Jessica Vairinhos and Maria Graça Miguel*

# Essential oils of spontaneous species of the genus *Lavandula* from Portugal: a brief review

https://doi.org/10.1515/znc-2020-0044
Received March 1, 2020; revised April 20, 2020; accepted April 24, 2020

**Abstract:** Spontaneous lavender growing in uncultivated fields in Portugal have been used in traditional medicine for internal and external uses. The essential oils (EOs) of *Lavandula stoechas* subsp. *luisieri* are characterized by the presence of *trans*-α-necrodyl acetate and *trans*-necrodol. These EOs are able to prevent the generation and deposition of neurotoxic β-amyloid peptide in Alzheimer's disease. The EOs also present antibacterial, antifungal, anti-*Leishmania*, antioxidant, anti-inflammatory and antifeedant effects. In the case of hydrodistillation, the predominant compound of *Lavandula viridis* EO was 1,8-cineole, nevertheless in the case of supercritical fluid extraction, the main constituent was camphor. In in vitro shoots EOs, 1,8-cineole and α-pinene were the most important compounds. The EOs presented anti-fungal activity particularly against *Cryptococcus neoformans* and dermatophytes. The antioxidant and anti-protozoal activities of *L. viridis* EOs were lower than *L. stoechas* subsp. *luisieri* EOs, with hydrodistillation being the best method for obtaining samples with higher antioxidant and anti-acetylcholinesterase activities. The presence of fenchone, 1,8-cineole and camphor was a common trace of the *Lavandula pedunculata* subsp. *pedunculata* EOs and in in vitro axillary shoots EOs. *Lavandula pedunculata* subsp. *lusitanica* EOs were predominantly constituted of fenchone and camphor. The antioxidant activity of *L. pedunculata* subsp. *lusitanica* EOs was poorer than other *Lavandula* EOs from Portugal.

**Keywords:** biological properties; *Lavandula stoechas* subsp. *Luisieri*; *L. latifolia*; *L. multifida*; *L. pedunculata*; *L. viridis*.

***Corresponding author: Maria Graça Miguel,** Mediterranean Institute for Agriculture, Environment and Development, Department of Chemistry and Pharmacy, Faculty of Science and Technology, University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal, E-mail: mgmiguel@ualg.pt
**Jessica Vairinhos:** Department of Chemistry and Pharmacy, Faculty of Science and Technology, University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

## 1 Introduction

The genus *Lavandula* comprises 39 species, hybrids and many cultivars, all belonging to the Lamiaceae family. They are aromatic plants of great economic importance due to their uses in several industry branches (pharmaceutical, food, cosmetics, perfumery and aromatherapy), particularly *Lavandula angustifolia* (fine lavender), *Lavandula x intermedia* (lavandin), *Lavandula latifolia* (spike lavender) and *Lavandula stoechas* (Spanish lavender) [1–4]. Since ancient times lavender has been used to perfume bathing water to help purify the body and spirit; and to alleviate insomnia; anxiety; fatigue; meteorism; flatulence; vomiting; loss of appetite; headaches; toothaches; joint pain and sores [5]. These properties have been attributed to its essential oils (EOs), nevertheless some authors in their systematic review and meta-analysis that have focused on the effect of lavender EOs in humans concluded that more attention should be paid in the interpretation of results due to the following factors: heterogeneity between studies, small number of studies and small sample sizes [6–8].

Species of the genus *Lavandula* are native of the Mediterranean region but have been cultivated in different regions of the world: Europe, South West Asia, the Arabian Peninsula, India and North and South America [1]. According to a review by Lesage-Meessen et al. [9], Bulgaria, the UK, France, China, Ukraine, Spain and Morocco dominate the lavender EO market.

As regards the EOs composition of *Lavandula* species, *Lavandula angustifolia* EOs are the most investigated, among the 17 species studied (*L. angustifolia*, *L. x intermedia*, *L. latifolia*, *L. stoechas*, *Lavandula bipinnata*, *Lavandula canariensis*, *Lavandula coronopifolia*, *Lavandula dentata*, *Lavandula heterophylla*, *Lavandula gibsonii*, *Lavandula lanata*, *Lavandula luisieri*, *Lavandula multifida*, *Lavandula pedunculata*, *Lavandula pinnata*, *Lavandula pubescens*, *L. viridis*) [1]. Linalool and linalyl acetate generally occur in high percentages in *L. angustifolia*, *L. x intermedia* and *L. latifolia* EOs, although may also occur in other species but are only detected in very few examples. The percentages of those monoterpenes vary according to the plant part being used, geographical region or chemotype. For example, linalool and linalyl acetate have been

also found in some examples of *L. stoechas* from Tunisia. Generally, these oxygen-containing monoterpenes are not present in *L. stoechas* EOs [1].

In Portugal it is possible to find the ornamental *L. dentata*, the industrial grown *L. angustifolia* and the spontaneous *L. latifolia* Medik. (spike lavender; Portuguese common name: "alfazema-brava") (Figure 1), *L. multifida* L. (ternleaf lavender or Egyptian lavender; Portuguese common name: "alfazema-de-folhas-recortadas") (Figure 2); *L. stoechas* subsp. *luisieri* (Rozeira) Rozeira (Portuguese common name: "rosmaninho" or "rosmaninho-menor") (Figure 3), *L. pedunculata* (Miller) Cav. (French lavender; Portuguese common name: "rosmaninho-maior") and *L. viridis* L'Her. (green lavender or white lavender; Portuguese common names: "rosmaninho-menor", "rosmaninho-verde" or "rosmaninho-branco") (Figure 4) [10]. Prazeres [11] considered it possible to detect three distinct taxa: *Lavandula sampaiana* (Rozeira) Rivas Mart., *L. pedunculata* (Mill.) Cav. subsp. *lusitanica* (Chaytor), and *L. stoechas* subsp. *luisieri* (Rozeira) Rozeira, after a combined analysis of morphometric, morphological and micromolecular studies, using genetic variability by inter simple sequence repeats (ISSR) molecular markers. However, other authors [12] consider that *L. pedunculata* should be treated as a subspecies of *L. stoechas* and *L. stoechas* subsp. *luisieri* should be treated as a distinct species due

**Figure 2:** *Lavandula multifida* (from https://jb.utad.pt. UTAD Botanical Garden, Digital Flora of Portugal).

**Figure 1:** *Lavandula latifolia* by António Crespí (from http://jb.utad.pt. UTAD Botanical Garden, Digital Flora of Portugal).


**Figure 3:** *Lavandula stoechas* subsp. *luisieri* (by Thistle Garden from https://jb.utad.pt. UTAD Botanical Garden, Digital Flora of Portugal).

**Figure 4:** *Lavandula viridis* from https://jb.utad.pt. Botanical Garden, Flora Digital de Portugal.

to the results obtained by plastid trnK-matK markers analysis. Chemically, the composition of *L. stoechas* L. EOs is considerably different from those of *L. stoechas* subsp. *luisieri*. *Lavandula stoechas* L. EOs is predominantly constituted of fenchone and camphor [13], and morphologically, Upson and Andrews [14] had also reported dissimilar characters (bracts, indumentum and form of the corolla tube) for *L. stoechas* subsp. *luisieri*).

The chemical composition of the EOs of the spontaneous species of the *Lavandula* genus growing in Portugal is reviewed in the present work as well as their biological properties, taking into account the name of the species used by the authors.

## 2 *Lavandula latifolia* Medik.

*Lavandula latifolia* is an aromatic shrub, 30–80 cm tall, that grows wild in Mediterranean regions (former Yugoslavia, Italy, France, Spain and Portugal) [15]. This species generally grows on calcareous soils and presents a cylindrical spike with violet flowers measuring 8–10 mm [15, 16]. According to Herraiz-Peñalver et al. [17], *L. latifolia* has been used as an antispasmodic, as a sedative, as an antihypertensive agent, as an antiseptic, in healing and as an anti-inflammatory. In Spain, this species has been of great interest as traditionally it has been used in cosmetics, for preparing bath salts, room sprays or disinfectants and in perfumery [15, 17]. In spite of the description of *L. latifolia* occurring throughout the Iberian Peninsula, it has been particularly in Spain that most studies have been done, not only for evaluating the chemical composition, but also for the determination of some biological properties. The literature showed that Spanish *L. latifolia* EOs are relatively homogenous due to the fact that the major compounds are always 1,8-cineole, linalool and camphor independent of the collection region or season [15, 17–19], but in different proportions, that permitted classifying such oils in three different groups according to their high, intermediate or low proportion of linalool, which, in turn, were correlated to the Supra-, Meso- and Thermo-Mediterranean bioclimatic belts where the populations were located, respectively [20].

There is a publication with Portuguese and Spanish researchers [21] who describe the antioxidant activity and chemical composition of *L. latifolia* EO, but it is not clear what the origin of the sample was. Also, in this case, 1,8-cineole (**7**), linalool (**9**) and camphor (**6**) (Figure 5) were the major constituents of the EO. This sample was able to reverse the oxidation and improved the oxidative stability of soybean oil when submitted to microwave heating. More peer-reviewed publications concerning Portuguese *L. latifolia* EOs were not found, which may indicate the low distribution of this plant in the country.

## 3 *Lavandula multifida* L.

*Lavandula multifida* (fern leaf lavender, Egyptian lavender) is a species of the section Pterostoechas occurring commonly along the Mediterranean coast (Egypt, Tunisia, Morocco, Algeria, Spain, Portugal). In Italy, the plant has been found in the hot and arid climatic conditions of Calabria and Sicily [22, 23], whereas in Tunisia the plant can be found in upper semi-arid bioclimates, particularly in open calcareous garrigues [24]; and in Morocco it also grows on calcareous soils and on the borders of rivers of temporary drainage, between 800 and 2000 m altitude [25]. In Portugal, *L. multifida* grows in the southern region (Sesimbra, Arrábida and Mértola) [23]. Generally, *L. multifida* populations are reduced and fragmented due to the human impact on its natural habitat [22]). Owing to this negative fact, Panuccio et al. [26] have developed germination strategies in order to preserve the genetic biodiversity of autochthon *L. multifida* plants.

*Lavandula multifida* is a semi-evergreen perennial shrub growing 30–100 cm tall, with triangular pinnatisect leaves and a flower spike composed of blue or purple flowers that can measure 10–12 mm [16, 27, 28], generally used in folk medicine in decoctions against rheumatism, colds and as a digestive [23].

Zuzarte et al. [23] studied two essential oils collected in two regions of Portugal (Sesimbra/Arrábida and Mértola) and both were predominantly constituted

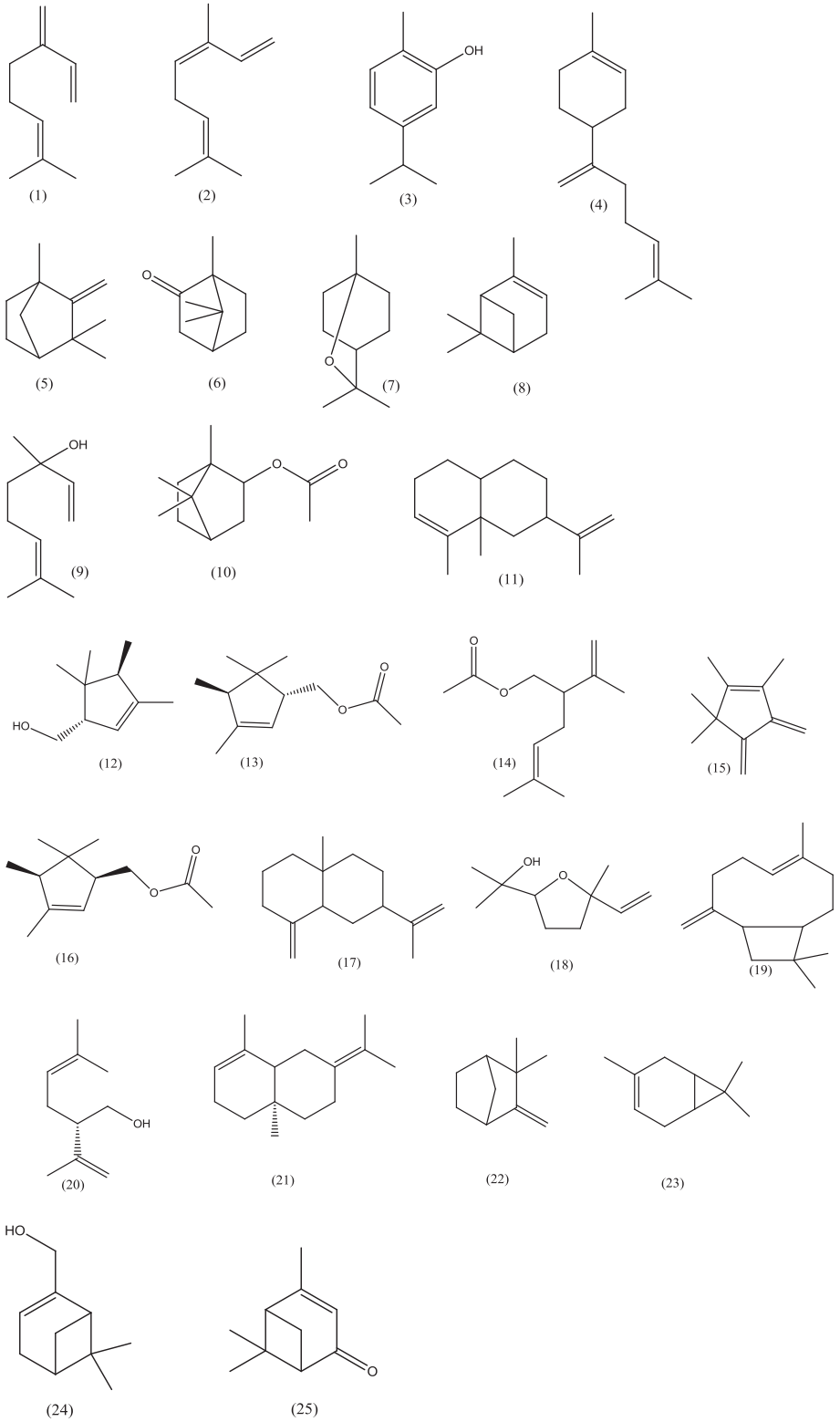


**Figure 5:** Main compounds (>5%) present in at least one species EO of the genus *Lavandula* from Portugal. (**1**) Myrcene; (**2**) *cis*-β-ocimene; (**3**) carvacrol; (**4**) β-bisabolene; (**5**) fenchone; (**6**) camphor; (**7**) 1,8-cineole; (**8**) α-pinene; (**9**) linalool; (**10**) bornyl acetate; (**11**) eremophylene; (**12**) *trans*-α-necrodol; (**13**) *trans*-α-necroyl acetate; (**14**) lavandulyl acetate; (**15**) tetramethyl-5-methylene-cyclopenten-2-enone; (**16**) *cis*-necrodyl acetate; (**17**) β-selinene; (**18**) linalool oxide;(**19**) *E*-caryophyellene; (**20**) lavandulol; (**21**) selina-3,7(11)-diene; (**22**) camphene; (**23**) Δ3-carene; (**24**) myrtenol; (**25**) verbenone.

of carvacrol (**3**) and *cis*-β-ocimene (**2**) (Table 1). The relative high percentage of this compound was responsible for completely inhibiting filamentation in *Candida albicans* (Table 1). Both essential oils were able to prevent the growth of *Candida* strains, *Cryptococcus neoformans*, dermatophytes, and *Aspergillus* strains, but particularly, *Cr. neoformans* and dermatophyte (Table 1). The high amounts of carvacrol in Portuguese *L. multifida* EOs are in accordance to those reported from Moroccan [25, 48], and Algerian samples [49], nevertheless they must be considered different since *cis*-β-ocimene (**2**) also occurs in relatively high amounts, not observed for the Moroccan and Algerian samples. According to Khadir et al. [50] and Messaoud et al. [51], the EOs obtained from *L. multifida* collected in several places of Algeria or Tunisia, respectively, were predominantly constituted of carvacrol (**3**) and β-bisabolene (**4**). This profile was also previously reported by Chograni et al. [52] who found those compounds in samples collected in different places in Tunisia, however, in the same country, Msaada et al. [53] reported linalool-rich samples. Such results are in accordance with previous reports, such as [54] who considered that populations of *L. multifida* are not strictly grouped according bioclimates or geographic location.

## 4 *Lavandula pedunculata* (Miller) Cav.

*Lavandula pedunculata* is an aromatic shrub that can reach up to 70 cm in height that presents long-stalked spikes that can reach to 24 cm. The ovoid or subcylindrical shape of spikes measure 10–35 × 8–17 mm and are constituted of 6–8 mm lilac flowers [16, 55]. This species is native to the Iberian Peninsula, North Africa and Turkey [32, 56, 57]. In Portugal, Franco [16] considered three subspecies for *L. pedunculata:* subsp. *pedunculata* in northwest Portugal, subsp. *sampaiana* in north and central Portugal and subsp. *lusitanica* in central and south Portugal. In Portuguese folk medicine, the infusion of the flowered parts *L. pedunculata* was used for anxiety, insomnia, anorexia, coughs, bronchitis and as a tonic; and in Madeira and the Porto Santo Islands (Portugal), the whole plant had the same applications, and the smoke produced by burning the leaves was also used for treating apoplexy, for long-term use [58, 59].

In spite of the presence of *L. pedunculata* in subsp. *sampaiana* in north and central Portugal, its chemical composition had not been evaluated as far as we know, only in Spain was it found as a doctoral thesis [60] in which it was reported that Spanish *L. pedunculata* in subsp. *sampaiana* EOs were predominantly made up of camphor (4.3–84.4%).

*Lavandula pedunculata* subsp. *lusitanica* EOs were predominantly made up of fenchone and camphor, according to the works developed by two Portuguese research teams [29, 30]. For *L. pedunculata* subsp. *pedunculata* EOs, the presence of fenchone at relatively high concentrations along with 1,8-cineole (**7**) and camphor (**6**) was a common trace element with the exception of one type in which 1,8-cineole (**7**) and camphor (**6**) were the major compounds of the EOs (Table 1). As Zuzarte et al. [32] considered that plant micropropagation was able to guarantee a large-scale production in controlled conditions, in a short period of time, without negative impacts on habitats, they developed techniques of in vitro propagation of *L. pedunculata* and determined the chemical composition of plantlet EOs and compared them to those of the parent plants. The authors concluded that in vitro axillary shoot proliferation was a rapid method for the multiplication of this species without loss of EO characteristics (Table 1).

The antioxidant activity of *L. pedunculata* subsp. *lusitanica* EOs was poorer than other *Lavandula* EOs from Portugal, independent of the method used, according to the study developed by Matos et al. [29]. Similar results were observed by Costa et al. [30] who reported that polar compounds present in *L. pedunculata* subsp. *lusitanica* extracts were more efficient as antioxidants than the EOs, nevertheless they were less active as anti-acetylcholinesterase (Table 1). Ferreira et al. [59] also reported that *L. pedunculata* EOs, at 0.5 and 1 mg/mL were more active for inhibiting acetylcholinesterase activity than the ethanolic extracts, nevertheless decoctions at 5 mg/mL had better anti-acetylcholinesterase activity than the EOs. Alcoholic extracts and decoctions were always better antioxidants than EOs [59]. The antifungal activity of *L. pedunculata* subsp. *pedunculata* EOs was evaluated and they were more active against dermatophyte strains (*Epidermophyton floccosum* FF9, *Trichophyton mentagrophytes* FF7, *Microsporum canis* FF1, *Trichophyton rubrum* CECT 2794 and *Microsporum gypseum* CECT 2908), particularly those with the highest percentage of camphor (Table 1). The antimycotic activity was also performed by Baptista et al. [61] who tested 12 fungi belonging to the Basidiomycota and Ascomycota divisions, and the authors found that *L. pedunculata* EOs had better activity against three fungi (*Candida*

**Table 1:** Main compounds (>5%) of the essential oils of spontaneous species of the genus *Lavandula* from Portugal and their properties.

| Origin | Plant part | Compounds | Biological properties | Reference |
|---|---|---|---|---|
| | | ***Lavandula stoechas* subsp. *luisieri*** | | |
| Sesimbra/Arrábida-Mértola | Aerial parts | Myrcene (**1**)[a] (5.7–5.5)[b], *cis*-β-ocimene (**2**) (27.4–27.0), carvacrol (**3**) (42.8–41.5), β-bisabolene (**4**) (5.6–5.0) | The EO was effective against dermatophytes and *Cr. neoformans*, with MIC and MLC values of 0.16 μL/mL and 0.32 μL/mL, respectively. The EO completely inhibited filamentation in *Ca. albicans* at 0.08 μL/mL, with *cis*-β-ocimene being the main compound responsible for this inhibition (0.02 μL/mL). The mechanism of action of EO leads to cytoplasmic membrane disruption and cell death | [24] |
| | | ***Lavandula pedunculata*** | | |
| Ludo, Faro (Algarve) | | Subsp. *lusitanica*: fenchone (**5**) (41.9), camphor (**6**) (34.6) | Poorer antioxidant activity (DPPH scavenging activity and prevention of lipid peroxidation) than *L. stoechas* subsp. *luisieri* | [29] |
| Gambelas, Faro (Algarve) | Aerial parts | Subsp. *lusitanica*: fenchone (**5**) (38.0), camphor (**6**) (40.6) | The bioactive compounds of polar extracts (3-*O*-caffeoylquinic acid, 4-*O*-caffeoylquinic, 5-*O*-caffeoylquinic acid, rosmarinic acid, luteolin, apigenin) were more efficient free-radical scavengers (peroxyl and ABTS), $Fe^{2+}$ chelators and inhibitors of malondialdehyde production than EO, while the EO was the most active against acetylcholinesterase | [30] |
| Mirandela/Bragança and Guarda and Coimbra | Aerial parts | 1,8-Cineole (**7**) (2.4–55.5%), fenchone (**5**) (1.3–59.7%), camphor (**6**) (3.6–48.0%) | A significant antifungal activity of the oils was found against dermatophyte strains (*E. floccosum* FF9, *T. mentagrophytes* FF7, *Microsporum canis* FF1, *T. rubrum* CECT 2794 and *M. gypseum* CECT 2908), particularly the EO with the highest content of camphor with MIC and MLC values ranging from 0.32 to 0.64 μL/mL | [31] |
| Plant A (1,8-cineole/camphor chemotype) was collected in Trás-os-Montes region<br>Plant B (fenchone chemotype) in Coimbra region | Aerial parts and in vitro plantlets | Sample A – Plantlet A<br>α-Pinene (**8**) (6.9–13.6), 1,8-cineole (**7**) (24.0–18.0), linalool (**9**) (5.2–8.3), camphor (**6**) (32.4–12.5), bornyl acetate (**10**) (0.1–10.4), eremophillene (**11**) (1.5–5.5)<br>Sample B-Plantlet B<br>α-Pinene (**8**) (4.8–10.2), 1,8-cineole (**7**) (2.4–7.1), fenchone (**5**) (48.7–49.7), camphor (**6**) (3.6–11.6) | Not determined | [32] |
| Not reported | Plant – in vitro plantlet | 1,8-Cineole (**7**) (9.8–7.1), fenchone (**5**) (48.6–34.0), camphor (**6**) (14.1–7.2) | Not determined | [33] |
| | | ***Lavandula stoechas* subsp. *luisieri*** | | |
| Serra-do-Açor, near the village of Piodão | Aerial parts | *trans*-Necredol (**12**) (8.4), *trans*-α-necrodyl acetate (**13**) (16.0), lavandulyl acetate (**14**) (6.1), 2,3,4,4-tetramethyl-5-methylene-cyclopent-2-enone (**15**) (5.2) | Inhibition of BACE-1, a key enzyme in the generation and deposition of neurotoxic β-amyloid peptide (Ab) in Alzheimer's disease, particularly to the presence of the monoterpenic ketone 2,3,4,4-tetramethyl-5-methylene-cyclopent-2-enone | [34] |

**Table 1** (continued)

| Origin | Plant part | Compounds | Biological properties | Reference |
|---|---|---|---|---|
| | | ***Lavandula stoechas* subsp. *luisieri*** | | |
| Penamacor | Flowers | *trans*-α-Necrodyl acetate (**13**) (1.8–20.3), 1,8-cineole (**7**) (2.7–40.0), camphor (**6**) (8.2–20.8), lavandulyl acetate (**14**) (nd–7.2) | *Escherichia coli* (MIC: 22 mg/mL; MBC: 22 mg/mL); *Staphylococcus aureus* (MIC: 22 mg/mL; MBC: 22 mg/mL); *Salmonella* spp. (MIC: 22 mg/mL; MBC: 22 mg/mL) | [35] |
| | Leaves | *trans*-α-Necrodyl acetate (**13**) (5.1–18.7), 1,8-cineole (**7**) (6.3–16.4), camphor (**6**) (1.1–42.9) | *E. coli* (MIC: 22 mg/mL; MBC: 22 mg/mL); *S. aureus* (MIC: 11 mg/mL; MBC: 11 mg/mL); *Salmonella* spp. (MIC: 22 mg/mL; MBC: 22 mg/mL) | |
| Évora | Leaves | 1,8-Cineole (**7**) (18.8), *trans*-necrodyl acetate (**13**) (15.6), *E*-caryophyllene (**19**) (6.0), isoborneol (10.0), *trans*-necrodol (**12**) (10.1), lavandulol (**20**) (11.0) | Bacterial isolates from mastitic sheep milk origin: *E. coli* (MIC: 500 - > 4000 μg/mL) *S. epidermidis* (MIC: 1 000 – > 4000 μg/mL) | [36] |
| Vila Velha Rodão | Flower | Fenchone (**5**) (36.77), linalool (**9**) (6.25), *trans*-α-necrodyl acetate (**13**) (10.27) | 1,8-Cineole and 2,3,4,4-tetramethyl-5-methylen-2-cyclopenten-1-one exhibited a significant correlation with antifeedant effects against *Spodoptera littoralis*; 2,3,4,4-tetramethyl-5-methylen-2-cyclopenten-1-one, camphor, bornyl acetate and 1,8-cineole against *R. padi*. When two compounds were used, the best results were found for *R. padi* using a combination of camphor and 2,3,4,4-tetramethyl-5-methylen-2-cyclopenten-1-one | [37] |
| | Leaves | Fenchone (**5**) (19.16), *trans*-α-necrodyl acetate (**13**) (19.38) | | |
| Mata | Flowers | Fenchone (**5**) (12.99), *trans*-α-necrodyl acetate (**13**) (22.84) | | |
| | Leaves | Linalool (**9**) (5.38), *trans*-α-necrodol (**12**) (11.51), *trans*-α-necrodyl acetate (**13**) (48.22), sesquiterpene acetate $C_{17}H_{28}O_3$ (5.57) | | |
| Casal da Fraga | Flowers | Camphor (**6**) (9.31), *trans*-α-necrodyl acetate (**13**) (9.40) | | |
| | Leaves | 2,3,4,4-Tetramethyl-5-methylen-2-cyclopenten-1-one (5.69) (**15**), *trans*-α-necrodyl acetate (**13**) (8.92) | | |
| Penamacor | Flowers | Camphor (**6**) (7.67), *trans*-α-necrodyl acetate (**13**) (29.99), *cis*-α-necrodyl acetate (**16**) (7.69), β-selinene (**17**) (12.82) | | |
| | Leaves | Linalool oxide (**18**) (6.45), *trans*-α-necrodyl acetate (**13**) (25.23), β-selinene (9.31) | | |
| Collection of plant extracts of the Faculty of Pharmacy, University of Coimbra | Aerial parts | *trans*-α-Necrodyl acetate (**13**) (19.0), *trans*-α-necrodol (**12**) (8.4), lavandulyl acetate (**14**) (6.1), 2,3,4,4-tetramethyl-5-methylen-cyclopenten-2-enone (5.2) (**15**) | The EO significantly reduced iNOS (inducible nitric oxide synthase) by 54.9 and 81.0%, respectively) and phosphorylated IκB-α by 87.4% and 62.3%, respectively, in primary human chondrocytes and the intestinal cell line, C2BBe1, stimulated with IL-1β or IFN-γ, IL-1β and TNF-α, respectively | [38] |

**Table 1** (continued)

| Origin | Plant part | Compounds | Biological properties | Reference |
|---|---|---|---|---|
| | | ***Lavandula stoechas* subsp. *luisieri*** | | |
| Piódão - Cabo de S. Vicente | Aerial parts | 1,8-Cineole (**7**) (6.4-33.9), fenchone (**5**) (nd–18.2), linalool (**9**) (6.2–3.0), α-*trans*-necrodol (**12**) (7.1–4.5), *trans*-necrodyl acetate (**13**) (17.4–3.2), lavandulyl acetate (**14**) (7.6–2.2) | For dermatophytes, MIC values ranged from 0.16 to 0.32 μL/mL for sample from Piódão and 0.32–0.64 μL/mL for sample from Cabo de S. Vicente. For *Aspergillus* strains, MIC values ranging from 0.32 to2.5 and 1.25–10 μL/mL, for samples from Piódão and Cabo de S. Vicente, respectivley. For *Candida* spp. and *C. neoformans*, the oils showed very similar activity with MIC ranging from 0.64 to 2.5 μL/mL, for both samples. Furthermore, MIC and MLC values were very similar for both samples, except for *Aspergillus* strains<br>In general, for concentrations as low as MIC/64 (0.01–0.02 μL/mL) for sample from Piódão and MIC/32 (0.02–0.04 μL/mL) for sample from Cabo de S. Vicente, more than 50% of germ tube formation were inhibited | [39] |
| Sagres (Algarve) | Aerial parts | *trans*-α-Necrodol (**12**) (8.4), 2,3,4,4-tetramethyl-5-methylen-cyclopenten-2-enone (**15**) (5.2), *trans*-α-necrodyl acetate (**13**) (16.0), lavandulyl acetate (**14**) (6.1) | *T. rubrum* (MIC: 200 - >400 μg/mL)<br>*T. mentagrophytes* (MIC: 200–400 μg/mL)<br>*T. interdigitale* (>400 μg/mL)<br>Positive interaction of EO with terbinafine against the terbinafine-resistant *T. rubrum* ATCC MYA-4438 in all fixed-ratio concentrations (synergistic activity between the drug and EO) | [40] |
| Beira Alta | Aerial parts | 1,8-Cineole (**7**) (18.9), necrodane derivatives (36.0), lavandulyl acetate (**14**) (7.2) | EO exhibited anti-*Leishmania* effects ($IC_{50}$ = 31–263 μg/mL).<br>At concentrations corresponding to $IC_{50}$ values, EO-exposed *Leishmania infantum* promastigotes suffered marked ultrastructural modifications: presence of aberrant-shaped cells, mitochondrial and kinetoplast swelling, and autophagosomal structures. *L. luisieri* EO exerted its leishmanicidal activity through different mechanisms, but mainly through unleashing apoptosis | [41] |
| Montenegro, Salir, Vila Real de S. António (Portugal) | Aerial parts | 1,8-Cineole (**7**) (25.7-34.3), fenchone (**5**) (0.2-6.6), *trans*-α-necrodol (**12**) (2.8-8.2), *trans*-α-necrodyl acetate (**13**) (11.3-17.5), 2,3,5,5-tetramethyl-4-methylen-2-cyclopenten-1-one (**15**) (2.4-5.1) | *L. stoechas* subsp. *luisieri* EOs namely those from Salir and Vila Real de S. António showed moderate antioxidant capacity, determined through the capacity for scavenging DPPH free radicals, since at 1000 mg/L the antioxidant index attained 57 and 40%, respectively, after 30 min<br>In thiobarbituric acid reactive substances (TBARS) assay, the inhibition percentages were 66% and 69%, at 500 mg/L, for samples from Salir and Vila Real de S. António | [29] |

**Table 1** (continued)

| Origin | Plant part | Compounds | Biological properties | Reference |
|---|---|---|---|---|
| | | ***Lavandula stoechas* subsp. *luisieri*** | | |
| Évora | Aerial parts | 1,8-Cineole (**7**) (18.80), *trans*-α-necrodyl-acetate (**13**) (16.16), *E*-caryophyllene (**19**) (6.00), *trans*-α-necrodol (**12**) (10.63), lavandulol (**20**) (11.68) | High ability to inhibit lipid peroxidation and showed an effect against a wide spectrum of microorganisms, such as Gram-positive and Gram-negative bacteria and pathogenic yeasts<br>The analgesic effect studied in rats was dose dependent, reaching a maximum of 67% at 60 min with the dose of 200 mg/kg. The anti-inflammatory activity with 200 mg/kg caused an inhibition in carrageenan-induced rat paw edema (83%), higher than dexamethasone 1 mg/kg (69%) | [42] |
| Casal da Fraga, Mata, Penamacor, Vila Velha de Ródão | Aerial parts | 1,8-Cineole (**7**) (0-5), fenchone (**5**) (0-36.7), linalool (**9**) (0-6.2), camphor (**6**) (0-9.7), necrodol (0-11.4), *trans*-α-necrodyl-acetate (**13**) (0-49.9) | Not determined | [43] |
| | | ***Lavandula viridis*** | | |
| Algarve | Aerial parts | α-Pinene (**8**) (9.2), 1,8-cineole (**7**) (29.7), linalool (**9**) (9.0), camphor (**6**) (10.0), selina-3,7(11)-diene (**21**) (6.6) | *L. viridis* EO displayed less activity against *L. infantum* ($IC_{50}$/24 h = 263 μg/mL) than *L. luisieri* EO | [41] |
| Vale das Águas (Aljezur, Algarve) | Aerial parts | α-Pinene (**8**) (9.0), camphene (**22**) (7.7), 1,8-cineole (**7**) (33.3), camphor (**6**) (20.4) | *L. viridis* EOs had lower antioxidant activity in all assays than *L. luisieiri* | [29] |
| Barranco do Velho, Salir (Algarve) | Aerial parts | 1,8-Cineole (**7**) (34.5-42.2), camphor (**6**) (13.4), α-pinene (**8**) (9.0), linalool (**9**) (6.7–7.9) | Dermatophytes and *Cr. neoformans* were the most sensitive fungi (MIC and MLC values ranging from 0.32 to 0.64 μL/mL), followed by *Candida* species (at 0.64–2.5 μL/mL). For most of these strains, MICs were equivalent to MLCs, indicating a fungicidal effect of the essential oil. The oil was shown to completely inhibit filamentation in *Candida albicans* at concentrations below the respective MICs (as low as MIC/16). Flow cytometry suggested a mechanism of action leading to cytoplasmic membrane disruption and cell death | [44] |
| S. Bartolomeu de Messines (Algarve) | Aerial parts, in vitro shoot cultures, and micropropagated | α-Pinene (**8**) (8.8-14.4), $\Delta^3$-carene (**23**) (0.1-6.5), 1,8-cineole (**7**) (18.2–25.1), linalool (**9**) (traces-5.3), camphor (**6**) (9.1–15.7) | Not determined | [45] |
| S. Bartolomeu de Messines (Algarve) | In vitro shoot cultures and micropropagated plants | Headspace solid phase micro-extraction:<br>α-Pinene (**8**) (0.3–8.3), camphene (**22**) (0.1–5.0), 1,8-cineole (51.9–74.0), camphor (**6**) (2.9–15.3), selina-3,7(11)-diene (**21**) (nd–6.7) | Not determined | [46] |
| S. Bartolomeu de Messines (Algarve) | Aerial parts | Hydrodistillation:<br>1,8-Cineole (**7**) (21.31)<br><br>Supercritical fluid extraction:<br>1,8-cineole (**7**) (nd–7.81), *cis*-linalool oxide (nd-10.49), *trans*-linalool oxide (nd-13.17), camphor (**6**) (1.61–22.48), epoxy-linalool (nd–6.80), myrtenol (**24**) (nd–5.38), verbenone (**25**) (0.84–13.97) | The EO had higher capacity for scavenging acetylcholinesterase activity (411.33 μg/mL) than the extracts obtained by supercritical fluid extraction. All extracts obtained by this procedure had worse capacity for scavenging peroxyl and DPPH free radicals than the EO (468.85 μmol trolox equivalent/g and 56.03%, respectively) | [47] |

INF-γ, interferon-γ; IL-1β, interleukin-1β; $IC_{50}$, half maximal inhibitory concentration; MBC, minimum bactericidal concentration; MIC, minimum inhibitory concentration; MLC, minimum lethal concentration; TNF-α, tumor necrosis factor-α. [a](number of the chemical structure); [b](percentage of the compound in the EO).

*guillermondii*, *Cr. neoformans* and *Rhodotorula rubra*), along with hexane extracts.

## 5 *Lavandula stoechas* subsp. *luisieri* (Rozeira) Rozeira

*Lavandula stoechas* subsp. *luisieri* is a perennial shrub that can reach up to 60 cm tall with short-stalked spikes (0–3 cm), made up of small lilac flowers, involving a dense indumentum composed of several types of secretory hairs. The narrow and oblong-lanceolate leaves are opposite with different sizes and of gray colour [61]. In Portugal and in folk medicine, the aerial parts or flower head of *L. stoechas* subsp. *luisieri* have been described for the treatment of blood circulation, heart-burn, seasickness, as a nasal decongestant and as an anti-dermatosic [62].

EOs of *L. stoechas* subsp. *luisieri* have been reported as being mainly made up of necrodane derivatives, particularly *trans*-α-necrodyl acetate in relative amounts, and *trans*-necrodol, although in a very few cases, this compound has not been detected (Table 1). The presence of these irregular monoterpenoids in relative high amounts in *L. stoechas* subsp. *luisieri* EOs has been described as being characteristic of the Portuguese species whereas 2,3,4,4-tetramethyl-5-methylene-cyclopent-2-enone (**15**) is characteristic of the Spanish *L. stoechas* subsp. *luisieri* EOs [63]. Lavandulyl acetate (**14**) and fenchone (**5**), camphor (**6**), 1,8-cineole (**7**) and linalool (**9**) are other compounds that regularly appear in the Portuguese *L. stoechas* subsp. *luisieri* EOs (Table 1). In samples from the Algarve, the presence of *trans*-α-necrodyl acetate (**13**) was in concentrations higher than 5%, nevertheless it was not the major compound in the EO, in this case, 1,8-cineole (**7**) predominated in the *L. stoechas* subsp. *luisieri* EOs, in contrast to the remaining samples from Northern Portugal (Table 1). 2,3,4,4-Tetramethyl-5-methylene-cyclopent-2-enone (**15**) has also been reported in several samples with percentages higher than 5%, in one work it was described as being able to inhibit BACE-1, a key enzyme in the generation and deposition of neurotoxic β-amyloid peptide (Ab) in Alzheimer's disease [34]. González-Coloma et al. reported that *L. luisieri* had antifeedant effects against *Spodoptera littoralis* and *Rhopalosiphum padi* along with camphor (**6**), bornyl acetate (**10**) and 1,8-cineole [37] (Table 1).

Antibacterial (Gram-negative and Gram-positive), anti-fungal (particularly dermatophytes), anti-*Leishmania*, antioxidant (prevention of lipid peroxidation, capacity for scavenging free radicals), anti-inflammatory [reduction of inducible nitric oxide synthase (iNOS) and phosphorylated IκB-α; in vivo assays caused an inhibition in carrageenan-induced rat paw oedema] activities have been detected in *L. stoechas* subsp. *luisieri* EOs from Portugal (Table 1). With very few exceptions, the authors did not relate the activities found with the components of the EOs.

## 6 *Lavandula viridis* L'Her.

According to Franco [16], *L. viridis* is a xerophytic aromatic shrub which can reach up to 40 cm tall, with ovoid-cylindrical spikes made up of white flowers that can measure between 6 and 8 mm. This aromatic species is endemic to the southwest Iberian Peninsula (degraded soils of Alentejo and Algarve), Madeira and the Azores Islands [29, 45, 64]. In folk medicine and in Portugal, infusions of *L. viridis* have been used in the treatment of flu, headaches and for circulatory disturbances, whereas EOs were used as sedative and analgesics [65].

The predominant volatile compound present in *L. viridis* EO from Portugal was 1,8-cineole (**7**), independent on the region where the plants had been collected (Table 1) if the extraction method had been hydrodistillation. In the case of supercritical fluid extraction, the main constituent was camphor (Table 1). Camphor (**6**) was always the second most important compound in the EOs samples obtained by hydrodistillation, with the concentration ranging from 10 to 20.4%, whereas the percentages of 1,8-cineole (**7**) ranged from18.2 to 74.0% (Table 1). In the sample obtained by supercritical fluid extraction, the most important compounds observed in the volatile sample were camphor (**6**) (1.61–22.48) and verbenone (**25**) (0.84–13.97%) (Table 1). The microprogation of *L. viridis* was performed and in vitro shoot cultures and microprogated plants have also been a target of study [46, 64]. In shoot cultures, authors [64] reported that 1,8-cineole (**7**) and α-pinene (**8**) were the most important compounds. Camphor (**6**) was the third most important volatile compound in the in vitro shoots EOs.

When antioxidant and anti-protozoal activities of *L. viridis* EOs were compared to those of *L. luisieri*, it was verified that they were less active (Table 1). When different extraction methods were used for obtaining the volatile fractions and EOs, Costa et al. [47] verified that hydrodistillation was the best method for obtaining samples with higher antioxidant and anti-acetylcholinesterase activities than the volatile samples obtained by supercritical fluid extraction (7). In vitro anti-fungal activities of *L. stoechas* subsp. *luisieri* EOs were also studied, and they were active against *Cryptococcus neoformans*, and the dermatophytes

(*Trichophyton verrucosum* CECT 2992, *T. mentagrophytes* var. *interdigitale* CECT 2958, *T. rubrum* CECT 2794 and *Microsporum gypseum* CECT 2908) [44].

**Acknowledgments:** The authors wish to acknowledge the financial support provided by the Fundação para a Ciência e a Tecnologia – FCT; Portugal, under the project the Project UIDB/05183/2020.

**Funder Name:** Fundação para a Ciência e a Tecnologia, Funder Id: http://dx.doi.org/10.13039/501100001871, Grant Number: UIDB/05183/2020.

**Conflicts of Interest:** The authors declare that they have no conflicts of interest.

## References

1. Aprotosoaie AC, Gille E, Trifan A, Luca VS, Miron A. Essential oils of *Lavandula* genus: a systematic review of their chemistry. Phytochem Rev 2017;16:761–99.
2. Urwin NA, Mailer J. Oil content and fatty acid profiles of seed oil from the genus *Lavandula*. J Am Chem Soc 2008;85:491–2.
3. Carbone C, Martins-Gomes C, Caddeo C, Silva AM, Musumeci T, Pignatello R, et al. Mediterranean essential oils as precious matrix components and active ingredients of lipid nanoparticles. Int J Pharm 2018;548:217–26.
4. Pereira I, Severino P, Santos AC, Silva AM, Souto EB. Linalool bioactive properties and potential applicability in drug delivery systems. Colloids Surf B Biointerfaces 2018;171:566–78.
5. Gul S, Nisa NT, Shah TA, Shah MU, Wani AB. Research output on Lavender, 2008–2012. Eur J Integr Med 2015;7:460–6.
6. Donelli D, Antonelli M, Bellinazzi C, Gensini GF, Firenzuoli F. Effects of lavender on anxiety: a systematic review and meta-analysis. Phytomedicine 2019;65:153099.
7. Kang H-J, Nam ES, Lee Y, Kim M. How strong is the evidence for the anxiolytic efficacy of lavender?: systematic review and meta-analysis of randomized controlled trials. Asian Nurs Res 2019;13:295–305.
8. Kani KM, Mirzania Z, Mirhaghjoo F, Mousavi R, Akbarzadeh S, Jafari M. The effect of aromatherapy (with lavender) on dysmenorrhea: a systematic review and meta-analysis. Int J Pediatr 2019;7:9657–66.
9. Lesage-Meessen L, Bou M, Sigoillot J-C, Faulds CB, Lomascolo A. Essential oils and distilled straws of lavender and lavandin: a review of current use and potential application in white biotechnology. Appl Microbiol Biotechnol 2015;99:3375–85.
10. Figueiredo AC, Pedro LG, Barroso JG, Trindade H, Sanches J, Oliveira C, et al. *Lavandula luisieri* (Rozeira) Rivas-Martínez e *Lavandula pedunculata* (Mill.) Cav. Agrotec 2014;14:38–41.
11. Prazeres LIRCCV. Revisão do género *Lavandula* presente em Portugal Continental [Review of the genus *Lavandula* present in Portugal Continental]. Master Thesis, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Lisboa, Portugal, 2014.
12. Moja S, Guitton Y, Nicolè F, Legendre L, Pasquier B, Upson T, et al. Genome size and plastid trnK-matK markers give new insights into the evolutionary history of the genus *Lavandula* L. Plant Biosyst 2016;150:1216–24.
13. Baldovini N, Lavoine-Hanneguelle S, Ferrando G, Dusart G, Lizzani-Cuvelier L. Necrodane monoterpenoids from *Lavandula luisieri*. Phytochemistry 2005;66:1651–5.
14. Upson T, Andrews S. The genus *Lavandula*. Portland, OR: Timber Press, 2004:442.
15. Salido S, Altarejos J, Nogueras M, sánchez A, Luque P. Chemical composition and seasonal variations of spike lavender oil from southern Spain. J Essent Oil Res 2004;16:206–10.
16. Franco J. Nova Flora de Portugal (Continente e Açores). Lisboa: Escolar Editora., 1984.
17. Herraiz-Peñalver D, Cases MA, Varela F, Navarrete P, Sánchez-Vioque R, Usano-Alemany J. Chemical characterization of *Lavandula latifolia* Medik. essential oil from Spanish wild populations. Biochem Syst Ecol 2013;46:59–68.
18. Carrasco A, Martinez-Gutierrez R, Tomas V, Tudela J. *Lavandula angustifolia* and *Lavandula latifolia* essential oils from Spain: aromatic profile and bioactivities. Planta Medica 2015;82:163–70.
19. Guillén MD, Cabo N. Characterisation of the essential oils of some cultivated aromatic plants of industrial interest. J Sci Food Agric 1996;70:359–63.
20. Muñoz-Bertomeu J, Arrillaga I, Segura J. Essential oil variation within and among natural populations of *Lavandula latifolia* and its relation to their ecological areas. Biochem Syst Ecol 2007;35:479–88.
21. Rodrigues N, Malheiro R, Casal S, Asensio-S-Manzanera MC, Bento A, Pereira JA. Influence of spike lavender (*Lavandula latifolia* Med.) essential oil in the quality, stability and composition of soybean oil during microwave heating. Food Chem Toxicol 2012;50:2894–901.
22. Panuccio MR, Fazio A, Papalia T, Barreca D. Antioxidant properties and flavonoid profile in leaves of Calabrian *Lavandula multifida* L., an autochthon plant of Mediterranean southern regions. Chem Biodiversity 2016;13:416–21.
23. Zuzarte M, Vale-Silva L, Gonçalves MJ, Cavaleiro C, Vaz S, Canhoto J, et al. Antifungal activity of phenolic-rich *Lavandula multifida* L. essential oil. Eur J Clin Mcrobiol Infect Dis 2012;31:1359–66.
24. Chograni H, Messaoud C, Boussaid M. Genetic diversity and population structure in Tunisian *Lavandula stoechas* L. and *Lavandula multifida* L. (Lamiaceae). Biochem Syst Ecol 2008;36:349–59.
25. Znini M, Paolini J, Majidi L, Desjobert J-M, Costa J, Lahhit N, et al. Evaluation of the inhibitive effect of essential oil of *Lavandula multifida* L., on the corrosion behavior of C38 steel in 0.5 M $H_2SO_4$ medium. Res Chem Intermed 2012;38:669–83.
26. Panuccio MR, Fazio A, Musarella CM, Mendoza-Fernández AJ, Mota JF, Spampinato G. Seed germination and antioxidant pattern in *Lavandula multifida* (Lamiaceae): a comparison between core and peripheral populations. Plant Biosyst 2018;152:398–406.
27. Fazio A, Cerezuela R, Panuccio MR, Cuesta A, Esteban MÁ. *In vitro* effects of Italian *Lavandula multifida* L. leaf extracts on gilthead seabream (*Sparus aurata*) leucocytes and SAF-1 cells. Fish Shellfish Immunol 2017;66:334–44.
28. García-Caparrós P, Llanderal A, Pestana M, Correia PJ, Lao MT. *Lavandula multifida* response to salinity: growth, nutrient uptake, and physiological changes. J Plant Nutr Soil Sci 2017;180:96–104.

29. Matos F, Miguel MG, Duarte J, Venâncio F, Moiteiro C, Correia AI, et al. Antioxidant capacity of the essential oils from *Lavandula luisieri*, *L. stoechas* subsp. *lusitanica*, *L. stoechas* subsp. *lusitanica* x *L. luisieri* and *L. viridis* grown in Algarve (Portugal). J Essent Oil Res 2009;21:327–36.
30. Costa P, Gonçalves S, Valentão P, Andrade PB, Almeida C, Nogueira JM, et al. Metabolic profile and biological activities of *Lavandula pedunculata* subsp. *lusitanica* (Chaytor) Franco: studies on the essential oil and polar extracts. Food Chem 2013;141:2501–6.
31. Zuzarte M, Gonçalves MJ, Cavaleiro C, Dinis AM, Canhoto JM, Salgueiro LR. Chemical composition and antifungal activity of the essential oils of *Lavandula pedunculata* (Miller) Cav. Chem Biodiversity 2009;6:1283–92.
32. Zuzarte MR, Dinis AM, Cavaleiro C, Salgueiro LR, Canhoto JM. Trichomes, essential oils and *in vitro* propagation of *Lavandula pedunculata* (Lamiaceae). Ind Crops Prod 2010;32:580–7.
33. Zuzarte M, Dinis AM, Cavaleiro C, Canhoto J, Salgueiro L. Trichomes morphology and essential oils characterization of field-growing and *in vitro* propagated plants of *Lavandula pedunculata*. Microsc Microanal 2008;14(suppl 3):148–9.
34. Videira R, Castanheira P, Grãos M, Salgueiro L, Faro C, Cavaleiro C. A necrodane monoterpenoid from *Lavandula luisieri* essential oil as a cell-permeable inhibitor of BACE-1, the β-secretase in Alzheimer's disease. Flav Fragr J 2013;28:380–8.
35. Pombal S, Rodrigues CF, Araújo JP, Rocha PM, Rodilla JM, Diez D, et al. Antibacterial and antioxidant activity of Portuguese *Lavandula luisieri* (Rozeira) Tivas-Martinez and its relation with their chemical composition. SpringerPlus 2016;5:1711.
36. Queiroga MC, Coelho MP, Arantes SM, Potes ME, Martins MR. Antimicrobial activity of essential oils of Lamiaceae aromatic species towards sheep mastitis-causing *Staphylococcus aureus* and *Staphylococcus epidermidis*. J Essent Oil Bear Plants 2018;21:1155–65.
37. González-Coloma A, Delgado F, Rodilla JM, Silva L, Sanz J, Burillo J. Chemical and biological profiles of *Lavandula luisieri* essential oils from western Iberia Peninsula populations. Biochem Syst Ecol 2011;39:1–8.
38. Rufino AT, Ferreira I, Judas F, Salgueiro L, Lopes MC, Cavaleiro C, et al. Differential effects of the essential oils of *Lavandula luisieri* and *Eryngium duriaei* subsp. *juresianum* in cell models of two chronic inflammatory diseases. Pharm Biol 2015;53:1220–30.
39. Zuzarte M, Gonçalves MJ, Cruz MT, Cavaleiro C, Canhoto J, Vaz S, et al. *Lavandula luisieri* essential oil as a source of antifungal drugs. Food Chem 2012;135:1505–10.
40. Dias N, Dias MC, Cavaleiro C, Sousa MC, Lima N, Machado M. Oxygenated monoterpenes-rich volatile oils as potential antifungal agents for dermatophytes. Nat Prod Res 2017;31:460–4.
41. Machado M, Martins N, Salguero L, Cavaleiro C, Sousa MC. *Lavandula luisieri* and *Lavandula viridis* essential oils as upcoming anti-protozoal agents: a key focus on *Leishmaniasis*. Appl Sci 2019;9:3056.
42. Arantes S, Candeias F, Lopes O, Lima M, Pereira M, Tinoco T, et al. Pharmacological and toxicological studies of essential oil of *Lavandula stoechas* subsp. *luisieri*. Planta Med 2016;82:1266–73.
43. Delgado F, Gonçalves O, Amaro-Silva C, Silva L, Caldeira R, Castanheira I, et al. Seed germination and essential oil of *Lavandula luisieri* from Central Eastern Portugal. Acta Hort 2006;723:283–7.
44. Zuzarte M, Gonçalves MJ, Cavaleiro C, Canhoto J, Vale-Silva L, Silva MJ, et al. Chemical composition and antifungal activity of the essential oils of *Lavandula viridis* L'Hér. J Med Microbiol 2011;60:612–8.
45. Dias MC, Almeira R, Romano A. Rapid clonal multiplication of *Lavandula viridis* L'Hér through *in vitro* axillary shoot proliferation. Plant Cell Tissue Organ Cult 2002;68:99–102.
46. Gonçalves S, Serra H, Nogueira JM, Almeida JM, Almeira R, Custódio L, et al. Headspace-SPME of *in vitro* shoot-cultures and micropropagated plants of *Lavandula viridis*. Biol Plant 2008;52:133–6.
47. Costa P, Grosso C, Gonçalves S, Andrade PB, Valentão P, Bernardo-Gil MG, et al. Supercritical fluid extraction and hydrodistillation for the recovery of bioactive compounds from *Lavandula viridis* L'Hér. Food Chem 2012;135:112–21.
48. Sellam K, Ramchoun M, Alem C, El-Rhaffari L. Biological investigations of antioxidant-antimicrobial properties and chemical composition of essential oil from *Lavandula multifida*. Oxid Antioxid Med Sci 2013;2:211–6.
49. Saadi A, Brada M, Kouidri M, Dekkiche H, Attar F. Chemical composition and content of essential oil of *Lavandula multifida* from Algeria. Chem Nat Compd 2016;52:162–4.
50. Khadir A, Bendahou M, Benbelaid F, Abdoune MA, Bellahcene C, Zenati F, et al. Chemical composition and anti-MRSA activity of essential oil and ethanol extract of *Lavandula multifida* L. from Algeria. J Essent Oil Bear Plant 2016;19:712–8.
51. Messaoud C, Chograni H, Boussaid M. Chemical composition and antioxidant activities of essential oils and methanol extracts of three wild *Lavandula* L. species. Nat Prod Res 2012;26:1976–84.
52. Chograni H, Zaouali Y, Rajeb C, Boussaid M. Essential oil variation among natural populations of *Lavandula multifida* L. (Lamiaceae). Chem Biodiversity 2010;7:933–42.
53. Msaada K, Salem N, Tammar S, Hammami M, Saharkhiz MJ, Debiche, et al. Essential oil composition of *Lavandula dentata*, *L. stoechas* and *L. multifida* cultivated in Tunisia. J Essent Oil Bear Plant 2012;15:1030–9.
54. Chograni H, Boussaid M. Genetic diversity of *Lavandula multifida* L. (Lamiaceae) in Tunisia: implication for conservation. Afr J Ecol 2010;49:10–20.
55. Morales R. *Lavandula* L. Flora Iberica. In: Castroviejo S, editors. Madrid, Spain: Real Jardín Botánico, CSIC, 2010.
56. Lopes VR, Barata AM. *Ex situ* morphological assessment of wild *Lavandula* populations of Portugal. Arab J Med Aromat Plants 2017;3:87–100.
57. Lopes CL, Pereira E, Soković M, Carvalho AM, Barata AM, Lopes V, et al. Phenolic composition and bioactivity of *Lavandula pedunculata* (Mill.) Cav. samples from different geographical origin. Molecules 2018;23:1–19.
58. Rivera D, Obón C. The ethnopharmacology of Madeira and Porto Santo Islands, a review. J Ethnopharmacol 1995;46:73–93.
59. Ferreira A, Proença C, Serralheiro ML, Araújo ME. The *in vitro* screening for acetylcholinesterase inhibition and antioxidant activity of medicinal plants from Portugal. J Ethnopharmacol 2006;108:31–7.
60. García-Vallejo MI. Aceites esenciales de las Lavandulas Ibéricas. Ensayo de la quimiotaxonomia [Essential oils from Iberian Lavandulas. Chemotaxonomy assay]. Doctoral Thesis, Universidad Complutense de Madrid, Facultad de Biologia, Spain, 1992.
61. Baptista R, Madureira AM, Jorge R, Adão R, Duarte A, Duarte N, et al. Antioxidant and antimycotic activities of two native

*Lavandula* species from Portugal. Evid-Based Complement Anternat Med 2015;2015:1–10.
62. Novais MH, Santos I, Mendes S, Pinto-Gomes C. Studies on pharmaceutical ethnobotany in Arrabida Natural Park (Portugal). J Ethnopharmacol 2004;93:183–95.
63. González-Coloma A, Martín-Benito D, Mohamed N, García-Vallejo MC, Soria AC. Antifeedant effects and chemical composition of essential oils from different populations of *Lavandula luisieri* L. Biochem Syst Ecol 2006;34:609–16.
64. Nogueira JM, Romano A. Essential oils from micropropagated plants of *Lavandula viridis*. Phytochem Anal 2002;13:4–7.
65. Vairinhos JA. Género *Lavandula* L.: Usos, tradições e estudos de espécies Portuguesas [Uses, traditions and studies of Portuguese species]. Master thesis, Universidade do Algarve, Faro, Portugal, 2017.