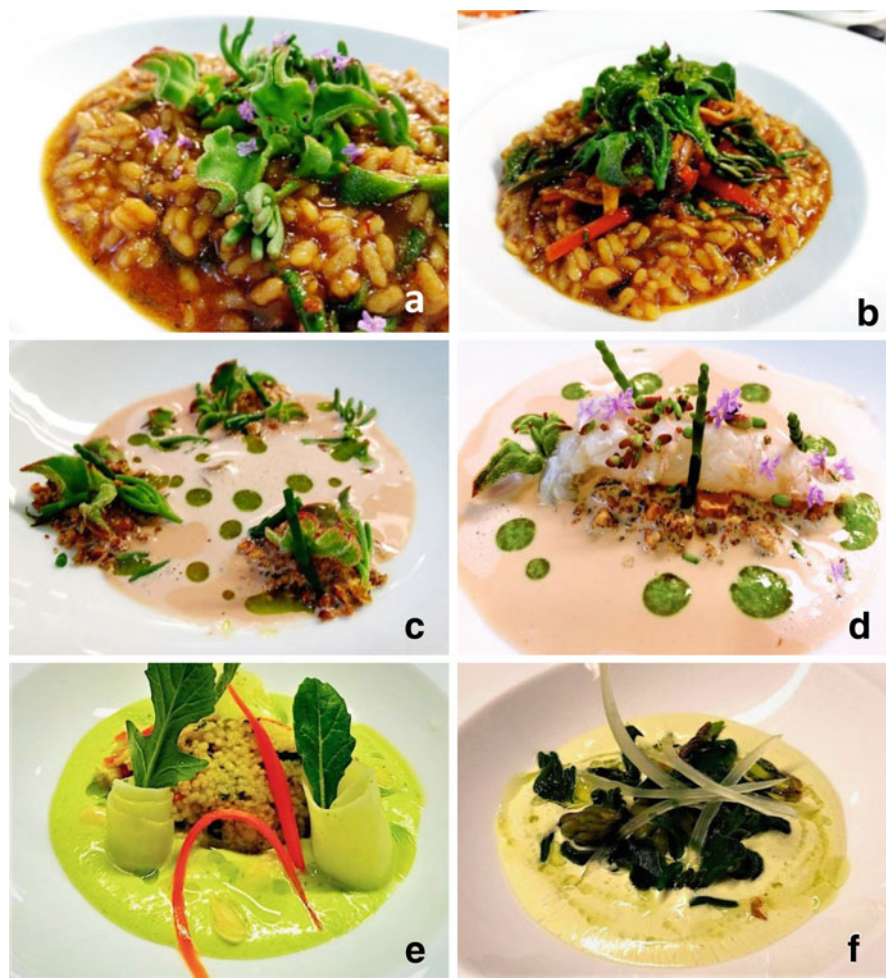
To make rice in a pressure cooker, it is important the presence of collagen in the broth to obtain mellow rice and not broth ones. In this case, to get unctuousness, animal products used as gelling agents are replaced with algae carrageenans.

For the *vegetable broth* (45 min. Approx.): Cut the onion in big pieces (including the external layers of dry skin) and start to heat in the pot letting it toast. Next, pour some extra virgin olive oil and add the halophytes, and then fry for a few minutes. On this, add the water and the algae and allow to cook 45 min more.

For the *stir-fry* (medium-low heat cooking, 60–90 min.): First add the chopped onion to a heated pot to toast it. Then add a little amount of oil and next add the chopped halophytes and hydrated algae. Once everything has been fried, add the natural crushed tomato and the dried tomato. When it is a little cooked, add a pinch of salt.

Once the broth and the stir-fry are done, it is the moment to prepare the rice in the pressure cooker. The proportions per person are 1 part of rice (75 g) for 3 of broth and 1 spoonful of stir-fry.

Put the pressure cooker on the fire and add two spoonfuls per person of crushed tomato and of extra virgin olive oil and also some salt. Then throw the stir-fry



**Fig. 5** Modern recipes made with wild gathered halophytes as main ingredients: (a) Spanish rice with fresh wild halophytes; (b) Spanish rice with halophytes, weeds, and seaweeds; (c) Cream of red samphire [“Crustáceos de Tierra”]; (d) Norway lobster marinated with cream of red samphire; (e). Iceplant cream and couscous in Mediterranean kimchi of cucumber and fermented weeds; (f) Halophytes pickled in brine with Plancton Algan<sup>®</sup>. (All recipes and photographs by D. Ariza)

reserved for this rice, and when it starts to consume, add the dried tomato and the vegetable broth. When it starts to boil, add “Bomba” short rice or similar and then close the pot and left it cooking 12 min. After this time, without pressure let the rice stand 2 min more.

### 5.1.3 Presentation

Serve the rice adding some fresh halophyte leaves over it.

## 5.2 Recipe 2. Spanish Rice with Halophytes, Weeds, and Seaweeds (Fig. 5b)

This is a recipe linked to the coastal landscape of southeastern Spain. This rice with wild vegetables and with fresh and fermented halophytes give it an acid and spicy touch.

### 5.2.1 Ingredients

#### For the rice

75 g of rice “Bomba” per person (Spanish variety of short rice: *Oryza sativa* var. *japonica* with high value of broth absorption)

Dried tomato 1/2 per person

Leaves of wild rocket (*Diplotaxis eruroides*)

Dandelion (*Taraxacum* gr. *officinale*)

Hedge mustard (*Sisymbrium officinale* and others)

Saffron

Vegetable broth with halophytes, vegetables, algae, and spices (see below)

Fermented weeds, vegetables, and spices (see below)

#### For the stir-fry

300 g onion (*Allium cepa*)

1 garlic (*Allium sativum*)

Saffron (*Crocus sativus*)

Iceplant (*Mesembryanthemum crystallinum*)

Dandelion (*Taraxacum* gr. *officinale*)

New Zealand spinach (*Tetragonia tetragonioides*)

Common pigweed or green amaranth (*Amaranthus hybridus*)

500 g tomato (*Lycopersicon esculentum*)

#### For the vegetable broth

2 onions (*Allium cepa*)

1 clove of garlic (*Allium sativum*)

1 carrot (*Daucus carota*)

Iceplant (*Mesembryanthemum crystallinum*)

Dandelion (*Taraxacum* gr. *officinale*)

New Zealand spinach (*Tetragonia tetragonioides*)

Algae: a mixture of wakame (*Undaria pinnatifida*), sea Lettuce (*Ulva* sp. pl.), dulse (*Palmaria palmata*), and/or others.

Saffron (*Crocus sativus*)

Salt

#### For the fermented weeds

100 g wild rocket (*Diplotaxis eruroides*)

50 g hedge mustard (*Sisymbrium officinale* and others)

50 g dandelion (*Taraxacum* gr. *officinale*)



50 g sow thistles (*Sonchus oleraceus*, *S. tenerrimus*, and/or *S. asper*)  
200 g onion (*Allium cepa*)  
4 cloves of garlic (*Allium sativum*)  
250 g carrots (*Daucus carota*)  
50 g ginger (*Zingiber officinarum*)  
200 g cooked and crushed rice  
200 g soy sauce (*Glycine max*)  
50 g honey  
Salt

### 5.2.2 Elaboration

To make rice in a pressure cooker, it is important the presence of collagen in the broth to obtain mellow rice and not broth ones. In this case, to get unctuousness, animal products used as gelling agents are replaced with algae carrageenans.

For the *fermented weeds* (48 h. approx.): First mix the onion in julienne and the peeled carrot. Then add the wild herbs, the garlic, and the well-chopped ginger and remove everything. Add the soy sauce, the honey, a pinch of salt, and the cooked and crushed rice. Mix it and let it to ferment 48 h at room temperature. Later reserve it in the fridge.

For the *vegetable stir-fry* (medium-low heat cooking, 60–90 min.): First add the chopped onion to a heated pot to toast it. Then add a little amount of oil and a pinch of saffron and next add the wild vegetables (iceplant, common pigweed, dandelion, and New Zealand spinach). Once everything has been fried, add the natural crushed tomato, and, finally, when it is a little cooked, add a pinch of salt.

For the *vegetable broth* (45 min. Approx.): Cut the onion in big pieces (including the external layers of dry skin) and start to heat in the pot letting it toast. Then do the same with a garlic head split in half. Next pour some extra virgin olive oil, and add the carrot and fry a little. Add the wild herbs and finally the algae. After a minute of cooking, we turn off the heat.

Once the broth and the stir-fry are done, it is the moment to prepare the rice in the pressure cooker. The proportions per person are 1 part of rice (75 g) for 3 of broth and 1 spoonful of stir-fry.

Put the pressure cooker on the fire and add two spoonfuls per person of crushed tomato until toast it. Then pour three spoonfuls per person of extra virgin olive oil and a pinch of salt and saffron and fry a little. Then throw the stir-fry reserved for this rice, and when it starts to consume, add the dried tomato and the vegetable broth. When it starts to boil, add “Bomba” short rice, and then close the pot and left it cooking for 10 min. After this time, without pressure let the rice stand 2 min more.

### 5.2.3 Presentation

Serve the rice adding the fermented weeds finely chopped and some fresh leaves of wild plants and halophytes over it.

### 5.3 Recipe 3. Cream of Red Samphire [“Crustáceos de tierra”] (Fig. 5c)

It is a cream based on different wild halophytes (called by the author as “crustáceos de tierra”) living in saline lagoon near to Alicante coast, mainly from Amaranthaceae family, with salt accumulation in leaves and stems.

#### 5.3.1 Ingredients

Young stems of green samphire (*Salicornia patula* and other similar halophytes species)

Flowers of iceplant (*Mesembryanthemum crystallinum*)

##### For the cream of red samphire

Mature stems of red samphire (*Sarcocornia lagascae* and other similar halophytes species)

1 clove of honey-garlic\* (*Allium sativum*)

Black pepper (*Piper nigrum*)

Extra virgin olive oil (*Olea europaea*)

Milk cream (it could also be with almonds)

Salt

##### For chopped almonds (75 g)

200 g no peeled almonds (*Prunus dulcis*)

200 g bread (*Olea europaea*)

25 g parsley (*Petroselinum crispum*)

25 g honey-garlic\* (*Allium sativum*)

#### 5.3.2 Elaboration

For the *chopped almonds* (12 h, approx.): Fry all separately, the almonds, the bread, the parsley, and the honey-garlic. Let cool everything on absorbent paper so that they lose the maximum oil. Crush everything and add salt and put again on absorbent paper. Dehydrate during 12 h.

For the *cream* (10 min.): Roast a clove of honey-garlic, add some oil and fry a little, then add the red samphire, and sauté. Pour this into the kitchen robot. Add the cream, the pepper, and the salt and crush.

#### 5.3.3 Presentation

Serve the cream of red samphire adding the chopped almonds and the flowers of iceplant and the buds of green samphire, to taste.

### 5.4 Recipe 4. Norway Lobster Marinated with Cream of Red Samphire (Fig. 5d)

The idea is to combine the flavor and texture of crustaceans with the halophytes (called by the author as “crustáceos de tierra”): two local products that give identity and personality to this recipe.

### 5.4.1 Ingredients

1 Norway lobster (*Nephrops norvegicus*)

Tender shoots of green samphire (*Salicornia patula* and other similar halophyte species)

Tender shoots of sea-blite (*Suaeda vera*)

Flowers of sea lavender (*Limonium parvibracteatum* and other similar halophyte species)

1 clove of honey-garlic\* (*Allium sativum*)

Black pepper (*Piper nigrum*)

Extra virgin olive oil (*Olea europaea*)

Milk cream (it could also be with almonds)

Whole sugarcane (*Saccharum officinarum*)

Salt

#### For the cream of red samphire

Tender shoots of red samphire (*Sarcocornia lagascae* and other similar species)

1 clove of honey garlic\* (*Allium sativum*)

Black pepper (*Piper nigrum*)

Extra virgin olive oil (*Olea europaea*)

Milk cream (it could also be with almonds)

Salt

#### For the iceplant oil

600 g seeds oil

100 g tender shoots of iceplant (*Mesembryanthemum* sp.pl.)

#### For chopped almonds

200 g no peeled almonds (*Prunus dulcis*)

200 g bread

25 g parsley (*Petroselinum crispum*)

25 g honey-garlic\* (*Allium sativum*)

### 5.4.2 Elaboration

For the *chopped almonds* (12 h, approx.): Fry all separately, the almonds, the bread, the parsley, and the garlic-honey. Let cool everything on absorbent paper so that they lose the maximum oil. Crush everything and add salt and put again on absorbent paper. Dehydrate during 12 h.

For the *cream of red samphire* (10 min.): Roast a clove of honey-garlic, add some oil, and fry a little, then add the red samphire, and sauté. Pour this into the kitchen robot. Add the milk cream, the pepper, and the salt and crush.

For the *iceplant oil* (3–5 min.): First put the tender shoots of iceplant into the kitchen robot at 60 °C, crushing it for 2 min. Then pour the seeds oil and crush for 1 min. This oil is used to emulsify.

Peel the Norway lobster and macerate it in whole sugarcane for 10 min, intensifying the flavor and increasing the texture. Fry all the rest ingredients separately and let them cool on absorbent paper so that they lose the maximum oil. Crush them and add salt to taste. Put them to dry on absorbent paper again and dehydrate everything for 12 h.

### 5.4.3 Presentation

Put the chopped almonds at the base of the dish. Place the tempered Norway lobster on top and add the hot cream of halophytes. Then put the tender shoots of sea-blite, green samphire, and flowers of sea lavender, pouring finally the iceplant oil.

## 5.5 Recipe 5. Iceplant Cream and Couscous in Mediterranean Kimchi of Cucumber and Fermented Weeds (Fig. 5e)

### 5.5.1 Ingredients

25 g of couscous (medium grain)  
 150 g of leaves of wild rocket (*Diplotaxis erucooides*)  
 1 cucumber (*Cucumis sativus*)  
 Iceplant cream (see below)  
 Wild rocket oil (see below)  
 Mediterranean kimchi (see below)

#### For the cream of iceplant

Flowers of iceplant (*Mesembryanthemum crystallinum*)  
 1 clove of honey-garlic\* (*Allium sativum*)  
 Black pepper (*Piper nigrum*)  
 Extra virgin olive oil (*Olea europaea*)  
 Almond milk (*Prunus dulcis*)  
 Salt

#### For the wild rocket oil

Wild rocket (*Diplotaxis erucooides*)  
 Extra virgin olive oil (*Olea europaea*)

#### For the Mediterranean kimchi

1 kg dandelion (*Taraxacum officinale*) and sow thistle (*Sonchus* sp.pl.)  
 250 g violet cabbage (*Moricandia arvensis*)  
 25 g fruits of wild rocket (*Diplotaxis erucooides*)  
 4 cloves of garlic (*Allium sativum*)  
 50 g honey  
 250 g carrots (*Daucus carota*)  
 200 g onion (*Allium cepa*)  
 200 g cooked and crushed rice  
 50 g of ginger (*Zingiber officinarum*)  
 1 turnip (*Brassica napus*)  
 Soy sauce (*glycine max*)  
 Salt

### 5.5.2 Elaboration

For the *Mediterranean kimchi* (48 h. approx.): Take the leaves of dandelion, sow thistle, and violet cabbage, and cure them with salt for about 10 or 15 min. Next wash the wild leaves to remove all the salt.

Mix the onion, turnip, chopped carrots, and violet cabbage, and remove everything well. Then put the garlic and the well-chopped ginger and remove again. Add the fruits of wild rocket very chopped and the soy sauce, honey, and salt. Mix everything with cooked and crushed rice, let it ferment 48 h at room temperature, and reserve in the fridge.

For the *cream of iceplant* (10 min.): Roast a clove of honey-garlic, add some oil and fry a little, then add the leaves of Iceplant, and sauté. Pour this into the kitchen robot. Add the almond milk, the pepper, and the salt and crush.

For the *wild rocket oil* (3–5 min.): First put the tender shoots of wild rocket into the kitchen robot at 60 °C, crushing it for 2 min. Then pour the extra virgin olive oil and crush for 1 min. This oil is used to emulsify.

Hydrate the couscous with cold water and salt. Mix it with the Mediterranean kimchi and wild rocket oil.

### 5.5.3 Presentation

Put the iceplant cream at the base of the dish. Add the couscous, some cucumber, and carrots on ribbons and finally some leaves of wild rocket.

## 5.6 Recipe 6. Halophytes Pickled in Brine with Plancton Algan<sup>®</sup> (Fig. 5f)

This recipe mixes the tradition of halophyte pickles in brine on the Island of Tabarca (Alicante, Spain), also adding Plancton Algan<sup>®</sup> (cultivated *Spirulina arthrospira* sp. pl.) as innovation.

### 5.6.1 Ingredients

Couscous

Plankton oil (see below)

Iceplant and vegetables in plankton brine (see below)

Plankton cream (see below)

#### For the plankton oil

Plancton Algan<sup>®</sup>

Extra virgin olive oil

#### For the iceplant and vegetables in plankton brine

Onions

1 bunch of asparagus (*Asparagus officinalis*)

Leaves of iceplant (*Mesembryanthemum crystallinum*)

Plancton Algan<sup>®</sup>

Vinegar

Salt

#### For the plankton cream

Plancton Algan<sup>®</sup>

1 clove of honey-garlic\* (*Allium sativum*)

Extra virgin olive oil (*Olea europaea*)

Almond milk (*Prunus dulcis*)

### 5.6.2 Elaboration

**For the plankton cream (10 min.):** Roast a clove of honey-garlic, add some oil and fry a little, then add the almond milk, and reduce. Pour this into the kitchen robot. Add the plankton and emulsify.

For the iceplant and vegetables in plankton brine (48 h. approx.): Put the vegetables (onions and asparagus) and the leaves of iceplant to macerate separately during 48 h at room temperature in a mixture of water with 15% of vinegar and 5% of salt and plankton. This maceration requires a previous boil.

For the *plankton oil* (3 min.): Put the plankton into the kitchen robot, pour the extra virgin olive oil, and crush for 2–3 min. This oil is used to emulsify.

Hydrate the couscous with cold water and salt and mix with the plankton cream.

### 5.6.3 Presentation

Put the plankton cream mixed with the couscous at the base of the dish, then incorporate the leaves of iceplant and the vegetables in plankton brine, and finally pour a little of plankton oil.

**Note:** \* *Honey-garlic* is a special garlic clove confit, slowly fried over moderate heat in sunflower oil and preserved in honey. After vacuum packing, it can be kept in the fridge. Garlic cloves are previously scalded three times in cold water until it boils. Confit in haute cuisine is not only a sweet confection, but, on the contrary, in many cases tries to confit in various types of fats (Delgado 1997).

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## 6 Crops and Commercialization

The young fleshy tips of the different species of *Salicornia* L. and *Sarcocornia* L. are commercialized with the name “samphire” or “sea asparagus” (Barreira et al. 2017). Local producers and/or collectors all over Europe usually have sold a mixture of *Salicornia* species due to incorrect taxonomical identification (Barreira et al. 2017). Their difficult taxonomy makes almost impossible for non-specialists to determine all the species (Fig. 4e and f). Frequently the names *Salicornia europaea* L. or *S. herbacea* L. (actually TPL database (TPL 2020) consider *S. herbacea* as synonym of *S. europaea*) are used in a very broad sense to include most of the species in the genus (Kadereit et al. 2007).

Until today these plants have been gathered regularly from wild populations and sold in local markets (Fig. 4). Minor cultivation is mostly limited to private crops and kitchen gardens (Ventura and Sagi 2013). Therefore, the herb market demands products of the highest quality, so it is necessary to grow as a gourmet vegetable that ensures a selected and homogeneous product.

*Salicornia* has recently emerged as commercial edible halophyte in the agriculture sector and can be cultivated by using sea water irrigation without any fertilizers or pesticides (Fita et al. 2015). Ventura and Sagi (2013) have proposed the next list of halophyte plants with highest potential as vegetable crop for saline irrigation: *Aster tripolium*, *Atriplex hortensis*, *Batis maritima*, *Cochlearia officinalis*, *Crambe maritima*, *Crithmum maritimum*, *Diplotaxis tenuifolia*, *Limbarda crithmoides*, *Mesembryanthemum crystallinum*, *Plantago coronopus*, *Portulaca oleracea*,

*Salicornia* sp., *Sarcocornia* sp., and *Tetragonia tetragonioides*. All of them have a salt tolerance level above 100 mM (Figs. 1, 2, and 3).

The young shoots of *Salsola soda* L., called in Italian agretti, are considered a delicacy in Umbria and other parts of Central Italy and are sold in spring in their local markets (Facciola 1998). It is used boiled in Apulia, Italy (Guarrera and Savo 2016), and the agretti seeds are sold by the nurseries.

*Limonium sinuatum* in Alicante have been cultivated in pot, and the plant has developed large leaves that resemble a lettuce (Fig. 2f). Many plants look very different when they grow wild in their natural habitat and when they are grown in greenhouse conditions. In Fig. 2e, we can see *Limonium sinuatum* in its habitat which has small and hard leaves, and also when it is grown in a greenhouse in the province of Alicante where it is supplied with irrigation, then it has tender and much larger leaves.

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## 7 Halophyte Food Composition and Health Risks and Benefits

Many halophytes, which are already common foodstuffs and others recently consumed through the nouvelle cuisine, are plants whose current consumption is interesting due to their content in useful molecules such as various antioxidants, minerals, and omega-3 fatty acids. On the contrary, their high contents of sodium and oxalic acid advice a moderate consumption of these plants, except if they are subjected to several washes that decrease the level of these salts.

### 7.1 Health Benefits

Edible halophytes have medicinal uses, some of them studied. The nutritional profile and in vitro antioxidant activity of four edible halophytes, *Salicornia ramosissima*, *S. perennis* subsp. *alpini*, *S. perennis* subsp. *perennis*, and *Arthrocaulon macrostachyum*, have been studied by Barreira et al. (2017). *A. macrostachyum* had the most interesting nutritional profile with high levels of minerals, vitamin C, and  $\beta$ -carotene. Also it is rich in polyunsaturated fatty acids (PUFA), and it can be a potential source of antioxidants. Its notable content in phenolic and tocopherols justifies its use as succulent salty shoots in gourmet cuisine (Barreira et al. 2017).

*Crithmum maritimum* (sea fennel) has been much studied. It is rich in volatile compounds as sabinene,  $\gamma$ -terpinene, thymol, dillapiole, methylether,  $\alpha$ -pinen, p-cymol, apiole, cis- $\beta$ -ocimene, and terpinen-4-ol (Atia et al. 2011). It also contains different water-soluble compounds as sugars, organic acids, and many minerals. Furthermore, the lipids extracted from leaves are rich sources of omega-3 and omega-6 fatty acids and also of carotenes (Guil-Guerrero and Rodriguez-Garcia 1999). The content of flavonoids, tannins, and total polyphenols in the aerial parts of this plant is high (Atia et al. 2011).

*Tripolium pannonicum* which is used for fresh salads and cooked as vegetable is rich in minerals and polyphenols, and it has highest potential as vegetable crop for saline irrigation (Ventura and Sagi 2013).

*Cynomorium coccineum* L. is an edible plant used as anti-carcinogenic (Sdiri et al. 2018).

*Phragmites australis* contains some vitamins of the group A and vitamin C (Rivera et al. 2012b).

## 7.2 Toxicity

In the study on wild greens of Romojaro et al. (2013), a high oxalic acid content in *Mesembryanthemum crystallinum* has detected with quantities over 900 mg/100 g of fresh weight. Therefore this plant would only be recommended in small quantities although it would provide pleasant salty. Rather, *Crithmum maritimum* contains very low amounts of oxalic acid.

*Salicornia europaea* has been shown to reduce obesity, but it remains a problem as a food supplement because of its high salt content (25–35% NaCl). It is recommended the desalation for its use as supplement (Rahman et al. 2018).

## 8 Conclusion

Halophytes have been consumed since ancient times as food or condiments, either from wild or domesticated species. In times of famine, many wild halophytes have been used as survival foods. Currently, the halophytes of ancient traditional use, along new ones which have never or only occasionally been eaten, are part of a package of new resources for modern cuisine. It incorporates halophytes as the main ingredient, as an accompaniment that enhances the flavor, or as a gastronomic decoration in the creation of new recipes.

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