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BERRIES OF SHRIMP (*COREMA ALBUM*): BIOLOGICAL PROPERTIES AND FUTURE FUNCTIONALITIES

Ana Cristina Mendes Ferreira da Vinha
I3ID/``*Instituto de Investigação, Inovação, e Desenvolvimento Fernando Pessoa*``, Faculty of Health Sciences, Universidade Fernando Pessoa, Porto, Portugal.
LAQV/REQUIMTE, Department of Chemical Sciences, Faculty of Pharmacy, Universidade do Porto, Portugal.
ORCID ID: 0000-0002-6116-9593

Marta Isabel de Oliveira Soares
``*Instituto Politécnico de Saúde do Norte*``, *CESPU, Famalicão, Portugal.*
ORCID ID: 0000-0002-9097-1518

Abstract: Edible wild plants are part of the ethnobotanical and gastronomic heritage of different geographical areas, often recognized as a local gastronomic tradition. Corema album L. is an endemic species of the dune systems of the Atlantic coast of the Iberian Peninsula. This plant, especially the fruit, has aroused growing interest, not only for its nutritional value and organoleptic characteristics but also as a way of diversifying eating habits and promoting biodiversity and ecological sustainability. Like other fruits with similar morphology, the Corema album berry is rich in polyphenols, which have recognized biological activities. The use of natural products for the development of new compounds with antioxidant and antimicrobial activity is becoming increasingly imperative, both for nutraceutical and pharmaceutical products. In view of the above, this article aims to report the importance of shrimp berries as a sustainable food alternative and/or a plant with extractable active ingredients for future incorporation into pharmaceuticals or cosmetics.
Keywords: Shrimp, natural resource, polyphenols, biological properties, sustainable economy.

INTRODUCTION

Edible wild plants have been the subject of increasing interest, not only for their nutritional value, but also as a way of diversifying eating habits and promoting biodiversity and ecological sustainability. The sustainable use and fair distribution of natural resources have been considered one of the main priorities for humanity, as defined by the International Treaty on Plant Genetic Resources for Food and Agriculture, of the Food and Agriculture Organization of the United Nations (FAO). . However, despite certain advantages, it must be taken into account that many undervalued endemic plants may contain some toxic compounds, which is a reason that promotes their exhaustive study. Likewise, promoting its consumption must occur in a controlled and safe manner, and only after extensive chemical characterization of each plant (Lagneaux et al., 2021). It is well recognized that food is essential, but in its vital role in the lives of the population, health is often disregarded (Alexandri et al., 2022). However, this mentality has been changing, as industry, researchers and consumers are now paying more attention to disease prevention through healthier diet management and balanced, natural foods, boosting choice of undervalued products and/or by-products (Damián et al., 2022).

In fact, it is common knowledge that the effects of poor diets on the population include malnutrition, non-communicable diseases and obesity. 'Hidden hunger', also known as micronutrient deficiency, leads to several health-related disorders and diseases. Wild plants, in the form of fruits and/or vegetables, are currently the target of study as an alternative source of nutrients and bioactive phytochemicals, satisfying both dietary needs and health promotion.

SHRIMP (*COREMA ALBUM*)

Corema album L. (Figure 1), known as shrimp or white mulberry, is a plant endemic to the Iberian Peninsula, belonging to the Ericaceae family. It is a small shrub, which spreads throughout the Portuguese coastal strip.

The generic name Corema comes from the Greek 'Korema' which means broom, an object that can be made using the dry branches of this plant and the specific epithet 'album' comes from the Latin, meaning white, given the color of the ripe shrimp berries. According to Gil-López (2011), in recent decades, due to multiple endogenous and exogenous factors, there has been a regression in the spread of

shrimp, including its extinction in some areas of the western coast of the Iberian Peninsula. In fact, dune ecosystems have been affected by the appearance of invasive nitrophilic plants, such as *Carpobrotus edulis*, and the reduction of fauna responsible for the dispersion of seeds and, consequently, the propagation of the species. The continuous loss of habitat and competition with invasive species have compromised the regeneration and survival of several populations of C. album, with a consequent decrease in the production and respective commercialization of these berries. However, being a little-known species, its consumption is known through records that mention its use as food by coastal populations, especially during World War II (a period of famine) and, given its nutritional and chemistry, is currently investigated in the area of small fruits (Barroca and Moreira da Silva, 2021; Oliveira et al., 2020; Jacinto et al., 2019). The lack of genetic information and studies on C. album is one of the biggest limitations to its establishment as a new crop and, consequently, its recovery and future cultivation. However, taking into account its health benefits, it is imperative to increase its production, always from an economically sustainable perspective.

BIOACTIVE COMPOUNDS FROM SHRIMP

The shrimp, being an endemic and wild species, develops under variable, sometimes even abrupt, edaphic and clamateria conditions. As the impact of global warming intensifies the effects of drought, plants need to adapt to drought and other climate change-induced stresses through several defense mechanisms. One of them is the increased synthesis of bioactive compounds, which help plants overcome adverse environmental conditions (Dujmovic et al., 2023). Bioactive compounds are products of different metabolic pathways in plants and their synthesis is influenced by abiotic and biotic factors. It is known that different stress factors can intensify and improve the synthesis of secondary metabolites. Numerous studies show that plants subjected to induced stress conditions and changes in the growth environment, such as drought, salinity and thermal stress, can increase the synthesis and accumulation of some bioactive compounds (phenolic acids, flavonoids, anthocyanins and glucosinolates). The profile of secondary metabolites present in the shrimp berry appears to be very heterogeneous. Some studies have found a high diversity of phytochemicals, specifically, phenolic acids (in their free, ester and glycosidic forms), flavonoids and tannins (Andrade et al., 2017; Paredes-López et al., 2010). Methanolic extracts from C. album berries allowed the quantification of 75% of phenolic acids, 22% of flavonoids and1% of anthocyanins. Andrade et al. (2017) identified high levels of phenolic compounds, particularly phenolic acids (with benzoic, caffeic and ferulic acids being the predominant ones) (Figure 2), flavonols (especially quercetin 3-O-glucoside and rutin) (Figure 3), and as an dye anthocyanins (delphinidin 3-O-hexoside, cyanidin 3-O-glucoside and cyanidin 3-O-pentoside). However, León-González et al. (2013) reported other phenolic acids, including gallic acid, chlorogenic acid, p-coumaric acid, vanillic acid, and syringic acid. The same authors considered benzoic, caffeic, syringic and vanillic acids as the predominant ones in the fruit (León-González et al., 2013).

Chlorogenic acid (Figure 4) has also been referred to as one of the main phenolic acids in shrimp berry (Jacinto et al., 2021).

It is known that coffee and fruits are the largest exogenous sources of chlorogenic acid in the diet and some epidemiological studies have suggested an association between

the consumption of these foods and disease prevention (Wang et al., 2022; Zielińska et al., 2020).

Although studies carried out to date are not conclusive, however, everything indicates the existence of an inverse relationship between the consumption of foods rich in chlorogenic acid and the risk of developing chronic non-communicable diseases (Chai et al., 2023; Murai and Matsuda, 2023; Zhang et al., 2023).

Regarding compounds with chromophoric action, it is known that there are few chemical groups that present these characteristics in the plant kingdom. In addition to chlorophylls (photosynthetic pigments), there are anthocyanins (flavonoids), betalains (colored alkaloids) and carotenoids (tetraterpenes).

The organothetic characteristics of the fruits are also directly related to the presence of bioactive compounds. In fact, all chromophore compounds exert diverse functions on the plant, such as protection from UV, attraction to pollinating agents and/or predators (Vinha et al., 2023a; Kapoor et al., 2022). However, from the consumer's perspective, one of the first perceptions of food is its color, a characteristic that strongly influences food choice. The berries (berries) have a white hue throughout their ripening process. This tone justifies the presence of low levels of anthocyanins (cyanidin and delphinidin). However, the small amount of this group of flavonoids does not invalidate the presence of another type of flavonoids. For example, quercetin (3,5,7,3′,4′-pentahydroxyflavone) is a colorless flavonoid and is widely distributed in flowers, bark, stems, roots, wine, vegetables, tea, fruits such as apples, dill, onion fruits and capers (Aghababaei and Hadidi, 2023). Due to the lack of color in the shrimp berry, it is believed that its presence is even more obvious.

BIOLOGICAL PROPERTIES OF SHRIMP

Currently, polyphenolic compounds occupy a unique place in environmental science as an important class of bioactive natural molecules. Polyphenols are found in almost all plant families and are concentrated in leaf tissue, epidermis, bark layers, flowers and fruits. In recent years, with the increasing recognition of the biological properties of phenolic compounds, it has been discovered that they exert several activities, such as antioxidant (Vinha et al., 2023a; Martins et al., 2016), antimicrobial (Lobiuc et al., 2023), anticarcinogenic (Bakrim et al., 2022), anti-inflammatory (Liu et al., 2023), preventers of cardiovascular diseases (Vázquez-Ruiz et al., 2022), diabetes (Dias et al., 2022) and associated diseases oxidative stress (Vinha et al., 2023b).

This way, through the chemical profile described, it can be said that the synergistic effect between the different compounds present in the shrimp berry can present multiple activities. For example, the phenolic acids described in this fruit (benzoic, vanillic, gallic, p-coumaric, syringic and chlorogenic acids) have substantial lipid and aqueous solubility and can inhibit oxidative deterioration when added as functional ingredients in emulsions (seasonings, sauces, soups and desserts) (Kiokias et al., 2020). However, the hypothesis of the use of these berries as antimicrobial agents, commonly valid for use in the food and/or pharmaceutical industry, cannot be discounted.

PHENOLICS AND THEIR BIOLOGICAL FUNCTIONS

Based on the profile of the aforementioned phenolic compounds present in the shrimp berry, some of the most relevant activities of each of them are mentioned.

Figure 1. Plant morphology:*Corema album*.

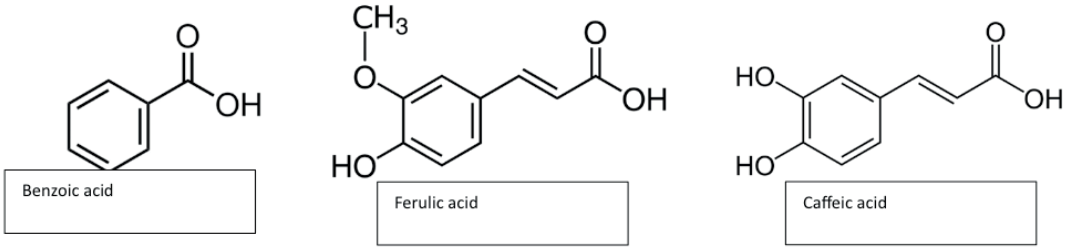

Figure 2. Chemical structures of the main phenolic acids present in berries of *C. album*.

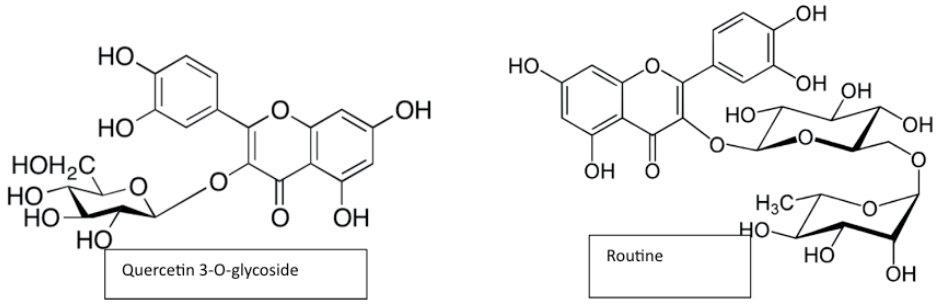

Figure 3. Chemical structures of the main flavonols present in berries of *C. album*.

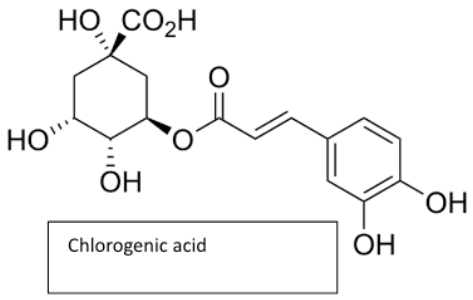

Figure 4. Chemical structure of chlorogenic acid (ester of caffeic acid and (L)-quinic acid).

BENZOIC ACID AND DERIVATIVES

Benzoic and p-hydroxybenzoic acid are organic chemical compounds obtained both naturally and through chemical synthesis. Several studies cite various biological properties of this compound(s), such as antimicrobial, antimutagenic, antiestrogenic, hypoglycemic, anti-inflammatory, antiplatelet, nematicidal, antiviral and antioxidant (Walczak-Nowicka and Herbet, 2022; Li et al., 2020). It is also used as a scavenging agent for hydroxyl radicals produced during cerebral ischemia and reperfusion and is also widely used as a preservative (additive) in medicines, cosmetics, pharmaceuticals, foods and beverages (Walczak-Nowicka and Herbet, 2022).

The drastic increase in multidrug-resistant microbial infections has become a serious danger to public health. 4-p-hydroxybenzoic acid exhibits antimicrobial activity against various microorganisms such as Gram positive and Gram negative bacteria such as: *Escherichia coli*, *Bacillus aureus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Candida albicans*, *Lactobacilos*, *Listeria monocytogenes*, *Fusarium culmorum* and *Saccharomyces cervisae* (Ecevit et al., 2022).

GALLIC ACID

Gallic acid or 3,4,5-trihydroxybenzoic acid is one of the most abundant phenolic acids in the plant kingdom. This acid has several applications in the food and pharmaceutical industries. Gallic acid has been isolated from different plant species, such as Quercus spp. and Punica spp., through various chromatographic methods; however, from an industrial point of view, gallic acid is produced through the hydrolytic breakdown of tannic acid using a glycoprotein esterase (tanase). Due to its high antioxidant power, this acid is capable of inhibiting the oxidation and rancidity process in oils and fats, therefore, it can be useful as additives in the food and/or pharmaceutical industry.

In addition to its application as a flavoring and preservative, several studies report biological and pharmacological activities, with an emphasis on antioxidant, antimicrobial, anti-inflammatory, anticarcinogenic, cardioprotective, gastroprotective and neuroprotective effects (Salimi et al., 2023; Ramezani-Aliakbari et al., 2019). gallic acid can inhibit motility, adhesion and formation of *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus mutans*, *Chromobacterium violaceum* and *Listeria monocytogenes* (Salimi et al., 2023). The compound can also disrupt cell membrane integrity in Gram-positive and Gram-negative bacteria and alter the charge, hydrophobicity, and permeability of the membrane surface. *Campylobacter jejuni* (Ramezani-Aliakbari et al., 2019).

CAFFEIC ACID AND ITS ESTERS

Caffeic acid, a hydroxycinnamic acid present in most fruits, can be in its free form or as an ester of quinic acid, called chlorogenic acid. The antioxidant properties of caffeic acid and, consequently, its esters are associated with the presence of two hydroxyl groups in its aromatic ring. Furthermore, the presence of a double bond in the carbon chain (the unsaturated double bond of the 2,3 side chain) increases the stability of the phenoxyl radical, enhancing its biological activities. Due to these chemical characteristics, caffeic acid easily binds to divalent metals that catalyze oxidation reactions or enzymatic cofactors of chemical reactions related to the formation of reactive oxygen species and modulation of gene expression function in anti-inflammatory and immunoregulatory processes (Pérez et al., 2023). Furthermore, its combination with other compounds such as chlorogenic acid and caftaric acid has shown

an increase in antioxidant activity in in vitro and in vivo systems, playing an important role in the protective effect of chlorogenic acid against ischemia-reperfusion injury (Cizmarova et al., 2020).

The Caffeic acid has high antioxidant and antimicrobial potential, particularly against Gram+ bacteria, namely:*Bacillus*, *Clostridium*, *Propionibacterium*, *Enterococcus*, *Staphylococcus* and *Streptococcus*. A recent study reported inhibitory effects of chlorogenic and caffeic acid against acetylcholinesterase, an enzyme associated with the development of Alzheimer's disease (Suzukamo et al., 2022; Andrade et al., 2021).

FLAVONOIDS

Flavonoids are a broad class of polyphenolic compounds based on a basic 2-phenyl chromone structure. To date, more than 8,000 flavonoid derivatives have been recognized in nature, both in the free state (genin) and in the conjugated state, as ester or glycosidic derivative. Rutin, a natural flavonoid synthesized by plants, is considered one of the main therapeutically active phytochemicals and one of the main bioactive constituents of a variety of natural foods (Semwal et al., 2021).

In addition to its recognized antioxidant potential, rutin has shown protective effects on the liver and blood vessels, including coronary arteries (Zhang et al., 2023). It was also discovered that this molecule exhibits a protective effect against cisplatin-induced ovarian toxicity, improving the levels of several enzymes that are associated with oxidative stress. On the other hand, its protective effect against ethanol-induced hepatotoxicity has also been confirmed in human hepatoma HepG2 cells by reducing the activities of hepatic aminotransferases and the inflammatory response (Meng et al., 2022; Semwall et al., 2021). The antibacterial properties of rutin have also been proven, which may promote future practical applications in the era of antibiotic resistance. Previous scientific research has demonstrated rutin's antimicrobial activity against Gram-positive and Gram-negative bacteria (*Staphylococcus aureus*, *Staphylococcus epidermidis*, *Enterococcus faecalis*, *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Enterobacter cloacae, Pseudomonas aeruginosa e Acinetobacter baumannii*) (Rodríguez-Valdovinos et al., 2021; Ganeshpurkar and Saluja, 2017).

Regarding quercetin 3-O-glucoside, it is recognized as an important active flavonoid obtained from different natural resources (Zhang et al., 2023), exerting diverse pharmacological activities, such as antioxidant, anti-inflammatory, hepatoprotective and antiproliferative properties (Aghababaei and Haddidi, 2023; Liu et al., 2023). Similarly, Nguyen and Bhattacharya (2022) demonstrated that quercetin inhibits the growth of different Gram-positive and Gram-negative bacteria (*Streptococcus mutans*, *Streptococcus sobrinus*, *Lactobacillus acidophilu*, *Streptococcus sanguis*, *Actinobacillus actinomycetemocomitans e Prevotella intermedia*).

CONCLUSIONS

Global changes are causing serious problems and enormous challenges in terms of food, health, soil and climate changes, among others. The management of natural resources and the development of agricultural technologies require the contribution of a series of areas of knowledge, in order to guarantee food, in a sustainable way, for the general population.

Consequently, another challenge aims to improve health conditions. In this context, plants, highlighted by Corema album, play a central role not only as undervalued food sources, but also in medicinal applications.

Therefore, the study of these berries has focused on the characterization of bioactive compounds and their beneficial effects on health, with a view to their use in functional foods. The small fruits of the shrimp are considered potential sources of polyphenols such as phenolic acids, stilbenes and flavonoids, which have antioxidant activity and are also responsible for the color and characteristic flavor. The main phenolic compounds present in shrimp berries include phenolic acids such as benzoic, vanillic, caffeic and ferulic acids, flavonoids including quercetin and rutin and anthocyanins. Unlike most small fruits, white shrimp berries have a lower anthocyanin content than black or red berries. However, they contain a higher content of caffeic acid and derivatives that contribute to the acidic flavor, antioxidant capacity and chemoprotective effect of the berry. In fact, the antioxidant activity of the bioactive compounds present in shrimp helps to balance the production of free radicals and protect the body from oxidative stress, and, therefore, promote beneficial effects on human health and help prevent chronic degenerative diseases such as cancer, diabetes, inflammation, among others. Shrimp berries have even shown a promising effect in reducing the incidence of Parkinson's neurodegenerative disorder. Due to the antimicrobial action that the compounds present, shrimp becomes a natural alternative in the prevention of bacterial infections and/or preservative additives with applications in various industries.

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