Essential Oil Content and Chemical Composition in 14 Selected Species From a Stretch of Restinga in Southern Brazil

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Abstract

The restinga is an Atlantic Forest ecosystem characterized by tree, shrub, and herb species that are rich sources of essential oils. In this study, we aim to quantify the essential oil content and determine the chemical constituents of fresh leaves of 14 plant species in a restinga stretch in southern Brazil. Essential oils were obtained by hydrodistillation in a Clevenger-type apparatus and analyzed by gas chromatography coupled to mass spectrometry. *Campomanesia reitziana*, *Cortaderia selloana*, and *Sophora tomentosa* had no essential oils. Total essential oil content ranged from 0.01% (*Mikania involucrata*) to 1.56% (*Varronia curassavica*). In total, 60 chemical constituents were identified, representing between 46.2% and 96.5% of the chemical composition of the essential oils. Limonene was the common constituent in all species in which the essential oils were present. The major constituents were ar-curcumene (15.1%) and cis-chrysanthenol (14.2%) in *Ambrosia elatior*; benzyl benzoate (43.5%) and benzyl salicylate (23.7%) in *Aniba firmula*; caryophyllene oxide (35.7%) and spathulenol (10.6%) in *Austroeupatorium inulaefolium*; spathulenol (19.8%) and caryophyllene oxide (14.0%) in *Baccharis spicata*; caryophyllene oxide (16.3%) in *Eugenia astringens*; curzerene (30.0%), limonene (13.0%), and germacrene (11.9%) in *Eugenia uniflora*; caryophyllene oxide (17.1%) and ledol (11.3%) in *Lantana camara*; caryophyllene oxide (27.7%) and limonene (12.7%) in *M. involucrata*; 1,8-cineole (19.8%) in *Psidium cattleianum*; limonene (10.2%) in *Schinus terebinthifolius*, and allo-aromadendrene (15.2%) in *V. curassavica*.

We expect that our results can assist in selecting species of potential interest for herbal, phytotherapeutic, and cosmetic products.

Keywords: bioprospecting, native species, phytochemicals, aromatic plants

1. Introduction

The restinga is an ecosystem type that originated from Quaternary marine deposits and is part of the Atlantic Forest biome. Restingas are characterized by dunes and sandy coastal plains, with vegetation growing in open and/or inaccessible places such as lagoons, lakes, and marshes. These communities include a mosaic of plants with physiognomic and xeromorphic variations that respond to the numerous constraints imposed by nutrient-poor sandy soils, drought, salinity, solar radiation, constant winds, and high air and soil temperatures (Reinert et al., 1997). The unique character of the restinga comes from a plant community with high ecological plasticity. Many restinga species colonize, grow, and survive in inhospitable situations despite their origin in forest environments.

The ecological balance of species in the restinga is largely maintained through the propagation of specific plants, including the abundant aromatic herbs, shrubs, and trees. The botanical families of Asteraceae, Fabaceae, Myrtaceae, and Poaceae are the most representative of this habitat (Melo Junior & Boeger, 2015). Other common families include Anacardiaceae, Boraginaceae, Lauraceae, and Verbenaceae. Species of this ecosystem are characterized by adaptations to its adverse conditions. Plants use various strategies to deal with their difficult environmental conditions (Amorim & Melo Júnior, 2017). These include changes in secondary metabolism, resulting in the production of a wide variety of compounds, including essential oils.
Essential oils are complex mixtures of volatile, lipophilic, generally aromatic, and liquid substances, the characteristics of which change depending on environmental conditions. Researchers have recently devoted considerable attention to their applications in herbal medicine, including antioxidant, antimicrobial, antifungal, antiviral, antinociceptive, and antitumor activities (Ali et al., 2015). Essential oils have been noted for their agricultural uses as acaricides, insecticides, fungicides, and herbicides (Ootani et al., 2013). They are also widely used in cosmetics and perfumes (Sarkic & Stappen, 2018). Despite the wealth of applications, the bioprospecting of essential oil-producing restinga plants has been limited to certain Myrtaceae species (Ramos et al., 2010; Albuquerque et al., 2012). Research into species of other families may uncover the potential of the Brazilian restinga as a source of secondary metabolites of potential interest.

Here, two hypotheses about the prospection of essential oils from native species can then be presented: the hypothesis of ‘commercial potential’ and the hypothesis of ‘species conservation strategy’. The ‘commercial potential’ hypothesis suggests that the collected species could be commercially inserted, as they resemble existing species on the market. The hypothesis of a ‘species conservation strategy’ implies that the choice of these species would serve as an alternative for the sustainable management of the Atlantic Forest biome, which is highly degraded and in need of conservation. In this context, given the considerable interest in finding new sources of essential oils, the chemical richness of restinga plants, and the growing demand for phytotherapeutic, phytosanitary and cosmetic products, we selected a variety of herbaceous, shrub, and tree species from a restinga stretch in southern Brazil. This study, which is part of a larger effort to investigate the aromatic flora of the Atlantic Forest systematically, aims to (i) quantify the essential oil content and (ii) determine the chemical constituents of the essential oils in the fresh leaves of 14 plant species.

2. Method

2.1 Plant Material

Leaves of 14 plant species were collected in February 2014 in Penha, Santa Catarina, Brazil (between 26°47′57.9″S, 48°35′39.3″W and 26°48′39.7″S, 48°35′52.4″W). The sampling site is comprised of a restinga ecosystem with herbaceous, shrub, and tree communities. The study area has approximately 3.51 ha of coastline (Figure 1). The region’s climate is subtropical, with hot and rainy summers and mostly dry winters. During the collection period, the mean monthly temperature was 26.1 °C, the mean monthly precipitation was 113.0 mm, and the mean monthly relative humidity was 85.0%.

Figure 1. Location of the study area and its vegetation aspects. (A) Location map of the study area. (B) Detail of the collection area (arrow). (C-D) Panoramic views with vegetation formed by a restinga ecosystem covering the communities herbaceous, shrub and tree. (E) Shrub vegetation in the foreground and herbaceous vegetation in the background.
The species analyzed were *Ambrosia elatior* L. (Asteraceae), *Aniba firmula* (Nees & Mart.) Mez. (Lauraceae), *Austro eupatorium inulaefolium* (Kunth) R.M.King & H.Rob. (Asteraceae), *Baccharis spicata* (Lam.) Baill. (Asteraceae), *Campomanesia reitziana* D. Legrand (Myrtaceae), *Cortaderia selloana* (Schult. & Schult. f. Asch. & Graebn. (Poaceae), *Eugenia astringens* Cambess. (Myrtaceae), *Eugenia uniflora* L. (Myrtaceae), *Lantana camara* Linn. (Verbenaceae), *Mikania involucrata* Hook. & Arn. (Asteraceae), *Psidium cattleianum* Sabine (Myrtaceae), *Schinus terebinthifolius* Raddi (Anacardiaceae), *Sophora tomentosa* L. (Fabaceae), and *Varronia curassavica* Jacq. (Boraginaceae) (Figure 2).

Figure 2. Species collected off the coast of Penha, Santa Catarina, Brazil, for essential oil extraction. *Schinus terebinthifolius* (A); *Baccharis spicata* (B); *Austro eupatorium inulaefolium* (C); *Mikania involucrata* (D); *Ambrosia elatior* (E); *Varronia curassavica* (F); *Sophora tomentosa* (G); *Aniba firmula* (H); *Campomanesia reitziana* (I); *Eugenia astringens* (J); *Eugenia uniflora* (K); *Psidium cattleianum* (L); *Cortaderia selloana* (M); *Lantana camara* (N)

The plants were selected based on their aroma and botanical groups based on aromatic characteristics, as reported in the literature (Trombin-Souza et al., 2017; de Souza et al., 2020; de Souza et al., 2021). Three leaf samples were collected from the terminal portion of a branch of each species during its vegetative period. Samples were collected from at least ten plants per species to provide sufficient quantity for essential oil extraction.

2.2 Extraction and Quantification of Essential Oil Content

Three 100g samples of fresh leaves per species were prepared by cutting the leaves into segments of approximately 2 cm in length. The plant material then underwent hydrodistillation in a Clevenger-type apparatus for 4.5 h. After obtaining the essential oil, it was dried over anhydrous sodium sulfate and then stored at 4°C until analysis was performed. Essential oil yield (%) was calculated as a percentage of dry matter using the following formula:

\[
\text{Essential oil yield (\%)} = \frac{\text{Mass of essential oil obtained (g)}}{\text{Mass of dry matter (g)}} \times 100
\]  

(1)

2.3 Analysis and Quantification of Essential Oils

The analysis of the chemical composition of the essential oils was performed in a gas chromatograph (Agilent 6890) coupled to a mass selective detector (Agilent 5973N). The gas chromatograph was equipped with a fused HP-5MS capillary column (film thickness 30 m × 0.25 mm × 0.25 μm) coated with a stationary phase of 5% phenyl-95% dimethylpolysiloxane. Helium was used as carrier gas at a flow rate of 1.0 mL/min. The temperature programming was set from 60 °C to 240 °C at a rate of 3 °C/min and heated at 240 °C for 10 min. The injector temperature was maintained at 250 °C. The essential oil samples were diluted to 1% in dichloromethane, and 1.0 μL of the solution was injected with a separation ratio of 1:20. The mass detector was operated in electron
ionization mode (70 eV) at a speed of 3.15 scans/min and a scanning range of 40-450 Da. The transfer line was kept at 260 °C, the ion source at 230 °C, and the analyte (in four replicates) at 150 °C.

For quantification, the essential oils were injected into a gas chromatograph (Agilent 7890) equipped with a flame ionization detector operated at 280 °C. Hydrogen was used as a support gas at a flow rate of 1.5 mL/min, using the same column and conditions described above. The quantification of each constituent was estimated by electronic integration of the flame ionization detector with the corresponding peak area, which was determined using the average of three injections.

2.4 Identification of the Chemical Constituents of the Essential Oil

Identification of the chemical constituents of the essential oil was performed by comparing Kovats indices (KIs) obtained from a correlation of the homologous series of alkanes (C₈-C₂₆) and matching their mass spectra with those of libraries, and comparing KIs from the literature (Adams, 2007).

2.5 Statistical Analyses

Essential oil content data were tested for homogeneity using Bartlett’s test. An analysis of variance (ANOVA) was performed using ASSISTAT® software, version 7.7 (Silva & Azevedo, 2016), and a Tukey test was used to determine significance at the p > 0.05 level.

3. Results and Discussion

The essential oil was obtained through the hydrodistillation process from 11 of the 14 species sampled. Although these species are recorded in other coastal regions of the Atlantic Forest biome (Silva et al., 2021), to our knowledge, there is no information about the chemical compounds of essential oil found in these populations. Sophora tomentosa, Campomanesia reitziana, and Cortaderia selloana did not have essential oil in their leaves (Table 1). Though the plants exhibited presumed aromatic potential at the time of collection, these may be attributed to the presence of other compounds. Many water-soluble substances have odors that can be confused with the presence of essential oils, such as free amino acids, soluble carbohydrates, and aliphatic oxygenated compounds (Eisenreich et al., 1997).

Table 1. Description of essential oil content from collected herbs, shrubs, and trees from a patch of restinga in Penha, Santa Catarina, Brazil

| Family          | Species                                           | Growth habit | Essential oil content * |
|-----------------|---------------------------------------------------|--------------|------------------------|
| Anacardiaceae   | Schinus terebinthifolius Raddi                     | Tree         | 1.04 b***              |
| Asteraceae      | Baccharis spicata (Lam.) Baill.                    | Bush         | 0.48 c                 |
| Asteraceae      | Austroeupatorium inulaefolium (Kunth) R.M.King & H.Rob. | Herbaceous   | 0.14 e                 |
| Asteraceae      | Mikania involucrata Hook. & Arn.                  | Herbaceous   | 0.01 f                 |
| Asteraceae      | Ambrosia elatior L.                                | Herbaceous   | 0.14 e                 |
| Boraginaceae    | Varronia curassavica Jacq.                         | Bush         | 1.56 a                 |
| Fabaceae        | Sophora tomentosa L.                               | Tree         | ***                    |
| Lauraceae       | Aniba firma (Nees & Mart.) Mez                     | Tree         | 0.33 d                 |
| Myrtaceae       | Campomanesia reitziana D.Legrand                  | Tree         | ***                    |
| Myrtaceae       | Eugenia astringens Cambess.                       | Bush         | 0.29 d                 |
| Myrtaceae       | Eugenia uniflora L.                                | Bush         | 0.11 e                 |
| Myrtaceae       | Psidium cattleianum Sabine                        | Tree         | 0.56 c                 |
| Poaceae         | Cortaderia selloana (Schult. & Schult. f.) Asch. & Graebn. | Herbaceous   | ***                    |
| Verbenaceae     | Lantana camara Linn.                              | Herbaceous   | 0.08 ef                |

Note. * Content expressed as % of essential oil extracted from fresh leaves by hydrodistillation. ** Means followed by the same letter are not significantly different from each other according to the Tukey test at the 5% probability level. *** No essential oil present in their leaves.

The highest essential oil content was observed in Varronia curassavica (1.56%), while essential oil content ranged between 0.01% and 1.04% in the remaining plants (Table 1). Although phytochemical studies have been carried out for the selected species, comparisons of essential oil content are not an easy task due to their heterogeneous profiles. For example, the essential oil content of Lantana camara reported in the literature ranges
from 0.004% (Zhu et al., 2013) to 0.09% (Sousa et al., 2010). These differences may be attributed to several reasons, including the duration and method of extraction, population genetics of each species (Nizio et al., 2015), the plant part used (Cole et al., 2014), collection time (Sousa et al., 2010), exposure to sunlight (Feijó et al., 2014), seasonality, temperature, and precipitation (Matias et al., 2016).

A total of 60 chemical constituents were identified in the essential oils extracted, comprising between 46.2% and 96.5% of their chemical compositions (Table 2). Of these constituents, 7.5-18.7% were from the hydrocarbon monoterpene class, 0.3-27.2% oxygenated monoterpenes, 2.5-32.1% hydrocarbon sesquiterpenes, 3.9-69.8% oxygenated sesquiterpenes, 1.4% phenylpropanoids, and 1.8-68.9% were esters. Limonene was the only common constituent in all the species analyzed, with a concentration ranging between 4.9% and 13.0% (Table 2).

This similarity may be associated with the role of limonene as a precursor of monoterpene biosynthesis (Trombin-Souza et al., 2017; de Souza et al., 2021).

Table 2. Chemical constituents of essential oils from the fresh leaves of herbs, shrubs, and trees from a stretch of restinga in Penha, Santa Catarina, Brazil

| Constituent       | KI9    | KI10   | Species               |
|-------------------|--------|--------|-----------------------|
|                   | S01    | S02    | S03 | S04 | S05 | S06 | S07 | S08 | S09 | S10 | S11 |
| 1. α-pinene       | 933    | 932    | 4.01 | -   | 2.9 | 1.6 | 0.2 | 0.6 | 0.6 | 5.3 | 0.4 | 1.8 |
| 2. camphene       | 949    | 946    | -   | -   | -   | 6.7 | 0.1 | -   | -   | -   | -   | -   |
| 3. β-pinene       | 976    | 974    | 1.5 | 1.9 | 4.8 | 2.1 | 0.3 | 0.6 | 0.7 | 3.7 | 0.7 | 0.4 |
| 4. myrcene        | 992    | 988    | -   | -   | -   | -   | 0.2 | 0.2 | -   | -   | 2.5 |
| 5. p-cymene       | 1024   | 1025   | 1.6 | -   | 0.4 | 0.5 | 0.4 | 0.6 | 0.8 | 2.2 | 0.4 | 1.1 |
| 6. limonene       | 1028   | 1029   | 10.2| 5.8 | 4.9 | 12.7| 6.6 | 8.3 | 6.9 | 7.5 | 13.0| 8.8 |
| Monoterpene hydrocarbon | 17.3   | 7.7    | 13.0| 16.9| 7.5 | 17.0| 9.3 | 18.7| 14.5| 14.6| 8.7 |
| 7. 1,8-cineole    | 1031   | 1026   | -   | -   | -   | -   | 0.3 | -   | -   | 19.8| -   |
| 8. α-camphorinal  | 1127   | 1129   | -   | -   | 0.3 | -   | -   | -   | 1.7 | -   | -   |
| 9. trans-pinocarveol | 1138  | 1142   | 1.7 | 1.7 | 0.7 | -   | 0.3 | 0.1 | 2.5 | -   | 0.2 |
| 10. cis-chrysanthenol | 1163 | 1163   | -   | -   | -   | 14.2| -   | -   | -   | -   | -   |
| 11. borneol       | 1165   | 1169   | -   | -   | 0.2 | 4.2 | -   | -   | -   | -   | -   |
| 12. terpinen-4-ol | 1177   | 1174   | 4.6 | 0.9 | 0.6 | 0.4 | -   | 0.2 | 1.6 | -   | 0.6 |
| 13. p-cymen-8-ol  | 1187   | 1187   | -   | 1.6 | -   | -   | -   | -   | 8.2 | -   | -   |
| 14. cryptone      | 1188   | 1189   | 5.7 | -   | -   | -   | -   | 0.1 | -   | -   | -   |
| 15. α-terpineol   | 1191   | 1190   | 4.5 | 1.7 | 0.5 | 0.8 | -   | 0.3 | 4.6 | -   | 2.9 |
| 16. myrtenol      | 1197   | 1198   | 2.7 | 1.5 | 0.7 | -   | -   | -   | 1.5 | -   | -   |
| 17. cis-piperitenone epoxide | 1253 | 1254   | -   | -   | -   | -   | -   | 3.5 | -   | -   |
| 18. thymol acetate| 1344   | 1355   | -   | -   | -   | -   | -   | 3.6 | -   | -   | -   |
| Oxygenated monoterpene | 14.8  | 7.0    | 6.2 | 2.8 | 18.4| 0.3 | 1.0 | 27.2| 0.0 | 23.5| 0.0 |
| 19. α-copaene     | 1374   | 1374   | -   | -   | 0.4 | 0.7 | -   | 0.4 | 0.6 | -   | 3.2 |
| 20. β-elemene     | 1392   | 1391   | 0.8 | -   | 0.5 | 1.5 | -   | 1.2 | -   | -   | 2.6 |
| 21. (E)-caryophyllene | 1418 | 1417   | 0.7 | -   | 1.8 | 6.8 | 0.8 | 6.3 | 0.4 | -   | 0.9 |
| 22. aromadendrene | 1438   | 1439   | 0.6 | -   | 0.6 | -   | 0.2 | 0.3 | 1.6 | -   | 0.2 |
| 23. α-humulene    | 1452   | 1452   | 0.3 | -   | 0.8 | 1.6 | 0.5 | 2.4 | 0.1 | -   | 0.3 |
| 24. (E)-β-farnesene| 1457  | 1459   | 1.4 | -   | -   | -   | 0.7 | -   | -   | -   | -   |
| 25. allo-aromadendrene | 1459 | 1461   | -   | -   | -   | -   | 15.2| 0.8 | 0.4 | -   | 1.7 |
| 26. γ-murolene    | 1476   | 1478   | 2.1 | 0.6 | 0.9 | 1.0 | -   | 0.1 | -   | 1.5 | 3.5 |
| 27. ar-curcumene  | 1483   | 1482   | 0.6 | -   | -   | 15.1| -   | -   | -   | -   | -   |
| 28. β-selinene    | 1484   | 1486   | 0.5 | 2.9 | -   | 0.8 | 0.6 | -   | 0.8 | 2.0 | 0.3 |
| 29. germacrene D  | 1485   | 1484   | 2.5 | -   | -   | -   | 0.2 | -   | -   | -   | -   |
| 30. α-murolene    | 1500   | 1500   | 1.4 | 0.8 | 0.3 | -   | -   | 0.3 | -   | -   | 0.3 |
| 31. γ-cadinene    | 1514   | 1513   | 0.8 | 1.0 | -   | -   | 0.1 | -   | 0.1 | -   | 0.2 |
| 32. trans-calamenene | 1523 | 1525   | 2.7 | 1.0 | -   | -   | -   | 0.1 | 0.5 | -   | 0.6 |
| 33. zonarene      | 1534   | 1533   | 3.7 | -   | -   | -   | -   | -   | -   | 5.0 | -   |
| 34. α-cadinene    | 1514   | 1517   | -   | -   | -   | -   | 5.1 | -   | -   | -   | 0.6 |
| 35. selina-3,7(11)-diene | 1541 | 1543   | 1.8 | -   | -   | -   | -   | -   | -   | 2.0 | -   |
| 36. germacrene B  | 1557   | 1558   | 1.2 | -   | -   | -   | -   | -   | -   | 5.0 | -   |

27
28.3.8.6.8.14.5.16.4.32.1.3.8.2.5.8.4.16.3.19.7.

37. curzerene 1498 1497 - - - - - - - - - - - - 30.0 - -
38. (E)-nerolidol 1564 1561 - - - - - - - - - - - - - -
39. spathulenol 1576 1576 3.1 19.8 10.6 8.2 - - - - - - - - - - - - - -
40. caryophyllene oxide 1582 1581 4.7 14.0 35.7 27.7 - 4.7 2.5 16.3 - 7.9 17.1
41. globulol 1584 1583 - - - - - - - - - - - - - - - - - - - -
42. viridiflorene 1592 1591 2.3 0.9 0.6 - - - 0.2 1.1 3.0 0.6 - - - -
43. ledol 1602 1602 - 2.9 - 1.1 - 2.4 0.4 - - 0.5 11.3
44. 1-epi-cubenol 1628 1627 2.6 2.6 - 5.4 - - 0.2 - - 1.2 0.9
45. epi-α-muurolol 1641 1640 2.5 0.9 0.6 - - - 0.2 - - 2.5 0.7
46. α-muurolol 1646 1644 0.7 2.8 0.6 - - - - - - - - - - - - - -
47. α-cadinol 1652 1657 2.8 12.0 6.9 4.9 0.6 - 2.5 16.3 - 7.9 17.1
48. 1-epi-α-cadinol 1661 1662 - - - - - - 0.3 - - - - - - - -
49. atractilone 1662 1660 - - - - - - - - - - 4.0 - - - -
50. 14-hydroxy-9-epi-caryophyllene 1671 1662 - - - - - - - - - - - - - -
51. α-bisabolol 1684 1687 - - - - 3.3 - - - - - - - - - -
52. α-bisabolol 1687 1687 - - - - - - - - - - - - - - - - - -
53. germacrone 1697 1699 - - - - - - - - 11.9 - - - - - - - -
54. Oxygenated sesquiterpene 18.8 69.8 62.0 53.8 3.9 20.9 13.5 22.5 58.4 24.7 49.6
55. (E)-methyl-isoeugenol 1488 1489 - - - - - - - - - - 1.4 - - - -
56. α-terpinyl acetate 1349 1347 - - - - - - - - - - - - - - - - - - - -
57. geranyl butyrate 1561 1663 - - - - - - - 5.9 - - - - - - - -
58. benzyl benzoate 1769 1767 - - - - - - 43.5 - - - - - - - -
59. 2-phenylethyl benzoate 1879 1880 - - - - - - 23.7 - - - - - - - -
60. benzyl salicylate 1887 1889 - - - - - - - - - - - - - - - - - - - -
61. Ester 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1.8 0.0
62. Total constituents (%) 70.1 88.3 88.0 88.0 46.2 70.3 96.5 76.8 81.3 82.3 78.0

Note. Species: Klit = Kovats literature index; KIcal = Kovats experimental index; S 01: Schinus terebinthifolius; S 02: Baccharis spicata; S 03: Austroeupatorium inulaefolium; S 04: Mikania involucrata; S 05: Ambrosia elatior; S 06: Varronia curassavica; S 07: Aniba firmula; S 08: Eugenia astringens; S 09: Eugenia uniflora; S 10: Psidium cattleianum; S 11: Lantana camara. -: trace element < 0.1%. 1: Content expressed in %.

Limonene was only the most abundant constituent in *Schinus terebinthifolius*, accounting for 10.2% of the essential oil. The presence of 9-epi-(E)-caryophyllene (10.1%) and p-cymen-7-ol (22.5%) have been reported in fresh leaves of the species (Silva et al., 2010), as well as germacrene D (23.8%), bicyclogermacrene (15.0%) (Santana et al., 2012), and δ-3-carene (68.78%) (Uliana et al., 2016). However, the concentrations of these constituents measured in this study were lower or absent (Table 2). Quantitative and qualitative variations in the species’ essential oil may be related to the metabolic plasticity of *S. terebinthifolius*. The production of secondary metabolites is likely influenced by the peculiarities of each environment, including abiotic and edaphic conditions, as well as herbivores, pollinators, and seed dispersers. Furthermore, alterations in essential oil biosynthesis may also reflect a possible deviation in metabolic pathways to help the plant survive in particular environments.

The most abundant constituents in the Asteraceae species were spathulenol (19.8%), caryophyllene oxide (14.0%), α-cadinol (12.0%), and epi-α-muurolol (10.4%) in *Baccharis spicata*; caryophyllene oxide (35.7%) and spathulenol (10.6%) in *Austroeupatorium inulaefolium*; caryophyllene oxide (27.7%) and limonene (12.7%) in *Mikania involucrata*, and ar-curcumene (15.1%) and cis-chrysanthenol (14.2%) in *Ambrosia elatior* (Table 2). The chemical profiles of these oils indicated a predominance of sesquiterpenes (3.8-69.8%) over monoterpenes (2.8-18.4%). These findings can be interpreted as a competition between two pathways for the same precursor. It is known that the concentrations of monoterpenes and sesquiterpenes are negatively correlated (Ghaffari et al., 2011). Thus, the highest flux of isopentenyl diphosphate (IPP) among the species studied tended to be in the cytosol (the site of sesquiterpene biosynthesis) in the restinga environment. Higher proportions of sesquiterpenes may also indicate the stressful conditions that plants undergo in this ecosystem since high temperatures, strong winds, and solar radiation contribute to the volatilization of smaller molecules such as monoterpenes. In contrast
to our results, the essential oils of other Asteraceae species collected in non-coastal areas of the Atlantic Forest had roughly equal proportions of monoterpenes and sesquiterpenes (Amaral et al., 2017). This suggests that site-specific characteristics (i.e., environmental differences) are determining factors in terpene variation.

The sesquiterpene hydrocarbon allo-aromadendrene was the most common constituent in \textit{V. curassavica} (15.2%; Table 2). The chemical constituents most commonly found in the species’ essential oil are trans-caryophyllene (14.4%), caryophyllene oxide (15.8%) (Feijó et al., 2014), α-pinene (16.2%), β-phellandrene (11.0%), sabine (69.7%), γ-elemene (12.6%), δ-elemene (12.6%), β-caryophyllene (11.5%), γ-caryophyllene (15.6%), and germacrene B (13.8%) (Matias et al., 2016). Variations in essential oil composition have often been associated with plant growth conditions, seasonality (Matias et al., 2016), and solar radiation (Feijó et al., 2014). Recently, sampling from 59 \textit{V. curassavica} accessions showed that the genetic composition of the plants and/or the genotype × environment interaction is probably the most influential factor on the diversity chemical constituents in the essential oil (Nizio et al., 2015). Thus, plants collected in the same locality have been classified into different chemical groups.

In \textit{Aniba firmula}, the main constituents were benzyl benzoate (43.5%) and benzyl salicylate (23.7%; Table 2). The essential oils of Brazilian species of Lauraceae are generally divided into groups of chemotypes based on their main constituents. \textit{Aniba firmula} belongs to the benzoate group. Species in this family can also belong to the linalool and allylbenzene chemotypes, depending on the principal constituents, which remain consistent across each species (Morais et al., 1972). Similarly, \textit{Aniba firmula} exhibited low variation in the main constituents of its essential oil and lower sensitivity to environmental characteristics. These findings are interesting because they reveal that the restinga conditions did not result in significant changes in the essential oil composition.

The main constituents found in species of Myrtaceae were caryophyllene oxide (16.3%) in \textit{Eugenia astringens}; limonene (13.0%), curzerene (30.0%), and germacrene (11.9%) in \textit{Eugenia uniflora}, and 1,8-cineole (19.8%) in \textit{Psidium cattleianum} (Table 2). The chemical constituents of Myrtaceae essential oils belong predominantly to the hydrocarbons (14.5-18.7%), oxygenated monoterpenes (0-27.2%), and oxygenated sesquiterpenes (22.5-58.4%). This finding contrasts with earlier results for Myrtaceae plants in the Atlantic Forest, which showed that sesquiterpenes generally predominated (Nakamura et al., 2010; Albuquerque et al., 2012). In the restinga, an increase in hydrocarbon and oxygenated monoterpenes has been observed (Ramos et al., 2010; Defaveri et al., 2011). Although monoterpenes volatilize easily under conditions of high temperature and solar intensity (Arruda and Victório, 2011), the abundance of these compounds in species of this family can be explained by their thick and wax-covered leaves, especially in plants from the restinga (Donato and Morretes, 2007). Thus, the functional traits of the leaves indicate the existence of mechanisms to reflect incident light and protect against the loss of water and volatile substances.

In \textit{L. camara}, the most abundant constituents were caryophyllene oxide (17.1%) and ledol (11.3%; Table 2). The predominance of sesquiterpenes in this study reveals their importance for the species (Sousa et al., 2010; Medeiros et al., 2012; Zhu et al., 2013). The qualitative and quantitative presence of this class of compounds has been shown to vary in various organs of \textit{L. camara} (Medeiros et al., 2012; Zhu et al., 2013). In leaves, the major essential oil constituents are germacrene D (24.5%), bicyclogermacrene (33.3%), spathulenol (25.0%), eremophilene (20.6%), valencene (33.7%), viridiflorene (19.5%), and 1,10-di-epi-cubenol (21.3%) (Sousa et al., 2010). The variation in the chemical composition is also due to the numerous varieties of the species, such as \textit{L. camara var. aculeata}, \textit{L. camara var. avá}, \textit{L. camara var. hybrida}, \textit{L. camara var. mista}, and \textit{L. camara var. nivea} (Da Silva et al., 1999).

This study reports the chemical diversity present in the essential oils of plant species collected in the restinga ecosystem of southern Brazil. Although \textit{E. uniflora} and \textit{V. curassavica} are commercially exploited, in this work we report that these species have a high content of the substance of economic interest such as curzurenne (30.0%) and α-humulene (2.4%), which may represent a potential commercial. Likewise, the selection of matrices with economic value can be subsidized with sustainable use practices of the species, since they are distributed in Biome highly threatened by anthropogenic disturbance (de Souza et al., 2021). This information is critical when selecting species with economic potential for phytotherapeutic products, as well as for the phytosanitary and cosmetic industries.

4. Conclusions

In conclusion, our study reports the yield and chemical composition of essential oils from 14 species distributed on the coast of Santa Catarina, Brazil. The EO content ranges from 0.01% (\textit{M. involucrata}) to 1.56% (\textit{V. curassavica}). The major constituents are ar-curcumene (15.1%) and cis-chrysanthremol (14.2%) in \textit{A.elatior};
benzyl benzoate (43.5%) and benzyl salicylate (23.7%) in *A. firmaula*; caryophyllene oxide (35.7%) and spathulenol (10.6%) in *A. inulaefolium*; spathulenol (19.8%) and caryophyllene oxide (14.0%) in *B. spicata*; caryophyllene oxide (16.3%) in *E. astringens*; curzerene (30.0%), limonene (13.0%), and germacrone (11.9%) in *E. uniflora*; caryophyllene oxide (17.1%) and ledol (11.3%) in *L. camara*; caryophyllene oxide (27.7%) and limonene (12.7%) in *M. involucrata*; 1,8-cineole (19.8%) in *P. cattleianum*; limonene (10.2%) in *S. terebinthifolius*, and allo-aromadendrene (15.2%) in *V. curassavica*.

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