Review:
Natural products isolated from *Portulaca oleracea* (purslane, Ma-Chi-Xian): Focus on oleraciamides and oleracones

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Abstract. Bailly C. 2021. Review: Natural products isolated from *Portulaca oleracea* (purslane, Ma-Chi-Xian): Focus on oleraciamides and oleracones. *Nusantara Biosciences* 13: 202-210. The plant *Portulaca oleracea* L., known as purslane in English and Ma-Chi-Xian in Chinese, is largely used in traditional medicine to treat a variety of diseases and conditions, including dysentery, urinary tract dysfunctions, and post-partum bleeding. It is also an edible plant, with a high nutritional potential. Extracts of *P. oleracea* display antioxidant, anti-inflammatory and antiproliferative activities, associated with the presence of numerous bioactive secondary metabolites, including alkaloids, terpenoids, lignans and polysaccharides. The present review provides a specific focus on two subgroups of natural products isolated in recent years from *P. oleracea*: the alkaloids oleraciamides A-to-G, and the oleracones A-to-L which are mostly flavonoids. Their structural diversity and pharmacological properties, described in recent publications and patents, have been analyzed. These two subgroups of natural products deserve additional studies to delineate their mechanism of action. They could serve as a starting point to the design of novel anti-inflammatory agents, at least for some of them. This review provides a global view of these compounds, necessary to promote further phytochemical studies and to better apprehend the traditional use of the plant and its extracts.

Keywords: Alkaloids, cancer, flavonoids, inflammatory diseases, natural products, traditional medicine

INTRODUCTION

The plant *Portulaca oleracea* L. (purslane) is largely used in traditional medicine to treat various diseases and conditions. *P. oleracea* extracts are used to treat chronic cough and asthma (Khazdair et al. 2019; Moghaddam et al. 2020), gastrointestinal diseases and hepatic disorders (Farkhondeh and Samarghandian 2019; Farkhondeh et al. 2019; Ong and Kim 2020), urological infections (Jaradat et al. 2017), uterine bleeding (Mobli et al. 2015), dysuria (Jaladat et al. 2015), wound healing (Laitiff et al. 2010), and other conditions (Niazi et al. 2018). Extracts of *P. oleracea* display marked analgesic and anti-inflammatory effects, at the origin of the extensive traditional use of the plant in many countries (Chan et al. 2000). The traditional use of the plant goes back to ancient times, more than 2000 years ago. The plant *Portulaca sylvestris* (synonym for *P. oleracea*) was cited by the Greek botanist Pedanius Dioscorides of Anazarba (ca. 40-90 C.E.) in his famous book “De Materia Medica” (latinized title of the medical textbook which was hand-written in Greek). The book references about 600 plants, including Andracine which is the Greek name for *Portulaca*, the Latin name. The book mentioned the use of purslane together with axumina (animal fat) for the treatment of strumae (goiter) (Mitich 1997). Herba *Portulaceae Oleraceae* seed is used in traditional Iranian medicine for alleviating a wide spectrum of diseases (Mirabzadeh et al. 2013; Iranshahy et al. 2017) and in Malaysia where the plant is called Gelang pasir (Abu Bakar et al. 2018). The therapeutic use of the plant is mentioned in traditional Unani medicine (Sultana and Rahman 2013; Khanam et al. 2019). In Italy, the plant is known since the Roman Age (Danin et al. 2014). In Japan, a health food marketed under the name Gogyo-so-cha, made from *P. oleracea*, is used to treat intestinal infections and dysentery. Gogyo-so-cha efficiently inhibits the growth of intestinal pathogens, such as *Shigella dysenteriae* and *Vibrio cholerae* (Okuda et al. 2021). The plant (Figure 1) is also used in India and other countries (Masoodi et al. 2011; Kumar et al. 2021).

In China, the plant has different names, mainly Mǎ Chì Xiàn but also Zhu Mu Ru, Gua Zi Cai, Wu Xing Cai in Shanghai, Ma Zi Cai in Shanxi and Liaoning, Suan Cai in Fujian and Suan Xian in the Zhejiang province (Zhou et al. 2015). It has a variety of medical uses: to reduce the swelling and pain from snake bite or wasp stings, to treat dysentery, urinary tract infections and dysfunctions or pain, red and white vaginal discharge, and post-partum bleeding. In traditional Chinese medicine, the plant is often combined with other medicinal plants, such as in the preparation called Zhiyang Pingfu (Figure 1), used to treat skin damages and lesions induced by specific anticancer drugs (Wang et al. 2015; Peng et al. 2017, 2019; Zheng et al. 2018). Many herbal combinations are proposed, with dandelion herb (Pu Gong Ying), *Smilax glabra* roots (Tu Fu Ling), and others. Some modern herbal preparations also include *P. oleracea*, such as the seven herbal plant mixture BRM270 used to treat cancer, via the targeting of cancer stem cells (Chandimali et al. 2020). *Portulacae oleracea* exhibits marked anti-hyperglycemic, anti-
hyperlipidemic, reno-protective and hepatoprotective effects (Khazdair et al. 2021), and in recent years the plant has also revealed marked anticancer activities, owing to its anti-proliferative and immune-modulatory properties (Azarrifar et al. 2018; Rahimi et al. 2019; Alipour et al. 2021; Jia et al. 2021). The anti-obesity and antidiabetic effects of *P. oleracea* powder have been recently highlighted (Jung et al. 2021), as well as the hepatoprotective effects (Dar et al. 2021).

Beyond its medicinal use, *P. oleracea* is a wild edible plant with culinary and nutritional value, largely consumed in some countries (Pereira et al. 2020). The epithet *oleracea* is from Latin and means “of cultivation” or “suitable for food” (Mitich 1997; Kumar et al. 2021). The plant, widespread in temperate and tropical regions of the world, contains high amounts of omega-3 fatty acid, mineral elements (potassium and magnesium), alpha-tocopherol, ascorbic acid and other elements of a high nutritional potential (Uddin et al. 2014; Lyons et al. 2020; Melilli et al. 2020a). Purslane is highly nutritious and is considered for its major nourishing benefits in the current context of changing climate (Srivastava et al. 2021). The cultivated plant was found to contain greater amounts of amino acids and vitamins than wild purslane, but on the opposite, the content in phenolic acids, flavonoids, alkaloids, and betanin was two-fold higher in the wild than in cultivated purslane (Nemzer et al. 2020). The nutritional value and utility of the plant is more and more recognized (Petropoulos et al. 2019). A recent clinical study suggested that the consumption of purslane supplementation would be beneficial to control blood lipid and glucose levels (Hadi et al. 2019). The plant can be used as a supplement in breads (Melilli et al. 2020b) and other food products (including chewable tablets). A fermented *P. oleracea* juice has been proposed as a functional beverage to counteract intestinal inflammation (Di Cagno et al. 2019) and an aqueous extract has been tested with success as a nutritive anti-browning agent for fresh-cut potato (Liu et al. 2019).

The biologically active compounds found in *P. oleracea* are extremely diversified, comprising flavonoids, cyanins, lignans, terpenes, phenolic alkaloids as well as bioactive polysaccharides (Yang et al. 2009; Zhou et al. 2015; Duan et al. 2021). The plant is known for decades but novel natural products are regularly isolated and characterized (Nemzer et al. 2021; Park et al. 2021), such as oleralignan A (Xu et al. 2021) and oleraceins X and Y (Fernández-Poyatos et al. 2021). Over the past 3-5 years, new alkaloids were identified called oleracimides and new flavones designated oleracanes. A review of these natural products, their structural diversity, and biological properties, is presented here. These molecules have never been reviewed before; they would deserve more attention and to be better known by the phytochemistry/pharmacology community.

**OLERACIAMIDE ALKALOIDS**

Seven oleraciamide (OCM) alkaloids have been identified thus far, designated oleraciamides A-to-G (Figure 2). OCM A-to-E have been patented (Table 1). OCM-A and -B were isolated from *P. oleracea* in 2017 (Li et al. 2017a). They present the same di-substituted benzene core with a pivalamide (trimethylacetamide) group at position C-1 and an ethoxy group at position C-3 but they differ by the presence of a terminal morpholino group for OCM-A versus a (rare) dioxazepan group for OCM-B (Figure 2). OCM-A showed no cytotoxic property and OCM-B was not evaluated (Li et al. 2017a). The absence of cytotoxic effect with OCM-A may be due to its low bioavailability and rapid metabolization observed in rat plasma after oral and intravenous administration of a *P. oleracea* extract. Seven metabolites were identified in the plasma and urine, corresponding to hydrolyzation, glucuronidation, sulfation and glutathionylation of the natural product (Ying et al. 2018). It is mainly the intestinal first-pass effect which is responsible for the low bioavailability of OCM-A (5.7%) because the compound is a good substrate for cytochrome CYP3A and the efflux pump PgP (P-glycoprotein) (Zhao et al. 2019a). The compound is subject to a rapid efflux which strongly limits its intestinal absorption. The bioavailability can be considerably improved when the compound is administered by the rectal or intraportal route, to reach a bioavailability of 92.2% (hepatic route) and 84.9% (gastric route). The rectal administration could be used as a suitable delivery route for this compound (Zhao et al. 2019a).

![Illustration of the plant Portulaca oleracea L. (purslane, Ma-Chi-Xian) (photos from www.plantsoftheworldonline.org). Numerous natural products have been isolated from *P. oleracea*, including the oleraciamides and oleracones, reviewed here.](image-url)
OCM-C, isolated one year later, is a totally different amide alkaloid possessing an unusual 1,6 bis-substituted β-glucopyranose residue linked to a long (C15) hydrophobic alkylamide side chain (Figure 2). The compound showed no cytotoxic effect, but it was tested against one cell line only. Even more, at low concentration OCM-C seemed to stimulate markedly the growth of Human adipose-derived stem cells (Xu et al. 2017). OCM-D is a tryclic lactam alkaloid, bearing a central dihydropyridinone unit substituted with two hydroxyphenyl group (Figure 2). The compound has revealed a modest antiproliferative action against neuroblastoma SH-SY5Y cells when tested at a concentration of 50 μM. The compound could derive, biosynthetically, from the precursor N-trans-feruloyltyramine, also isolated from P. oleracea (Zhao et al. 2018). This tyramine derivative (also known as moupinamide), found in diverse plants and food components (such as the traditional Chinese food Laba garlic) (Gao et al. 2019), is known for its antioxidant and antiinflammatory effects, attributed to a downregulation of cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS) via suppression of transcription factors AP-1 and the JNK signalling pathway.

Table 1. Patent applications on oleraciamide alkaloids

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Patent numbers and titles</th>
<th>Registration / publication dates</th>
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<tbody>
<tr>
<td>Oleraciamide A</td>
<td>CN106220587B</td>
<td>Filing: 2016-08-15</td>
</tr>
<tr>
<td>Oleraciamide B</td>
<td>Two kinds of alkaloid compounds and its extraction separation method in purslane</td>
<td>Priority: 2016-08-15</td>
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<td>Publication (A): 2016-12-14</td>
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<td></td>
<td></td>
<td>Application granted: 2018-05-18</td>
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<tr>
<td></td>
<td></td>
<td>Publication (B): 2018-05-18</td>
</tr>
<tr>
<td>Oleraciamide C</td>
<td>CN106279305B</td>
<td>Filing: 2016-08-15</td>
</tr>
<tr>
<td>Oleraciamide D</td>
<td>CN106946766B</td>
<td>Filing: 2017-05-11</td>
</tr>
<tr>
<td>Oleraciamide E</td>
<td>CN109897077A</td>
<td>Filing: 2019-04-03</td>
</tr>
<tr>
<td>Oleraciamide F</td>
<td>CN108797087B</td>
<td>Priority: 2019-04-03</td>
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in RAW 264.7 macrophages (Jiang et al. 2015). N-trans-feruloyltyramine and its two analogues N-trans-feruloyl-3-methoxytyramine and N-trans-coumaroyltyramine have been isolated from a P. oleracea extract, together with the isoindole alkaloid named oleraisoindole (Jiang et al. 2018). Diverse trans-feruloyltyramine derivatives can be found in P. oleracea extracts, such as 7’-ethoxy-trans-feruloyltyramine which is a good antioxidant compound (Ying et al. 2020). OL-D warrants further investigations.

The structures and properties of OCM-E and F have been published one year ago (Liu et al. 2021) and OCM-E is described in a Chinese patent (CN109897077A in Table 1). They both include a feruloyl unit linked to a trihydroxy-phenyl-methylamine unit itself connected with a β-D-glucose, and they differ by the presence or not of a 3-methoxy substituent, as shown in Figure 2. The aglycone part share an analogy with N-trans-feruloyltyramine but it is one carbon shorter (phenyl-methylamine vs. phenyl-ethylamine). The carbohydrate unit is the same as for OCM-C (β-D-Glc). According to the patent, OCM-E displays anti-inflammatory properties, inhibiting the release of NO by LPS-stimulated RAW264.7 macrophages, as well as the production of interleukin 6 (IL-6), tumor necrosis factor alpha (TNFα) and prostaglandin E2 (PGE2). Its antiproliferative activity is modest, with IC50 varying from 20.2 to 39.1 µM depending on the cancer cell line tested. OCM-E also inhibits the acetylcholinesterase enzyme in vitro (IC50: 52.4 µM) (Liu et al. 2021). No biological data has been reported for OCM-F. Finally, the isolation of oleracimamide G (OCM-G) from P. oleracea has been recently published, together with an indole alkaloid named oleraindole D (Xu et al. 2020). OCM-G is a dihydriosoquinolinone derivative endowed with a weak anticholinesterase activity (IC50: 65.7 µM), roughly like that measured with oleraindole D (IC50: 58.8 µM).

OLERACONES

Thus far, the oleracone family includes 13 compounds, designated oleracone and oleracones A to L, mostly described in specific Chinese patents (Table 2) and a few publications (cited below). The patents essentially describe the isolation procedure and chemical characterization of the compounds, with relatively little biological information. Below, the compounds are presented in turn, in a chronological order of discovery. Their chemical structures are shown in Figure 3.

The first compound in the series was simply named oleracone (OL). It was isolated from P. oleracea in 2016 and its anti-inflammatory activity characterized in vitro. The compound was found to inhibit the production of pro-inflammatory cytokines, such as IL-6 and TNFα induced by lipopolysaccharide (LPS) in RAW264.7 macrophages (Meng et al. 2016). The compound was moderately potent, reducing also nitric oxide (NO) production and PGE2 release at 50 µM. However, the compound showed a rapid distribution in rat after oral administration and a satisfactory bioavailability of about 75% (Meng et al. 2016). This first compound was rapidly followed by the discovery of two molecules designated oleracones A and B described in a parallel study together with the alkaloids oleracimine and oleracimine A (Li et al. 2016). OL, OL-A and OL-B are atypical bicyclic molecules (Figure 3). OL-A includes an 8-oxo-cyclopenta-azocine bicycle with an acetamide substituent. OL-B bears an atypical tetrahydroazulenone core, rarely found in nature. There is very little information about this compound which has been also mentioned in a recent publication in Chinese (Sun et al. 2019).
activity of the three compounds ranks in the order OL-C > OL-D > OL-E and a very weak anti-cholinesterase activity was also reported with these compounds (IC50: 60-80 μM) (Yang et al. 2018b). Oleracone C, D and E have been discovered recently (Yang et al. 2018a). OL-D bears a characteristic 5-hydroxy,7-methoxy-chromene unit whereas OL-C is the corresponding chromane derivative. They contain both a 3-(2-hydroxy-benzyl) group. In other words, they are homoiosoflavone (OL-D) and homoisoflavonone (OL-C) compounds (Figure 3). In contrast, OL-E is dihydrochalcone, synthetic precursor to OL-C and OL-D, with a phenol unit linked to a dimethoxy-phenol unit via a 1-propanone linker (Figure 3). The antioxidant activity of the three compounds ranks in the order OL-D > OL-E > OL-C and a very weak anti-cholinesterase activity

<table>
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<tr>
<th>Compounds</th>
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| Oleracone          | CN105330588B Alkaloid Oleracone and its extraction separation method in purslane | Filing: 2015-10-16  
|                    | Priority: 2015-10-16  
|                    | Publication (A): 2016-02-17  
|                    | Application granted: 2017-09-26  
|                    | Publication (B): 2017-09-26  
|                    | Filing: 2015-10-16  
| Oleracone          | CN105232539B Two breeds of horses bitterroot source organism alkali is used as the application for preparing anti-inflammatory drug | Priority: 2015-10-16  
|                    | Publication (A): 2016-01-13  
|                    | Application granted: 2017-09-05  
|                    | Publication (B): 2017-09-05  
| Oleracone A        | CN106008502B Purslane middle skeleton alkaloid compound and its extraction separation method | Filing: 2016-06-06  
|                    | Priority: 2016-06-06  
|                    | Publication (A): 2016-10-12  
|                    | Application granted: 2017-09-26  
|                    | Publication (B): 2017-09-26  
| Oleracone B        | CN106083556B Azulene structural compounds and its extraction separation method in purslane | Priority: 2016-06-06  
|                    | Publication (A): 2016-11-09 (A)  
|                    | Application granted: 2018-05-18  
|                    | Publication (B): 2018-05-18  
| Oleracone C        | CN107746397B Compound Oleracone C and its extraction separation method in purslane | Filing: 2017-11-28  
|                    | Priority: 2017-11-28  
|                    | Publication (A): 2018-03-02  
|                    | Application granted: 2019-09-17  
|                    | Publication (B): 2019-09-17  
| Oleracone D        | CN107698546B Compound Oleracone D and its extraction separation method in purslane | Filing: 2017-11-28  
|                    | Priority: 2017-11-28  
|                    | Publication (A): 2018-02-16  
|                    | Application granted: 2019-09-17  
|                    | Publication (B): 2019-09-17  
| Oleracone E        | CN107827726A Compound Oleracone E and its extraction separation method in purslane | Filing: 2017-11-28  
|                    | Priority: 2017-11-28  
|                    | Publication (A): 2018-03-23  
| Oleracone F        | CN108558809B Compound Oleracone F in purslane and extraction and separation method thereof | Filing: 2018-04-17  
|                    | Priority: 2018-04-17  
|                    | Publication (A): 2018-09-21  
|                    | Application granted: 2020-01-21  
|                    | Publication (B): 2020-01-21  
| Oleracone G        | CN109824685A Compound oleracone G and its extraction separation method and application in purslane | Filing: 2019-04-03  
|                    | Priority: 2019-04-03  
|                    | Publication (A): 2019-05-31  
| Oleracone H        | CN110194755A In purslane compound Oleracone H and its extraction separation method and its with application | Filing: 2019-04-03  
|                    | Priority: 2019-04-03  
|                    | Publication (A): 2019-09-03  
| Oleracone I        | CN110294733A One kind Oleracone I of key compound containing peroxide and its extraction separation method and application in purslane | Filing: 2019-04-03  
|                    | Priority: 2019-04-03  
|                    | Publication (A): 2019-10-01  

Interestingly, in an interesting
vivo assay using wild-type N2 Caenorhabditis elegans, a treatment with OL-E and OL-F (at 20 μM) extended the lifespan of the nematodes by 13.8 and 11.8% (Yoon et al. 2019). This effect may contribute to the anti-aging properties of the plant. Indeed, purslane ethanolic extracts can attenuate aging alternations (Ahangarpour et al. 2016).

Oleracone G (OL-G) is a tetracyclic compound, with a pyrano[2,3-b]pyran scaffold. The compound is described in a recent patent (Table 2) and cited in a chemical work about the synthesis of the pyrano[2,3-b]pyran unit (Osyannin et al. 2020). Otherwise, there is little information about this compound, apart from its modest antioxidant capacity (IC₅₀: 40.1 μM in the standard DPPH (1,1-diphenyl-2-picryl-hydrazyl) assay and weak antiproliferative activities against various cancer cell lines in vitro (IC₅₀: 42-82 μM). OL-G exhibits a modest anti-inflammatory activity in vitro (Duan et al. 2021). Oleracone H (OL-H) is only described in a Chinese patent (Table 2). It is a 4-chromane derivative with propanoic acid side chain. The compound exhibits low antiproliferative activities against different cancer cell lines in vitro (IC₅₀: 38-96 μM), and a slightly better antioxidant capacity compared to OL-G (IC₅₀: 19.8 μM).

Oleracone I (OL-I) is a strange compound, with an endoperoxide bridge between the two phenyl units, delimiting a unique 11-membered central ring (Figure 3).

The compound is more cytotoxic than its congeners OL-G and OL-H, with IC₅₀ values in the range 20.3-30.9 μM against different cancer cell lines in vitro (but probably not very stable). OL-I dose-dependently reduces the production of inflammatory mediators such as IL-6, TNFα, NO, and PGE₂ by LPS-induced RAW264.7 macrophages. At the concentration of 50 μM, the production of these inflammatory mediators was almost completely suppressed (patent CN110294733A, Table 2). Oleracones J and K were isolated recently; they both showed a modest antioxidant capacity and a weak anticholinesterase effect (Duan et al. 2020). Oleracone L (OL-L) is the most recent member in the series with a modes anti-inflammatory activity in vitro (IC₅₀: 46 μM) (Cui et al. 2021). All these compounds deserve more studies to characterize their biological effects more deeply.

The procedures reported to isolate these compounds are generally relatively long and tedious, with multiple steps of extraction, chromatographic separations, concentrations, and final HPLC purification. An example of process for the isolation of OL-G is presented in Figure 4. The compound was isolated in 6 successive steps, starting from 150 kg of dried purslane, through several chromatographic separations (the final yield was not specified in the patent CN109824685A).

Figure 4. Summary of the purification process developed to extract and purify oleracone G (OL-G) from Portulaca oleracea (inferred from patent CN109824685A (Table 2). The process is divided into 6 steps implemented one after the other, to purify OL-G starting from the dried plant. TLC, thin layer chromatography.
CONCLUSION AND PERSPECTIVES

Portulaca oleracea, commonly known as purslane, is a popular plant of great value for its nutritive composition and its traditional medicinal uses in many countries. It also represents a reservoir of natural products, largely explored over the past thirty years but still incompletely known. A phytochemical survey of the natural products found in P. oleracea extracts was reported in 2015 (Zhou et al. 2015) and 2017 (Iranshahy et al. 2017) but over the past 3-4 years, many other new natural products have been identified from the plants. We can cite the alkaloid oleraisoindole aforementioned (Jiang et al. 2018) and its hydroxylated analogue named oleroisodole A (Ma et al. 2021), the alkaloid portulacatones A and B and portulacatal (Gu et al. 2020; Cui et al. 2021), the alkaloid 1-carbomethoxy-β-carboline (Kim et al. 2019), a series of water-soluble alkaloids called oleracines (Fu et al. 2021), but also several homoisoflavonoids (Lee et al. 2019), the chalcone 2,4'-di-hydroxy-3',5'-dimethoxychalcone (Wang et al. 2020) and chromone derivatives such as 5,7-dimethoxy-3-(2hydroxy-xybenzyl)-4'-chromanone and HM-chromanone (Park et al. 2019; Je et al. 2021; Kang et al. 2021; Park et al. 2021), a few lignans such as oleragnins A and B (Wei et al. 2019; Duan et al. 2021) and other compounds (Miao et al. 2019; Wei et al. 2019; Xiu et al. 2019; Zhao et al. 2019b; Wang et al. 2020). Recently, a metabolomic analysis of several taxa of P. oleracea L. has identified 85 metabolites including the large series of cyclo-dopa alkaloids, designated oleracines A-to-W (Farag and Shakour 2019). These products complete the panoply of compounds previously isolated from purslane such as the olerecinines alkaloids (Li et al. 2016, 2017b). With no doubt, P. oleracea L. is one of the richest plants in bioactive secondary metabolites.

This review provides, for the first time, a focus on two sub-groups of bioactive metabolites found in P. oleracea extracts: the oleraciamides and oleracones. It is useful to present a global view of their structures and properties even if the information available to date about their pharmacological properties remain very limited. Hopefully, this survey will encourage further studies of these compounds. The oleraciamide series is very disparate, with 7 compounds showing little or no structural homology between them. The most interesting compound in the series is arguably OCM-E, endowed with antiproliferative and antioxidant properties (Liu et al. 2019). This compound bears a structural analogy with the glycosylated indole alkaloid oleraindole D recently isolated (Xu et al. 2020). The oleracine series is more homogeneous, apart from OL and OL-A/B which are atypical compounds. OL-C-to-K forms a homogenous series, with bi-, tri- and tetracyclic members. The homoisoflavone derivatives OL-C and OL-K and the homoflavones OL-D, OL-F and OL-J bear structural analogies with known biologically active compounds. For example, OL-C presents a structural homology with the homoisoflavonane deoxysappanone B 7,4'-dimethyl ether (from the dried heartwood of the medicinal plant Caesalpinia sappan), recently characterized as a potent anti-angiogenic compound (Chen et al. 2020) and known as a microtubule inhibitor with a nanomolar anti-leukemic activity (Bernard et al. 2015). Antitumor homoisoflavone derivatives have been also isolated from Vietnamese coriander (Polygonatum odoratum) roots and shown to induce Bel-2 phosphorylation and apoptosis (Rafi et al. 2007). Other homoisoflavonoids could be cited; they represent a relatively rare subclass of flavonoids in nature, but with a large bioactivity potential (Lin et al. 2014; Abegaz and Kinfe 2019).

Therefore, it would be useful to deepen the study of the bioactivities and mechanism of action of compounds like OL-C and OL-K. Pharmacological studies with homoisoflavonoids from P. oleracea are now appearing, such as the study recently reported with a compound named HM-chromonone acting as an anti-adipogenesis agent (Je et al. 2021; Park et al. 2021). In the next few years, these products will surely deliver their secrets and mechanisms. Hopefully, this review will encourage phytochemists and biologists to investigate further these compounds.

REFERENCES


