Review

Essential Oil of the Plants Growing in the Brazilian Amazon: Chemical Composition, Antioxidants, and Biological Applications

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Abstract: Essential oils are biosynthesized in the secondary metabolism of plants, and in their chemical composition, they can be identified different classes of compounds with potential antioxidant and biological applications. Over the years in the Amazon, several species of aromatic plants were discovered and used in traditional medicine. The literature has shown that essential oils extracted from amazon species have several biological activities, such as antioxidant, antibacterial, antifungal, cytotoxic, and antiprotozoal activities. These activities are related to the diversified chemical composition found in essential oils that, by synergism, favors its pharmacological action. In light of this vital importance, this study aimed at performing a review of the literature with particular emphasis on the chemical composition and biological activities in studies conducted with species collected in the Amazon, taking into consideration in particular the last 10 years of collection and research.

Keywords: species of Brazil; essential oils; bioactive compounds; biological activities

1. Introduction

Brazil has the world’s highest plant diversity. It houses more than 46,000 species of plants, algae, and fungi, and most of this biodiversity is found in the Amazon [1,2]. This biome occupies 5 million km² of the territory, corresponding to 60% of the entire national territory. Such areas include the Brazilian Amazon, which accounts for 51% of all tropical plant species. The Brazilian Amazon forest accounts for approximately 26% of the remaining tropical rainforests on Earth [3,4].

Typifying this exuberance, 12 families that provide essential oil are predominant in the Amazon region (in descending order): Piperaceae, Asteraceae, Myrtaceae, Lamiaceae, Annonaceae, Lauraceae, Euphorbiaceae, Verbenaceae, Scrophulariaceae, Anacardiaceae, Burseraceae, and Rutaceae [5,6].

Essential oils are volatile, with a strong smell and taste derived from the secondary metabolites of the plants. Essential oils can be extracted from the roots, stems, leaves, and flowers by steam distillation, hydrodistillation, and squeezing citrus fruit pericarp.
The terminology “oil” is closely related to the physicochemical characteristics of these substances, as they are liquids at room temperature [7,8].

The biological activity of essential oils is due to the diversity of chemical components in these volatile oils. These properties include antibacterial, antifungal, and antioxidant activities [9–12]. Essential oils can also be used as raw materials for products such as cosmetics and perfumes, or in pharmaceutical industries to obtain structural derivatives (plant products) in addition to horticulture [7,13].

Although essential oils have several potential applications, many aromatic plants in the Amazon ecosystem are under constant environmental pressure, as this region undergoes increasing fires, deforestation, and unsustainable forest exploitation [5].

Although Brazil is still the largest natural angiosperm bank in the world and these aromatic plants have the potential for varied uses, part of this exuberance was lost long before scientific knowledge was gained [3,14]. Therefore, efforts and resources must be invested to acquire a greater awareness of the diversity and value of the plants that remain in the Amazon region.

Therefore, this chapter provides a bibliographic survey of scientific articles reporting the chemical composition and antioxidant and biological activities of species collected in the Amazon, taking into consideration the last ten years.

2. Chemical Composition of the Essential Oils of the Amazon

Table 1 shows the major chemical components found in the essential oils of the species from the Amazon region.

| Species                  | Family             | Extraction Method | Compounds                                                                                   | References |
|--------------------------|--------------------|-------------------|------------------------------------------------------------------------------------------------|------------|
| Anaxagorea brevipes      | Annonaceae         | HD                | β-eudesmol (13.16%), α-eudesmol (13.05%), γ-eudesmol (7.54%), guaiol (5.12%), caryophyllene oxide (4.18%) and β-bisabolene (4.10%) | [15]       |
| Aniba duckei (Synonym:   | Lauraceae          | HD                | linalool (89.34%)                                                                          | [16]       |
| A. rosaeodora) (leaves   |                    |                   |                                                                                                |            |
| and thin branches)       |                    |                   |                                                                                                |            |
| A. parviflora (Aerial    | Lauraceae          | HD                | linalool (45.0%)                                                                            | [17]       |
| parts)                   |                    |                   |                                                                                                |            |
| A. parviflora (branches) | Lauraceae          | HD                | γ-eudesmol (16.80%), (E)-caryophyllene (15.70%), linalool (12.40%), β-phellandrene (6.7%), and bicyclogermacrene (6.00%) | [18]       |
| A. parviflora (leaves)   | Lauraceae          | HD                | β-phellandrene (15.10%), linalool (14.10%) and γ-eudesmol (12.90%).                           | [18]       |
| A. rosaeodora (Aerial    | Lauraceae          | HD                | linalool (88.60%)                                                                           | [17]       |
| parts)                   |                    |                   |                                                                                                |            |
| A. rosaeodora (Aerial    | Lauraceae          | HD                | linalool (93.60%)                                                                           | [19]       |
| parts)                   |                    |                   |                                                                                                |            |
| Annona exsucca (Dry      | Annonaceae         | HD                | (E)-caryophyllene (31.26%), linalool (10.80%), β-elemene (10.30%), germacrene D (10.28%), bicyclogermacrene (9.84%) | [20]       |
| leaves)                  |                    |                   |                                                                                                |            |
Table 1. Cont.

| Species                  | Family       | Extraction Method | Compounds                                                      | References |
|--------------------------|--------------|-------------------|----------------------------------------------------------------|------------|
| Bauhinia ungulata        | Fabaceae     | HD                | (E)-caryophyllene (15.9%), Caryophyllene oxide (9.2%), α-humulene (8.1%) and epi-γ-eudesmol (7.5%) | [21]       |
| Bocageopsis pleiosperma  | Annonaceae   | HD                | β-bisabolone (38.53%), δ-cadinene (7.55%), β-selinene (6.46%) and α-selinene (5.18%) | [22]       |
| B. pleiosperma           | Annonaceae   | HD                | β-bisabolene (55.77%), (E)-α-bergamotene (6.94%) and β-farnesene (E) (6.05%) | [22]       |
| B. pleiosperma (twigs)   | Annonaceae   | HD                | β-bisabolene (34.37%), cryptomerite (9.60%) and (2Z, 6Z)-farnesol (7.20%) | [22]       |
| B. multiflora (Leaves)   | Annonaceae   | HD                | Spathulenol (20.30%) and β-bisabolene (11.90%) | [23]       |
| B. multiflora (Aerial parts) | Annonaceae | HD                | cis-linalool oxide (33.10%) and 1-epi-cubenol (16.60%) | [24]       |
| B. multiflora (fresh leaves) | Annonaceae | HD                | Spathulenol (13.00-16.20%), β-bisabolene (13.20-13.80%) and Caryophyllene oxide (10.70-12.00%) | [25]       |
| Copaifera multijuga      | Fabaceae     | Perforation in the trunk of the species | (E)-caryophyllene (57.29%), Caryophyllene oxide (10.34%) and α-humulene (9.11%) | [26]       |
| Croton cajucara          | Euphorbiaceae| HD                | 7-hydroxy-calamene | [27]       |
| Duguetia quitarensis     | Annonaceae   | HD                | 4-heptanol (33.80%), α-thujene (18.40%) and (E)-caryophyllene (14.40%) | [24]       |
| Endlicheria arenosa      | Lauraceae    | HD                | Bicyclergemacrecine (42.20%) and (E)-caryophyllene (10.40%) | [28]       |
| E. arenosa (Twigs)       | Lauraceae    | HD                | Limonene (33.20%) and terpinen-4-ol (15.60%) | [28]       |
| Ephedranthus amazonicus  | Annonaceae   | HD                | Spathulenol (16.90%) and humulene epoxide II (16.30%) | [23]       |
| Eugenia cuspidifolia     | Myrtaceae    | HD                | Caryophyllene oxide (57.46%) and α-copaene (3.75%) | [29]       |
| E. egensis (Aerial parts) | Myrtaceae    | HD                | 5-hydroxy-(Z)-calamenene (35.80%), (E)-caryophyllene (8.90%) and (E)-cadin-1,4-diene (6.30%) | [30]       |
| E. flavescens (Aerial parts) | Myrtaceae | HD                | (E)-γ-bisabolene (35.00%) and β-bisabolene (34.70%) | [30]       |
| E. patrisii (Aerial parts) | Myrtaceae   | HD                | (2E,6E)-Farnesol (34.50%) and (2E,6Z)-Farnesol (23.20%) | [30]       |
Table 1. Cont.

| Species            | Family       | Extraction Method | Compounds                                                                                           | References |
|--------------------|--------------|-------------------|-----------------------------------------------------------------------------------------------------|------------|
| *E. patrisii*      | Myrtaceae    | HD                | May: germacrene D (20.03%), bicyclogermacrene (11.82%) and (E)-caryophyllene (11.04%) September: γ-elemene (25.89%), (E)-caryophyllene (10.76%) and germacrene B (8.11%) | [31]       |
| (Dry leaves)       |              |                   | (E)-caryophyllene (32.00%) and bicyclogermacrene (10.00%)                                          | [32]       |
| *E. patrisii*      | Myrtaceae    | HD                | γ-elemene (17.48%), (E)-caryophyllene (16.46%) and bicyclogermacrene (8.11%)                        | [33]       |
| (Leaves)           |              |                   | germacrene D (18.40%), ishwarane (15.70%) and 7-epi-α-selinene (7.50%)                               | [30]       |
| *E. piauhiensis*   | Myrtaceae    | HD                | May: β-elemene (25.12%), (E)-caryophyllene (13.11%), bicyclogermacrene (9.88%) and selin-11-en-α-ol (9.16%) September: (E)-caryophyllene (11.47%), β-pinene (5.86%), bicyclogermacrene (5.86%), and γ-muurolene (5.55%) | [31]       |
| (dry leaves)       |              |                   | germacrene D (11.80%) and Z-α-bisabolene (8.38%).                                                  | [32]       |
| *E. polystachya*   | Myrtaceae    | HD                | γ-elemene (17.48%), (E)-caryophyllene (16.46%) and bicyclogermacrene (8.11%)                        | [33]       |
| (Aerial parts)     |              |                   | germacrene D (18.40%), ishwarane (15.70%) and 7-epi-α-selinene (7.50%)                               | [30]       |
| *E. punicifolia*   | Myrtaceae    | HD                | May: β-elemene (25.12%), (E)-caryophyllene (13.11%), bicyclogermacrene (9.88%) and selin-11-en-α-ol (9.16%) September: (E)-caryophyllene (11.47%), β-pinene (5.86%), bicyclogermacrene (5.86%), and γ-muurolene (5.55%) | [31]       |
| (Dry leaves)       |              |                   | germacrene D (11.80%) and Z-α-bisabolene (8.38%).                                                  | [32]       |
| *E. stipitata*     | Myrtaceae    | HD                | curzerene (34.40—53.10%)                                                                            | [34]       |
| (Leaves)           |              |                   |                                                                                                     |            |
| *E. uniflora*      | Myrtaceae    | HD                | curzerene (34.40—53.10%)                                                                            | [34]       |
| (leaves)           |              |                   |                                                                                                     |            |
| *E. tapacamensis*  | Myrtaceae    | HD                | caryophyllene oxide (55.95%) and α-copaene (13.67%)                                                | [29]       |
| (Dry leaves)       |              |                   |                                                                                                     |            |
| *Fusaea longifolia*| Annonaceae   | HD                | β-selinene (19.30%), cis-β-guaiene (18.30%), (Z)-α-bisabolene (12.00%) and (E)-caryophyllene (7.10%) | [24]       |
| (Aerial parts)     |              |                   |                                                                                                     |            |
| *Guatteria blepharophylla* | Annonaceae   | HD                | caryophyllene oxide (55.70%).                                                                      | [23]       |
| (Leaves)           |              |                   |                                                                                                     |            |
| *G. friciana*      | Annonaceae   | HD                | β-eudesmol (51.92 ± 9.15%), γ-eudesmol (18.91 ± 5.41%) and α-eudesmol (12.56 ± 2.80%)             | [35]       |
| (dry leaves)       |              |                   |                                                                                                     |            |
| *G. megalophylla*  | Annonaceae   | HD                | spathulenol (27.76%), γ-muurolene (14.34%), bicyclogermacrene (10.47%) and β-elemene (7.48%)        | [36]       |
| (dry leaves)       |              |                   |                                                                                                     |            |
| *G. pogonopus*     | Annonaceae   | HD                | spathulenol (24.80 ± 11.38%), γ-amorphene (14.72 ± 3.37%) and germacrene D (11.75 ± 6.33%).         | [35]       |
| (dry leaves)       |              |                   |                                                                                                     |            |
| *G. punctata*      | Annonaceae   | HD                | germacrene D (19.80%), (E)-nerolidol (9.90%) and (E)-caryophyllene (8.40%).                          | [24]       |
| (Aerial parts)     |              |                   |                                                                                                     |            |
| *Hedychium coronarium* | Zingiberaceae | HD                | eucalyptol (33.70%), β-pinene (30.00%) and α-pinene (10.00%)                                        | [37]       |
Table 1. Cont.

| Species                     | Family            | Extraction Method | Compounds                                                                 | References |
|-----------------------------|-------------------|-------------------|---------------------------------------------------------------------------|------------|
| *Ipomea setifera* (Dry leaves) | Convolvulaceae    | SD                | (E)-caryophyllene (36.70%) and β-elemene (20.49%)                        | [38]       |
| *I. asarifolia* (Dry leaves)  | Convolvulaceae    | SD                | phytol derivade (10.67–35.49%) and (E)-caryophyllene (15.93–19.93%)      | [38]       |
| *Iryanthera polyneura* (Leaves) | Myristicaceae    | HD                | spathulenol (6.42 ± 1.02%), α-cadinol (5.82 ± 0.40%) and τ-murolol (5.24 ± 0.03%) | [39]       |
| *Lippia gracilis* (dry leaves) | Verbenaceae      | HD                | limonene (56.16%), geraniol (12.09%) and β-myrcene (6.22%)                | [33]       |
| *L. origanoides* (aerial parts) | Verbenaceae      | HD                | carvacrol (37.12%), p-cymene (11.64%) and thymol (7.83%)                  | [40]       |
| *L. origanoides* (leaves)     | Verbenaceae      | HD                | carvacrol (48.31%), p-cymene (9.11%), thymol (8.78%), (E)-caryophyllene (6.74%) and 2,5-dimethoxyacetophenone (6.63%) | [41]       |
| *L. thymoides* (Fresh and Dry Leaves) | Verbenaceae    | HD                | thymol (59.29–62.78%), p-cymene (2.97–6.97%), (E)-caryophyllene (5.21–8.84%) and thymol acetate (4.92–7.22%) | [42]       |
| *L. thymoides* (Freash and Dry leaves) | Verbenaceae    | HD                | thymol (58.90–66.33%), thymol acetate (7.49–8.10%), γ-terpinene (5.58–9.36%) and p-cymene (5.30–8.36%) | [43]       |
| *L. thymoides* (Freash and Dry flowers) | Verbenaceae    | HD                | thymol (37.86–48.04%), thymol acetate (21.44–33.81), γ-terpinene (0.15–15.06%) and p-cymene (0.07–7.18%) | [43]       |
| *L. thymoides* (Freash and Dry branches) | Verbenaceae    | HD                | thymol (63.59–66.20%), thymol acetate (5.07–5.96%) γ-terpinene (3.39–3.96%) and p-cymene (3.27–3.35%) | [43]       |
| *L. thymoides* (Freash and Dry roots) | Verbenaceae    | HD                | (11Z)-11-hexadecenoic acid (38–02-40.92%), (9Z)-octadecenoic acid (27.40–28.21%) and thymol (19.34–22.18%) | [43]       |
| *Mentha piperita* (Dry leaves) | Lamiaceae        | HD                | linalool (51.80%) and epoxycimene (19.30%)                               | [44]       |
| *Mesophaerum suaveolens* (aerial parts) | Lamiaceae        | HD                | eucalyptol (30.15–64.44%), linalool (0.00–12.85%), β-pinene (3.27–9.04%) and sabine (0.00–8.58%) | [45]       |
| *Myrcia erythroxyylon* (Dry leaves) | Myrtaceae        | HD                | α-humulene (26.79%), bicyclogermacrene (13.26%) and (E)-caryophyllene (10.55%) | [33]       |
| *M. splendens* (Leaves)       | Myrtaceae        | HD                | (E)-caryophyllene (45.80%)                                               | [32]       |
Table 1. Cont.

| Species       | Family       | Extraction Method | Compounds                                                                 | References |
|---------------|--------------|-------------------|---------------------------------------------------------------------------|------------|
| *M. splendens* (Leaves) | Myrtaceae    | HD                | (E)-caryophyllene (36.23%), trans-γ-bisabolene (10.04%), cis-γ-bisabolene (8.33%) and trans-β-farnesene (7.81%) | [46]       |
| *M. sylvatica* (Leaves) | Myrtaceae    | HD                | germacrene B (24.50%) and γ-elemene (12.50%)                              | [32]       |
| *M. sylvatica* (Fresh leaves) | Myrtaceae  | HD                | 1-epi-cubenol (9.90%), cadalene (7.20%), β-selinene (7.00%), β-calacorene (5.40%), cis-calamenene (4.80%), muskatone (4.40%), δ-cadinene (4.20%), cubenol (4.20%) and ar-curcumene (1.90%) | [10]       |
| *M. sylvatica* (Dried Leaves) | Myrtaceae  | HD                | ar-curcumene (7.60%), 1-epi-cubenol (6.90%), β-selinene (6.00%), β-calacorene (5.80%), cis-calamenene (5.20%), arturmerol (4.90%), δ-cadineno (4.20%), cubenol (4.20%) and muskatone (3.40%) | [10]       |
| *M. tomentosa* (Dry leaves) | Myrtaceae    | HD                | May: γ-elemene (12.52%), germacrene D (11.45%) and (E)-caryophyllene (10.22%) September: spathulenol (40.70%), zingiberene (9.58%) and γ-elemene (6.89%) | [31]       |
| *Nectandra cuspidata* (Leaves) | Lauraceae    | HD                | (E)-caryophyllene (26.90%) and bicyclogermacrene (16.00%)                  | [47]       |
| *N. puberula* (Leaves) | Lauraceae    | HD                | apiole (22.20%), (E)-caryophyllene (15.10%) and β-pinene (13.30%)          | [47]       |
| *N. puberula* (branches) | Lauraceae    | HD                | apiole (28.10%), pogostol (19.80%) and viridiflorol (11.20%)               | [47]       |
| *Ocimum campechianum* (leaves and stems) | Lamiaceae | HD                | methyleugenol (80.00–87.00%)                                              | [48]       |
| *O. campechianum* (inflorescences) | Lamiaceae | HD                | methyleugenol (75.30–83.50%)                                              | [48]       |
| *O. canum* (dry leaves) | Lamiaceae    | HD                | thymol (42.15%), p-cymene (21.17%) and γ-terpinene (19.81%)               | [49]       |
| *Ocotea caniculata* (leaves) | Lauraceae    | HD                | β-selinene (20.30%), β-caryophyllene (18.90%) and 7-epi-α-selinene (14.30%) | [50]       |
| *O. caniculata* (branches) | Lauraceae    | HD                | selin-11-en-4-α-ol (20.60%), β-selinene (12.10%) and 7-epi-α-selinene (9.00%) | [50]       |
| *O. caudata* (leaves) | Lauraceae    | HD                | bicyclogermacrene (29.60%), germacrene D (19.90%) and α-pinene (9.80%)    | [50]       |
Table 1. Cont.

| Species                          | Family          | Extraction Method | Compounds                                                                 | References |
|----------------------------------|-----------------|-------------------|---------------------------------------------------------------------------|------------|
| *O. caudata* (branches)          | Lauraceae       | HD                | δ-cadinene (13.8%), germacrene D (8.9%), and α-muurulol (7.80%)           | [50]       |
| *O. cujumary* (leaves)           | Lauraceae       | HD                | β-caryophyllene (22.20%), caryophyllene oxide (12.40%) and 2-tridecanone (7.30%) | [50]       |
| *O. cujumary* (branches)         | Lauraceae       | HD                | selin-11-en-4-α-ol (20.60%), β-selinene (12.10%) and 7-epi-α-selinene (9.00%). | [50]       |
| *Oncyopetalum amazonicum* (leaves) | Annonaceae     | HD                | (E)-caryophyllene (17.00%), caryophyllene oxide (11.90%) and spathulenol (10.40%) | [51]       |
| *O. amazonicum* (trunk bark)     | Annonaceae      | HD                | α-epi-cadinol (14.00–24.10%), allo-aromadendrene (21.20%) and α-gurjunene (10.60–14.90%) | [51]       |
| *Piper aequale* (Aerial parts)   | Piperaceae      | HD                | δ-elemen (18.92%), β-pineno (15.56%), α-pineno (12.57%), cubebol (7.20%), β-atlantol (5.87%) and bicyclogermacrene (5.51%) | [52]       |
| *P. aduncum* (Aerial parts)      | Piperaceae      | HD                | dilapiol (64.40%), pipertone (3.30%) and (E)-β-ocimene (3.00%)            | [53]       |
| *P. aduncum* (Dry leaves)        | Piperaceae      | MAE               | dilapiol (91.07%)                                                        | [54]       |
| *P. aduncum* (Dry leaves)        | Piperaceae      | SD                | dilapiol (53.60%), myristicin (24.30%) and (Z)-carpacin (11.90%)          | [55]       |
| *P. alegraeum* (Aerial parts)    | Piperaceae      | HD                | β-elemene (16.30%), bicyclogermacrene (9.20%), δ-elemene (8.20%), germacrene D (6.90%) and (E)-caryophyllene (6.20%) | [12]       |
| *P. anonifolium* (Aerial parts)  | Piperaceae      | HD                | selin-11-en-4-ol (20.00%), β-selinene (12.70%), α-selinene (11.90%) and α-pinene (8.80%). | [12]       |
| *P. augustum* (Leaves)           | Piperaceae      | HD                | (E)-caryophyllene (27.10%), germacrene D (11.20%) and β-elemene (5.80%) | [37]       |
| *P. brachypetiolatum* (Fresh Leaves) | Piperaceae   | HD                | (E)-nerolidol (44.23 ± 2.23%) and caryophyllene oxide (10.08 ± 0.74%)     | [56]       |
| *P. callosum* (Aerial parts)     | Piperaceae      | HD                | Safrole (69.20%), methyleugenol (8.60%) and myrcene (6.20%)               | [53]       |
| *P. capitarianum* (Leaves, stems, and inflorescences) | Piperaceae   | HD                | (E)-caryophyllene (15.30–20.00%), α-humulene (9.10–12.70%), β-myrcene (1.40–10.50%), α-selinene (5.30–7.00%) and β-selinene (4.90–6.30%) | [57]       |
Table 1. Cont.

| Species                  | Family       | Extraction Method | Compounds                                                                 | References |
|--------------------------|--------------|-------------------|---------------------------------------------------------------------------|------------|
| *P. demeraranum* (dry leaves) | Piperaceae   | HD                | β-elemene (33.10%), Limonene (19.30%) and bicyclogermacrene (8.80%)       | [58]       |
| *P. divaricatum* (Aerial parts) | Piperaceae   | HD                | Methyleugenol (69.20%), Eugenol (16.20%) and germacrene D (3.50%)         | [53]       |
| *P. duckei* (dry leaves)    | Piperaceae   | HD                | (E)-caryophyllene (27.10%), germacrene D (14.70%) and eucalyptol (5.80%) | [58]       |
| *P. glandulosissimum* (Fresh Leaves) | Piperaceae   | HD                | (E)-caryophyllene (10.50%), α-humulene (9.50%), δ-3-carene (9.10%), α-copaene (9.16 ± 0.12%), limonene (6.90%), caryophyllene oxide (5.90%) and β-selinene (5.10%). | [12]       |
| *P. hispidum* (Aerial parts) | Piperaceae   | HD                | (E)-caryophyllene (21.80%), germacrene D (9.00%) and β-elemene (5.10%)    | [37]       |
| *P. leticianum* (Leaves)    | Piperaceae   | HD                | Caryophyllene oxide (16.92 ± 0.21%), selin-11-en-4-α-ol (9.26 ± 0.12%), β-copaene (9.16 ± 0.12%) and β-selinene (8.70 ± 0.11%). | [56]       |
| *P. madeiranum* (Fresh Leaves)  | Piperaceae   | HD                | (E)-isosmorhizole (32.20%) and (E)-anethole (26.40%)                      | [53]       |
| *P. marginatum* (Aerial parts) | Piperaceae   | HD                | p-mentha-1(7),8-diene (39.00%) and 3,4-methylenedioxy propiophenone (19.00%). | [53]       |
| *P. mollipilosum* (Fresh Leaves)  | Piperaceae   | HD                | β-selinene (32.44 ± 1.14%) and caryophyllene oxide (11.70 ± 0.42%)         | [56]       |
| *Psidium guajava*          | Myrtaceae    | HD                | epi-β-bisabolol (16.10%), ar-curcumene (9.80%), β-bisabolene (9.20%), (E)-caryophyllene (5.10%), and caryophyllene oxide (4.50%) | [32]       |
| *P. guineense* (Leaves)     | Myrtaceae    | HD                | Limonene (30.20–30.4%) and α-pinene (17.70–22.50%)                       | [32]       |
| *P. myrsinites* (dry Leaves) | Myrtaceae    | HD                | (E)-caryophyllene (26.05%), α-humulene (23.92%) and caryophyllene oxide (10.09%) | [33]       |
| *Renealmia breviscapa* (Fresh rhizomes) | Zingiberaceae | HD                | (E)-caryophyllene (62.38%), α-Humulene (9.56%) and guaiol (9.27%)          | [59]       |
| *R. breviscapa* (fresh leaves) | Zingiberaceae | HD                | (E)-caryophyllene (28.25%), cis-3-hexenol (15.05%) and bicyclogermacrene (6.90%) | [59]       |
| *R. chrysotricha* (Fresh rhizomes) | Zingiberaceae | HD                | α-terpineol (26.14%), coronarin E (25.10%) and eucalyptol (15.87%)         | [59]       |
Table 1. Cont.

| Species                  | Family          | Extraction Method | Compounds                                                                 | References |
|--------------------------|-----------------|-------------------|---------------------------------------------------------------------------|------------|
| R. chrysotricha          | Zingiberaceae   | HD                | cis-3-hexenol (57.28%), (E)-caryophyllene (6.85%) and caryophyllene oxide (4.92%) | [59]       |
| (Fresh leaves)           |                 |                   |                                                                           |            |
| R. nicolaioides          | Zingiberaceae   | HD                | (E)-caryophyllene (22.78%), α-terpineol (14.15%) and (E)-nerolidol (11.06%) | [59]       |
| (Fresh rhizomes)         |                 |                   |                                                                           |            |
| R. nicolaioides          | Zingiberaceae   | HD                | (E)-nerolidol (21.03%), α-terpineol (11.92%) and germacrene D (10.33%)   | [59]       |
| (fresh leaves)           |                 |                   |                                                                           |            |
| Siparuna aspera          | Siparunaceae    | HD                | germacrene D (23.30%), bicyclogermacrene (7.80%) and α-pinene (7.00%)     | [37]       |
| (Leaves)                 |                 |                   |                                                                           |            |
| S. camporum              | Siparunaceae    | HD                | γ-patchouline (28.63%), α-Phellandrene (12.80%) and Guaiadiene-6,9 (9.23%), | [33]       |
| (dry leaves)             |                 |                   |                                                                           |            |
| S. macrotepalata         | Siparunaceae    | HD                | germacrene D (42.10%), bicyclogermacrene (11.80%) and δ-cadinene (5.00%)   | [37]       |
| (Leaves)                 |                 |                   |                                                                           |            |
| Syzygium cumini          | Myrtaceae       | HD                | α-pinene                                                                  | [60]       |
| (leaves)                 |                 |                   |                                                                           |            |
| Virola calophyla         | Myristicaceae   | HD                | (E)-caryophyllene (55.70%) and caryophyllene oxide (9.80%)                | [61]       |
| (leaves)                 |                 |                   |                                                                           |            |
| V. multinervia           | Myristicaceae   | HD                | (E)-caryophyllene (54.80%) and bicyclogermacrene (10.00%)                | [61]       |
| (leaves)                 |                 |                   |                                                                           |            |
| V. pavonis               | Myristicaceae   | HD                | β-selinene (60.50%) and (E)-caryophyllene (12.70%)                        | [61]       |
| (leaves)                 |                 |                   |                                                                           |            |
| V. surinamensis          | Myristicaceae   | HD                | Aristolene (28.40 ± 5.03%), α-gurjunene (15.00 ± 3.17%) and valencene (14.10 ± 4.87%). | [62]       |
| (barks)                  |                 |                   |                                                                           |            |
| V. surinamensis          | Myristicaceae   | HD                | α-farnesene (14.50 ± 3.24), β-elemene (9.61 ± 1.02%) and bicyclogermacrene (8.10 ± 2.42%). | [62]       |
| (leaves)                 |                 |                   |                                                                           |            |
| Vismia cayennensis       | Hypericaceae    | HD                | germacrene (25.42%) and curzerene (25.29%)                               | [63]       |
| (Leaves)                 |                 |                   |                                                                           |            |
| V. guianensis            | Hypericaceae    | HD                | α-copaene (29.45%), (E)-nerolidol (24.06%) and (E)-caryophyllene (10.04%) | [63]       |
| (leaves)                 |                 |                   |                                                                           |            |
| Xylopia aromatica        | Annonaceae      | HD                | spathulenol (21.50%), trans-pinocarveol (10.20%) and dihidrocarveol (11.60%) | [23]       |
| (leaves)                 |                 |                   |                                                                           |            |

HD: Hydrodistillation; SD: steam distillation; MAE: microwave-assisted extraction.

In the documented studies, the essential oils were obtained by hydrodistillation, except in the case of the species Copaifera multijuga (perforation), Piper aduncum (MAE), P. aduncum (SD), Ipomea setifera (SD), and I. asarifolia (SD). Gas chromatography coupled with mass spectrometry (GC-MS) was used to identify the volatile compounds in the essential oils. There was little difference in the chemical composition and chemical profile of the essential oils of the species studied based on the families/genera/species, which may be related to the type of botanical material used from the plant in the extraction of the essential oils.
The chemical profile of essential oils from species of the Annonaceae family showed hydrocarbon and oxygenated sesquiterpenes as the main constituents, where the compounds β-bisabolene (55.77%), caryophyllene oxide (55.70%), and β-eudesmol (51.92%), were respectively dominant in the essential oils of Bocageopsis pleiosperma [22], Guatteria blepharophylla [23], and G. friesiana [35]. However, it was possible to observe other types of chemical classes in the genus Annonaceae, such as the oxygenated monoterpenes cis-linalool oxide (33.10%) in the essential oil of Bocageopsis multiflora [24] and the alcohol 4-heptanol (33.80%) in the essential oil of Duguetia quitensis [24].

Oxygenated monoterpenes, hydrocarbon sesquiterpenes, and phenylpropanoids are the major components in the essential oils of the Lauraceae family, where linalool (93.60%) is dominant in the essential oil of Aniba rosaeodora [16], as well as bicyclogermacrene (42.20%) and apiole (28.10%), respectively, in the essential oil of Endlicheria arenosa [28] and Nectandra piperulata [47]. Phenylpropanoids and oxygenated monoterpenes are also present in essential oils of the Lamiaeae family, where methyleugenol (80.00–87.00%) [48] and eucalyptol (16–33%) are dominant [64].

Studies carried out by Aranha et al. [29] and Da Silva et al. [30] confirmed the predominance of oxygenated sesquiterpenes and hydrocarbons in species of the genus Eugenia of the Myrtaceae family. Hydrocarbon sesquiterpenes were also observed as the main chemical classes in the essential oils of the genus Myrcia, where (E)-caryophyllene (45.80%) was dominant in the essential oil of M. splendens [32]. Monoterpene hydrocarbons characterize the essential oil profile of some species of the genus Psidium [32].

In species of the Piperaceae family, phenylpropanoids are present in the essential oils of some species of the genus Piper, as shown in the study of Piper aduncum essential oil by Nascimento et al. [54], the main component of which is dilapiol (91.07%). In species of the family Verbenaceae, the presence of oxygenated monoterpenes such as thymol (63.59–66.20%) was documented in Lippia thymoides essential oil [43]. In the species of Zingiberaceae, Siparunaceae, and Myristicaceae, sesquiterpenes are one of the main chemical classes in the chemical profile of the essential oil of some species, especially the compounds (E)-caryophyllene (62.38%) [59], and β-selinene (60.50%) [61].

3. Antioxidant Activity of Essential Oils

Essential oils comprise different organic compounds that have conjugated carbon double bonds, where the functional species are hydroxyl radicals, which can transfer hydrogen, inhibit free radicals, and minimize oxidative stress [65]. Essential oils with antioxidant properties are preferred over synthetic antioxidants because the former are safer for human health and are eco-friendly [66,67].

Aromatic plants are a well-known source of essential oils with antioxidant properties. These properties are exhibited by the raw essential oils and the isolated chemical constituents, both of which are efficient in preventing lipid oxidation [68]. The antioxidant potential of essential oils can be attributed to a single volatile constituent present in the chemical composition or to the synergistic effect among many components [69]. Table 2 summarizes the antioxidant potential of essential oils from Amazonian plants.

Studies on the antioxidant capacity of essential oils from the Amazon region have shown promising results. da Silva et al. [18] studied the essential oil from both the leaves and branches of Aniba parviflora, which strongly inhibited 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) free radicals. The authors indicated that the antioxidant activity may be related to the presence of β-phellandrene, linalool, β-caryophyllene, and γ-eudesmol, which presented antioxidant potential in other documented studies.
Table 2. Essential oils of the Amazon and their antioxidant activities.

| Species (Plants Part)       | Family       | Method | Results                                      | References |
|-----------------------------|--------------|--------|---------------------------------------------|------------|
| *Aniba parviflora* (Leaves) | Lauraceae    | DPPH   | TEAC = 90.1–287.9 mg TE/mL                  | [18]       |
| *A. parviflora* (Branches)  | Lauraceae    | DPPH   | TEAC = 94.1–358.4 mg TE/mL                  | [18]       |
| *A. rosaeodora* (Aerial parts) | Lauraceae   | ABTS   | EC$_{50}$ = 15.46 µg/mL                     | [19]       |
| *Endlicheria arenosa* (Leaves) | Lauraceae   | DPPH   | TEAC = 334.1 ± 41.6 mg TE/mL                | [28]       |
| *E. arenosa* (Twigs)        | Lauraceae    | DPPH   | TEAC = 252.6 ± 24.4 mg Te/mL                | [28]       |
| *Eugenia egensis* (Aerial parts) | Myrtaceae | DPPH   | TEAC = 216.5 ± 11.6 mg TE/mL                | [30]       |
| *E. flavescens* (Aerial parts) | Myrtaceae  | DPPH   | TEAC = 122.6 ± 6.8 mg TE/mL                 | [30]       |
| *E. patrisii* (Aerial parts) | Myrtaceae    | DPPH   | TEAC = 111.2 ± 12.4 mg TE/mL                | [30]       |
| *E. patrisii* (Leaves)      | Myrtaceae    | DPPH   | Inhibition = 28.9 ± 4.8%                   | [32]       |
| *E. patrisii* (Dry leaves)  | Myrtaceae    | DPPH   | Inhibition = 99.0 ± 0.099%                  | [31]       |
|                            |              |        | (Specimen A)                                |            |
|                            |              |        | Inhibition = 204.0 ± 0.877%                 |            |
|                            |              |        | (Specimen B)                                |            |
|                            |              |        | ABTS                                        |            |
|                            |              |        | Inhibition = 31.4 ± 0.1%                     |            |
|                            |              |        | (Specimen A)                                |            |
|                            |              |        | Inhibition = 17.9 ± 0.069%                  |            |
|                            |              |        | (Specimen B)                                |            |
| *E. punicifolia* (Dry leaves) | Myrtaceae   | DPPH   | Inhibition = 408.0 ± 0.10%                  | [31]       |
|                            |              |        | (Specimen A)                                |            |
|                            |              |        | Inhibition = 285.0 ± 0.028%                 |            |
|                            |              |        | (Specimen B)                                |            |
|                            |              |        | ABTS                                        |            |
|                            |              |        | Inhibition = 9.5 ± 0.034%                   |            |
|                            |              |        | (Specimen A)                                |            |
|                            |              |        | Inhibition = 37.7 ± 0.035%                  |            |
|                            |              |        | (Specimen B)                                |            |
| *E. uniflora* (Leaves)      | Myrtaceae    | DPPH   | Inhibition = 42.6 ± 0.3 to 64.2 ± 0.3%     | [34]       |
| *E. uniflora* (Dry leaves)  | Myrtaceae    | DPPH   | Inhibition = 30.3 ± 3.3 to 40.6 ± 1.9%     | [48]       |
|                            |              |        | β-Carotene                                  |            |
|                            |              |        | Inhibition = 153.5 ± 16.5 to 228.3 ± 19.2% |            |
|                            |              |        | MTT                                          |            |
|                            |              |        | Inhibition = 10.8 ± 3.4 to 26.3 ± 1.2%     |            |
| *Hedychium coronarium* (Rhizome) | Zingiberaceae | DPPH   | IC$_{50}$ = 9.04 ± 0.55 mg/mL              | [37]       |
|                            |              | ABTS   | IC$_{50}$ = 2.87 ± 0.17 mg/mL              |            |
| *Lippia thymoides* (Fresh Leaves) | Verbenaceae | DPPH   | Inhibition = 89.97 ± 0.31%                | [42]       |
| *L. thymoides* (Dry leaves) | Verbenaceae  | DPPH   | Inhibition = 63.53 b ± 5.04–73.63 ± 2.09% | [42]       |
| Species (Plants Part) | Family       | Method | Results | References |
|-----------------------|--------------|--------|---------|------------|
| Mentha piperita       | Lamiaceae    | DPPH   | AA = 79.9 ± 1.6% | [44]       |
| Myrcia splendens      | Myrtaceae    | DPPH   | Inhibition = 28.4 ± 7.1% | [32]       |
| M. sylvatica          | Myrtaceae    | DPPH   | Inhibition = 18.5 ± 3.5% | [32]       |
| M. tomentosa (Dry leaves) | Myrtaceae | DPPH   | Inhibition = 213.0 ± 0.905% (Specimen A) | [31]       |
|                       |              |        | Inhibition = 208.5 ± 0.940% (Specimen B) |            |
|                       |              |        | ABTS    | Inhibition = 53.6 ± 0.150% (Specimen A) | [31]       |
|                       |              |        |         | Inhibition = 0.333 ± 0.247% (Specimen B) |            |
| Ocimum campechianum   | Lamiaceae    | DPPH   | Inhibition = 36.0% (leaves and stems) | [48]       |
| (leaves and stems and |              |        |         | Inhibition = 41.6% (inflorescences) |            |
| inflorescences)       |              |        |         | TEAC = 58.5 mgTE/mL (leaves and stems) |            |
|                       |              |        |         | TEAC = 68.4 mgTE/mL (inflorescences) |            |
| Piper aequale (Aerial parts) | Piperaceae | DPPH   | TEAC = 280.9 ± 22.2 mg TE/mL | [52]       |
| P. aleyreanum (Aerial parts) | Piperaceae | DPPH   | TEAC = 412.2 ± 9.5 mg TE/mL | [12]       |
| P. anonifolium (Aerial parts) | Piperaceae | DPPH   | TEAC = 148.6 ± 26.9 mg TE/mL | [12]       |
| P. augustum (Leaves)  | Piperaceae   | DPPH   | IC₅₀ = 6.17 ± 0.33 mg/mL | [37]       |
|                       |              | ABTS   | IC₅₀ = 2.16 ± 0.20 mg/mL |            |
| P. brachypetiolatum (Fresh Leaves) | Piperaceae | DPPH   | EC₅₀ = 64.8 ± 3.8 μg/mL | [56]       |
|                       |              | ABTS   | EC₅₀ = 159.7 ± 8.3 μg/mL |            |
| P. glandulosissimum (Fresh Leaves) | Piperaceae | DPPH   | EC₅₀ = 104.4 ± 6.4 μg/mL | [56]       |
|                       |              | ABTS   | EC₅₀ = 200.9 ± 6.4 μg/mL |            |
| P. hispidum (Aerial parts) | Piperaceae | DPPH   | TEAC = 303.1 ± 49.2 mg TE/mL | [12]       |
| P. leticianum (Leaves) | Piperaceae   | DPPH   | IC₅₀ = 4.26 ± 0.11 mg/mL | [37]       |
|                       |              | ABTS   | IC₅₀ = 2.65 ± 0.25 mg/mL |            |
| P. madeirianum (Fresh Leaves) | Piperaceae | DPPH   | EC₅₀ = 66.8 ± 5.2 μg/mL | [56]       |
|                       |              | ABTS   | EC₅₀ = 242.6 ± 6.8 μg/mL |            |
| P. mollipilosum (Fresh Leaves) | Piperaceae | DPPH   | EC₅₀ = 79.0 ± 4.9 μg/mL | [56]       |
|                       |              | ABTS   | EC₅₀ = 280.5 ± 6.6 μg/mL |            |
| Psidium guajava (Leaves) | Myrtaceae   | DPPH   | Inhibition = 38.6 ± 7.0% | [32]       |
| P. guineense          | Myrtaceae    | DPPH   | Inhibition = 11.5 ± 2.0% (Pgui-1) | [32]       |
|                       |              |        |         | Inhibition = 27.7 ± 2.3% (Pgui-2) |            |
Table 2. Cont.

| Species (Plants Part) | Family     | Method | Results          | References |
|-----------------------|------------|--------|------------------|------------|
| *Siparuna aspera*     | Siparunaceae | DPPH   | \( IC_{50} = 20.70 \pm 0.80 \, \text{mg/mL} \) | [37]       |
| (Leaves)              |            | ABTS   | \( IC_{50} = 1.12 \pm 0.04 \, \text{mg/mL} \) |            |
| *S. macrotepala*      | Siparunaceae | DPPH   | \( IC_{50} = 29.37 \pm 1.15 \, \text{mg/mL} \) | [37]       |
| (Leaves)              |            | ABTS   | \( IC_{50} = 0.80 \pm 0.03 \, \text{mg/mL} \) |            |

DPPH, 2,2-Diphenyl-1-picrylhydrazyl; ABTS, 2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonate); \( EC_{50} \) (concentration required to obtain 50% antioxidant effect).

The antioxidant potential of some essential oils is equivalent to the inhibition potential of the Trolox standard determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, as observed for the essential oils of leaves and twigs of *Endlicheria arenosa* [28]. These results may be related to the difference in the chemical composition of the two oils because the chemical profile of the product distilled from the leaves was characterized by the sesquiterpene hydrocarbons bicyclogermacrene (42.2%), germacrene D (12.5%), and \( \beta \)-caryophyllene (10.1%).

Other studies have shown that the inhibition potential of essential oils for the free radicals DPPH and ABTS is higher than that of the Trolox standard, as in the case of the essential oils of *Eugenia patrisii*, *E. punicifolia*, and *Myrcia tomentosa* [31]. Some studies have also reported that a high thymol content may favor higher potential inhibition for essential oils, in which thymol is a major constituent [42]. This is a result of the presence of hydroxyl radicals that facilitate the capture of free radicals and reduce the effects of lipid oxidation [70].

4. Biological Activities of Essential Oils from the Amazon Region
4.1. Antibacterial Activity

There has been an increasing search for bioactive compounds of natural origin with antimicrobial activities. Natural products and their derivatives are invaluable sources of therapeutic agents [71,72]. In the last few years, essential oils have attracted the interest of researchers because they are composed of mixtures of volatile constituents with potent biological properties, including antibacterial properties [73,74]. The Amazon flora contains several species that are a source of essential oils, some of which have been investigated for their antibacterial activity, as shown in Table 3.

*Ocotea* is a genus of the Lauraceae family that is very important for the economy of the Amazon region. The activity of the essential oils of the leaves of *Ocotea caniculata*, *O. caudalata*, and *O. cujumary* against *Bacillus cereus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* was assessed. The respective oils presented high antimicrobial activity against *Escherichia coli*, with MIC values equal to 19.5 \( \mu \text{g/mL} \) for the three species. On the other hand, the essential oil of *Ocotea cujumary* presented moderate activity against *Staphylococcus epidermidis* (MIC = 312.5 \( \mu \text{g/mL} \)) and *Bacillus cereus* (MIC = 312.5 \( \mu \text{g/mL} \)), and the oil of *O. caudalata* presented moderate activity against *Staphylococcus epidermidis* (MIC = 312.5 \( \mu \text{g/mL} \)) [50].

The essential oil of the leaves of *Endlicheria arenosa* (Lauraceae) showed strong antibacterial activity against *Escherichia coli* (MIC = 19.5 \( \mu \text{g/mL} \)), and the oils of the leaves and branches showed moderate activity against *Bacillus cereus*, with MIC values of 156 \( \mu \text{g/mL} \) for both oils. Other species of the Lauraceae family have also been reported to have antibacterial activity, including *Aniba parviflora*, *A. rosaeodora*, *Nectandra cuspidata*, and *N. puberula* [17].
Table 3. Antibacterial activity of essential oils from species found in the Amazon.

| Species                  | Family         | Methodos                      | Microorganisms (Results)                                      | References |
|--------------------------|----------------|-------------------------------|---------------------------------------------------------------|------------|
| *Anaxagorea brevipes*    | Annonaceae     | Microbroth dilution           | *Kocuria rhizophila* (MIC = 50.00 µg/mL)                        | [13]       |
| (Leaves)                 |                |                               | *Staphylococcus aureus* (MIC = 250.00 µg/mL)                    |            |
|                          |                |                               | *Staphylococcus aureus* penicillinase-negative (8+) (MIC = 25.00 µg/mL) |            |
|                          |                |                               | *Staphylococcus aureus* penicillinase-positive (7+) (MIC = 250.00 µg/mL) |            |
|                          |                |                               | *Enterococcus faecalis* (MIC = 250.00 µg/mL)                    |            |
| *A. roseodora*           | Lauraceae      | Microbroth dilution           | *Klebsiella pneumoniae* (DDM = 9.20 mm/MIC = >10 µL/mL)         |            |
| (Barks)                  |                |                               | *Staphylococcus aureus* (DDM = 15.44 mm/MIC = >10 µL/mL)        |            |
|                          |                |                               | *Enterococcus faecalis* (DDM = 11.2 mm/MIC = >10 µL/mL)         |            |
|                          |                |                               | *Staphylococcus epidermidis* (DDM = 13.3 mm/MIC = >10 µL/mL)     |            |
|                          |                |                               | *Streptococcus pyogenes* (DDM = 13.3 mm/MIC = 1.3 µL/mL)         |            |
|                          |                |                               | *Escherichia coli* (DDM = 13.2 mm/MIC = >10 µL/mL)              |            |
|                          |                |                               | *Klebsiella pneumoniae* (DDM = 11.6 mm/MIC = >10 µL/mL)         |            |
|                          |                |                               | *Staphylococcus aureus* (DDM = 26.7 mm/MIC = 1.3 µL/mL)          |            |
|                          |                |                               | *Enterococcus faecalis* (DDM = 8.80 mm/MIC = 5 µL/mL)            |            |
|                          |                |                               | *Staphylococcus epidermidis* (DDM = 38.4 mm/MIC = 5 µL/mL)       |            |
|                          |                |                               | *Streptococcus pyogenes* (DDM >40/MIC = 1.3 µL/mL)               |            |
| *Aniba parviflora*       | Annonaceae     | Microdilution                 | *Staphylococcus aureus* (MIC = 0.19 mg/mL)                      | [23]       |
| (Aerial parts)           |                |                               | *Enterococcus faecalis* (MIC = 0.09 mg/mL)                      |            |
|                          |                |                               | *Streptococcus sanguinis* (MIC = 0.19 mg/mL)                    |            |
|                          |                |                               | *Pseudomonas aeruginosa* (MIC = 3.0 mg/mL)                      |            |
|                          |                |                               | *Escherichia coli* (MIC = 1.5 mg/mL)                           | [24]       |
| *B. multiflora*          | Annonaceae     | Microdilution                 | *Streptococcus mutan* (MIC = 4.68 mg/mL)                        | [24]       |
| (Leaves)                 |                |                               | *Streptococcus pyogenes* (MIC = 4.68 mg/mL)                     |            |
|                          |                |                               | *Escherichia coli* (MIC = 4.68 µg/mL)                           |            |
|                          |                |                               | *Pseudomonas aeruginosa* (MIC = 4.68 µg/mL)                     |            |
|                          |                |                               | *Streptococcus mutan* (MIC = 37.5 µg/mL)                        | [24]       |
|                          |                |                               | *Streptococcus pyogenes* (MIC = 37.5 µg/mL)                     |            |
| *B. multiflora*          | Annonaceae     | Microdilution                 | *Streptococcus mutan* (MIC = >1000 µg/mL)                       | [40]       |
| (Aerial parts)           |                |                               | *Streptococcus pyogenes* (MIC = 1000 µg/mL)                     |            |
|                          |                |                               | *Escherichia coli* (MIC = >1000 µg/mL)                         |            |
| *Buccegoepsis pleiosperma*| Annonaceae     | Microbroth dilution           | *Staphylococcus epidermidis* (MIC = 250 µg/mL)                  | [22]       |
| (Aerial parts)           |                |                               |                                                                |            |
| *Daguetia quitarensis*   | Annonaceae     | Microdilution                 | *Staphylococcus aureus* (MIC = 0.19 mg/mL)                      | [17]       |
| (Aerial parts)           |                |                               | *Enterococcus faecalis* (MIC = 0.09 mg/mL)                      |            |
|                          |                |                               | *Streptococcus sanguinis* (MIC = 0.19 mg/mL)                    |            |
| *Ephedrathus amazonicus*  | Annonaceae     | Microdilution                 | *Staphylococcus aureus* (MIC = 0.09 g/mL)                       | [23]       |
| (Leaves)                 |                |                               | *Enterococcus faecalis* (MIC = 0.19 mg/mL)                      |            |
|                          |                |                               | *Streptococcus sanguinis* (MIC = 2.50 mg/mL)                    |            |
|                          |                |                               | *Pseudomonas aeruginosa* (MIC = 3.0 mg/mL)                      |            |
| *Endlicheria arenosa*    | Lauraceae      | Microbroth dilution           | *Pseudomonas aeruginosa* (MIC = 1250.0 µg/ml)                   | [28]       |
| (Leaves)                 |                |                               | *Escherichia coli* (MIC = 19.5 µg/mL)                           |            |
| *E. arenosa*             | Lauraceae      | Microbroth dilution           | *Staphylococcus aureus* (MIC = 625.0 µg/mL)                     |            |
| (Twigs)                  |                |                               | *Staphylococcus aureus* (MIC = 625.0 µg/mL)                     |            |
|                          |                |                               | *Salmonella enterica* (MIC = 1.5 mg/mL)                         |            |
| *Fussa longifolia*       | Annonaceae     | Microdilution                 | *Staphylococcus aureus* (MIC = 1250.0 µg/ml)                    | [28]       |
| (Aerial parts)           |                |                               | *Pseudomonas aeruginosa* (MIC = 250.0 µg/mL)                    |            |
| *Guatteria blepharophylla*| Annonaceae     | Microbroth dilution           | *Staphylococcus aureus* (MIC = 0.05 mg/mL)                      | [23]       |
| (Leaves)                 |                |                               | *Enterococcus faecalis* (MIC = 0.05 mg/mL)                      |            |
|                          |                |                               | *Streptococcus sanguinis* (MIC = 0.02 mg/mL)                    |            |
|                          |                |                               | *Pseudomonas aeruginosa* (MIC = 1.5 mg/mL)                      |            |
|                          |                |                               | *Escherichia coli* (MIC = 1.5 mg/mL)                           | [24]       |
| *G. punctata*            | Annonaceae     | Microdilution                 | *Staphylococcus aureus* (MIC = 625.0 µg/mL)                     |            |
| (Aerial parts)           |                |                               | *Streptococcus mutan* (MIC = 4.68 mg/mL)                        | [24]       |
|                          |                |                               | *Streptococcus pyogenes* (MIC = 4.68 mg/mL)                     |            |
| *Lippia origanoides*     | Verbenaceae    | Microbroth dilution           | *Klebsiella pneumoniae* (DDM = 11.6 mm/MIC = >10 µL/mL)         | [17]       |
| (Aerial parts)           |                |                               | *Staphylococcus aureus* (DDM = 26.7 mm/MIC = 1.3 µL/mL)          |            |
| *Myricia splendens*      | Myrtaceae      | Microdilution                 | *Lavibacter michiganensis subsp. nebrukensis* (MIC = 125 µg/mL)  | [46]       |
| (Leaves)                 |                |                               | *Enterococcus faecalis* (MIC = 200 µg/mL)                       |            |
|                          |                |                               | *Listeria grayi* (MIC = 1000 µg/mL)                             |            |
|                          |                |                               | *Staphylococcus aureus* (MIC = 1000 µg/mL)                      |            |
|                          |                |                               | *Staphylococcus epidermidis* (MIC = 1000 µg/mL)                  |            |
Table 3. Cont.

| Species                     | Family     | Method       | Microorganisms (Results)                                                                 | References |
|-----------------------------|------------|--------------|----------------------------------------------------------------------------------------|------------|
| Myrcia splendita (Fresh leaves) | Myrtaceae  | Disk method  | Staphylococcus aureus (MIC = 2.5 µL/mL)                                                  | [10]       |
|                             |            |              | Staphylococcus epidermidis (MIC = 20 µL/mL)                                               |            |
|                             |            |              | Bacillus cereus (MIC = 0.2 µL/mL)                                                        |            |
|                             |            |              | Enterococcus faecalis (MIC = 20 µL/mL)                                                    |            |
| M. sylvatica (Dried Leaves) | Myrtaceae  | Disk method  | Staphylococcus aureus (MIC = 2.5 µL/mL)                                                  | [10]       |
|                             |            |              | Staphylococcus epidermidis (MIC = 20 µL/mL)                                               |            |
|                             |            |              | Bacillus cereus (MIC = 0.2 µL/mL)                                                        |            |
|                             |            |              | Enterococcus faecalis (MIC = 20 µL/mL)                                                    |            |
| Nectandra cuspidata (Leaves) | Lauraceae  | Microbroth dilution | Pseudomonas aeruginosa (MIC = 1250.0 µg/mL)                                               | [47]       |
|                             |            |              | Escherichia coli (MIC = 19.5 µg/mL)                                                      |            |
|                             |            |              | Staphylococcus epidermidis (MIC = 1250.0 µg/mL)                                           |            |
|                             |            |              | Staphylococcus aureus (MIC = 625.0 µg/mL)                                                 |            |
|                             |            |              | Bacillus cereus (MIC = 312.5 µg/mL)                                                      |            |
| N. puberula (Leaves)        | Lauraceae  | Microbroth dilution | Pseudomonas aeruginosa (MIC = 1250.0 µg/mL)                                               | [47]       |
|                             |            |              | Escherichia coli (MIC = 19.5 µg/mL)                                                      |            |
|                             |            |              | Staphylococcus epidermidis (MIC = 1250.0 µg/mL)                                           |            |
|                             |            |              | Staphylococcus aureus (MIC = 625.0 µg/mL)                                                 |            |
|                             |            |              | Bacillus cereus (MIC = 625.0 µg/mL)                                                      |            |
| Ooctea Camiculata (Leaves)  | Lauraceae  | Microbroth dilution | Pseudomonas aeruginosa (MIC = 1250.0 µg/mL)                                               | [50]       |
|                             |            |              | Escherichia coli (MIC = 19.5 µg/mL)                                                      |            |
|                             |            |              | Staphylococcus epidermidis (MIC = 1250.0 µg/mL)                                           |            |
|                             |            |              | Staphylococcus aureus (MIC = 625.0 µg/mL)                                                 |            |
|                             |            |              | Bacillus cereus (MIC = 312.5 µg/mL)                                                      |            |
| O. caudalata (Leaves)       | Lauraceae  | Microbroth dilution | Pseudomonas aeruginosa (MIC = 1250.0 µg/mL)                                               | [50]       |
|                             |            |              | Escherichia coli (MIC = 19.5 µg/mL)                                                      |            |
|                             |            |              | Staphylococcus epidermidis (MIC = 1250.0 µg/mL)                                           |            |
|                             |            |              | Staphylococcus aureus (MIC = 625.0 µg/mL)                                                 |            |
|                             |            |              | Bacillus cereus (MIC = 312.5 µg/mL)                                                      |            |
| O. cujumery (Leaves)        | Lauraceae  | Microbroth dilution | Pseudomonas aeruginosa (MIC = 1250.0 µg/mL)                                               | [50]       |
|                             |            |              | Escherichia coli (MIC = 19.5 µg/mL)                                                      |            |
|                             |            |              | Staphylococcus epidermidis (MIC = 1250.0 µg/mL)                                           |            |
|                             |            |              | Staphylococcus aureus (MIC = 625.0 µg/mL)                                                 |            |
|                             |            |              | Bacillus cereus (MIC = 312.5 µg/mL)                                                      |            |
| Ornychopedetum amazonicum (trunk bark) | Annonaceae | Microbroth dilution | Staphylococcus epidermidis (MIC = 62.5 µg/mL)                                              | [51]       |
|                             |            |              | lacticus rhizophila (MIC = 62.5 µg/mL)                                                     |            |
|                             |            |              | Escherichia coli (MIC = 62.5 µg/mL)                                                       |            |
| Vismia cagerenensis (Leaves) | Hypericaceae | Microplate dilution | Staphylococcus aureus (MIC = 62.5 µg/mL)                                                  | [63]       |
|                             |            |              | Escherichia coli (MIC = 350 µg/mL)                                                        |            |
| V. guianensis (Leaves)      | Hypericaceae | Microplate dilution | Staphylococcus aureus (MIC = >1000 µg/mL)                                                 | [63]       |
|                             |            |              | Escherichia coli (MIC = >1000 µg/mL)                                                      |            |
| Xylopia aromatica (Leaves)  | Annonaceae  | Microdilution | Staphylococcus aureus (MIC = 1.20 mg/mL)                                                  | [63]       |
|                             |            |              | Enterococcus faecalis (MIC = 0.05 mg/mL)                                                  |            |
|                             |            |              | Streptococcus sanguinis (MIC = 0.02 mg/mL)                                                |            |
|                             |            |              | Pseudomonas aeruginosa (MIC = 3.0 mg/mL)                                                  |            |
|                             |            |              | Escherichia coli (MIC = 3.0 mg/mL)                                                       |            |
|                             |            |              | Salmonella enterica (MIC = 1.5 mg/mL)                                                    |            |

MIC, minimum inhibitory concentration; DDM, disk diffusion method.

Terpenes are the main class of compounds in the essential oils of Myrcia (Myrtaceae), and are described in the literature as having inherent antimicrobial properties, as well as synergic action against pathogens in humans. Leomara et al. [10] showed that Myrcia sylvaltica essential oils are strong candidates for use individually or in combination with traditional antibiotic products for the manufacture of pharmaceutical products to control strains of resistant bacteria and prevent food deterioration [10].

The essential oil of the fresh and dried leaves of M. sylvatica is rich in sesquiterpene hydrocarbons and oxygenated sesquiterpenes, exhibiting activity against Bacillus cereus (MIC = 0.2 µL/mL) and Staphylococcus aureus (MIC = 2.5 µL/mL) and bacteriostatic potential against Staphylococcus epidermidis (20.0 µL/mL) and Enterococcus faecalis (20.0 µL/mL) [10]. The essential oil of M. splendens also presented a predominance of sesquiterpene compounds, but did not show antibacterial activity against human pathogens; however, it showed moderate activity against phytopathogenic strains such as Pseudomonas syringae pv. Syringae (MIC = 250 µg/mL) and Clavibacter michiganensis subsp. Nebraskensis (MIC, 125 µg/mL). This activity is related to the major constituent of the oil, trans-nerolidol [46].
Bay et al. [24] assessed the antibacterial activity of the essential oils of four species of Annonaceae against Escherichia coli, Pseudomonas aeruginosa, Streptococcus mutans, Streptococcus pyogenes, and MRSA. The oil of Bocageopsis multiflora was strongly active against the four microorganisms tested. Dugetia quitarensis and Guatteria punctata were active only against Streptococcus mutans and Streptococcus pyogenes. The oil of Fusaea longifolia showed potential against Pseudomonas aeruginosa, Streptococcus mutans, and MRSA [24].

Piperaceae is a typical family from tropical regions such as the Amazon. A few studies have pointed out the antimicrobial properties of some species of this family such as the genus Piper [75,76].

4.2. Antifungal Activity

The use of synthetic fungicides is common on plantations, where this continued use can lead to the development of resistance in fungi, in addition to harming the soil and environment, causing degradation of the medium into which it is discharged [77]. Fungi not only negatively affect plants, but are also harmful to human beings and can cause series of discomfort for their host [78]. For this reason, the bioactivity of essential oils has been increasingly researched, as these oils have promising activity against the action of fungal pathogens, and represent a non-degrading alternative to the environment in the fight against the damage caused by these agents [79]. The antifungal activity of essential oils plausibly results from penetration of chitin in the hyphal wall, triggering a series of damages to the fungal outer wall and destroying it [80].

The essential oils of the aerial parts of Piper divaricatum showed high inhibitory activity against the fungal species Fusarium solani [81]. In another study, the essential oil of P. divaricatum leaves demonstrated significant inhibition of the fungicidal activity of the pathogens Cladosporium cladosporioides and Cladosporium sphareospermum [82]. The antifungal activities of some essential oils from the Amazon are summarized in Table 4.

Table 4. Antifungal activity of essential oils from the Amazon.

| Species                  | Family    | Methods | Microorganisms (Results)                                                                 | References |
|--------------------------|-----------|---------|-----------------------------------------------------------------------------------------|------------|
| Copaifera multijuga      | Fabaceae  | ASD     | Aspergillus flavus (MIC = 0.08 mg/mL—19.5 ± 2.1)                                         | [26]       |
|                          |           |         | Aspergillus niger (MIC = 0.1 mg/mL—9.5 ± 0.7)                                            |            |
|                          |           |         | Aspergillus tamarii (MIC = 0.05 mg/mL—9.0 ± 0.0)                                         |            |
|                          |           |         | Aspergillus tamarii (MIC = 0.3 mg/mL—12.5 ± 3.5)                                         |            |
|                          |           |         | Aspergillus terreus (MIC = 0.3 mg/mL—11.5 ± 2.1)                                        |            |
|                          |           |         | Candida guilliermondii (MIC = 0.1 mg/mL—9.5 ± 1.1)                                      |            |
|                          |           |         | Candida tropicalis (MIC = 0.5 mg/mL—10.0 ± 0.0)                                         |            |
| Ocimum compechianum      | Lamiacea  | PDA     | Growth (%) Fusarium oxysporum                                                             | [48]       |
| (leaves/stems)           |           |         | (IC50 0.25 µL/mL—23.9 ± 3.8)                     (IC50 0.50 µL/mL—47.1 ± 6.2)                    |            |
|                          |           |         | (IC50 0.75 µL/mL—59.4 ± 1.2)                   (IC50 1.00 µL/mL—60.8 ± 3.7)                    |            |
|                          |           |         | (IC50 2.50 µL/mL—70.3 ± 8.7)                   |            |
| Ocimum compechianum      | Lamiacea  | PDA     | Germination (%) Fusarium oxysporum                                                        | [48]       |
| (leaves/stems)           |           |         | (IC50 0.50 µL/mL—22.6 ± 1.6)                   (IC50 0.75 µL/mL—31.5 ± 1.5)                    |            |
|                          |           |         | (IC50 1.00 µL/mL—33.0 ± 1.7)                   (IC50 2.50 µL/mL—58.7 ± 0.0)                    |            |
| Ocimum compechianum      | Lamiacea  | PDA     | Growth (%) Colletotrichum gossypii                                                        | [48]       |
| (leaves/stems)           |           |         | (IC50 0.25 µL/mL—0.0 ± 0.0)                   (IC50 0.50 µL/mL—0.0 ± 0.0)                     |            |
|                          |           |         | (IC50 0.75 µL/mL—31.5 ± 1.5)                   (IC50 1.00 µL/mL—50.7 ± 8.7)                    |            |
|                          |           |         | (IC50 2.50 µL/mL—55.0 ± 3.3)                   (IC50 2.50 µL/mL—100.0 ± 0.0)                   |            |
4.3. Cytoxicity

The search for new phytotherapeutics with anticancer (tumor) potential is extremely important because most anticancer drugs are of natural origin. Natural products have a high level of efficacy in use and application, constituting the main ally in the preparation and development of new treatments for cancer [86,87]. In this industry, the essential oils from botanical species of the Amazon region have shown favorable cytotoxic activity and applications, as reported in prior studies [38,88,89], in which the essential oils of two species of *Eugenia* (*E. cuspidifolia* and *E. tapacumensis*) collected in the forest reserve Adolfo Ducke, Manaus, Amazonas, Brazil, were assessed against five types of cancer cells: human malignant melanoma (SK-MEL-19), human colorectal carcinoma (HCT116), human breast adenocarcinoma (MCF7), human gastric adenocarcinoma (ACP02), and human embryonic lung (MRC-5) as a non-malignant cell line. The inhibitory activity of the essential oil of *E. cuspidifolia* (EO1) was demonstrated by the \( IC_{50} \) values of 18.11 \( \mu \)g/mL (MCF7), 15.25 \( \mu \)g/mL (HCT116), 26.17 \( \mu \)g/mL (SK-MEL-19), >50 \( \mu \)g/mL (ACP02), and 25.51 \( \mu \)g/mL (MRC-5). On the other hand, the essential oil of *E. tapacumensis* (EO2) presented inhibitory potential, with \( IC_{50} \) values of 24.35 \( \mu \)g/mL (MCF7), 12.37 \( \mu \)g/mL (SK-MEL-19), >50 \( \mu \)g/mL (ACP02), and 36.12 \( \mu \)g/mL (MRC-5). Such results show that EO1 and EO2 from the leaves reduced the viability of HCT116 cells, with \( IC_{50} \) values of 15.25 \( \mu \)g/mL and 12.37 \( \mu \)g/mL, respectively.

Essential oils from the leaves of *Eugenia patrisii*, *Eugenia stipitata*, *Myrcia splendens*, *Myrcia sylvatica*, *Psidium guajava*, and *Psidium guineense* (*Pgui-1 and Pgui-2*) were collected from several locations in the cities of Belem/Para/Brazil and Curuçá/Para/Brazil. The activity of the essential oils of these species against five types of cancer cells was analyzed: MCF7 breast cancer, SKMEL-19 melanoma, AGP01 Gastric, HCT116 colon cancer, and MRC5 human fibroblasts. The essential oil of *E. patrisii* exhibited no detectable activity against MCF7 breast type cell, but in the other types of cells, it showed the following inhibition potentials: \( IC_{50} \) = 5.80 \( \mu \)g/mL (SKMEL-19; melanoma), 3.21 \( \mu \)g/mL (AGP01; gastric), 6.70 \( \mu \)g/mL (HCT116; colon), and 3.5 \( \mu \)g/mL (MRC5; human fibroblast). The essential oil of *M. splendens* exhibited no

| Species                  | Family     | Methods         | Microorganisms (Results)                                      | References |
|--------------------------|------------|-----------------|---------------------------------------------------------------|------------|
| Ocotea longifolia       | Lauraceae  | PDA             | *Fusarium oxysporum* f. *sp. dianthi*—Inhibition: 31.2 ± 0.45% | [83]       |
| *O. macrophylla* (leaves)| Lauraceae  | PDA             | *Botrytis cinerea*—Inhibition: 32.8 ± 0.21%                   | [83]       |
| *Piper aduncum* (aerial parts) | Piperaceae | TLC plates      | *Cladosporium cladosporioides* (DL = 100 \( \mu \)g)           | [82]       |
| *P. aleymeanum* (aerial parts) | Piperaceae | TLC plates      | *Cladosporium cladosporioides* (DL = 0.1)                      | [12]       |
| *P. divaricatum* (aerial parts) | Piperaceae | MIC             | (MIC = 0.50 mg/mL = 38.93 ± 4.77)                             | [81]       |
| *P. divaricatum* (leaves) | Piperaceae | TLC plates      | *C. cladosporioides* (MIC = 0.5 \( \mu \)g)                   | [82]       |
| *P. hispidum* (aerial parts) | Piperaceae | TLC plates      | *C. cladosporium* cladosporioides (DL = 1.0)                  | [12]       |
| *P. krukoffii* (twig)   | Piperaceae | TLC plates      | *C. cladosporium* sphaerospermum (DL = 0.1)                   | [84]       |
| *P. krukoffii* (leaves) | Piperaceae | TLC plates      | *C. cladosporium* sphaerospermum (DL = 0.5 \( \mu \)g)        | [84]       |
| *P. marginatum* (aerial parts) | Piperaceae | MIC             | (MIC = 1.00 mg/mL = 77.10 ± 10.49)                            | [85]       |
| *P. hispidum* (aerial parts) | Piperaceae | TLC plates      | *C. cladosporium* sphaerospermum (DL = 0.1)                   | [12]       |
| *P. divaricatum* (leaves) | Piperaceae | TLC plates      | *C. cladosporium* sphaerospermum (DL = 25 \( \mu \)g/mL)      | [85]       |

\( IC_{50} \), minimum inhibitory concentration; DDM, disk diffusion method.
cytotoxic activity against the MCF7 breast type cell, but showed an inhibition potential of 8.50 µg/mL against (SKMEL-19; melanoma), with IC_{50} values of 4.70 µg/mL (AGP01; gastric), 8.80 µg/mL (HCT116; colon), and 6.5 µg/mL (MRC5; human fibroblast). The essential oil of M. sylvatica exhibited no detectable activity against (HCT116; colon) type cells; however, the essential oil of such species presented inhibition of >25 µg/mL (MCF7; breast), 20.01 µg/mL (SKMEL-19; melanoma), 17.31 µg/mL (AGP01; gastric), and 23.3 µg/mL (MRC5; human fibroblast). The essential oil of Psidium guajava, as well as the essential oil of two specimens of P. guineense (Pgui-1 and Pgui-2), did not show cytotoxic activity against cancer cells (HCT116; colon). However, the essential oil of P. guajava presented the following inhibition potentials: 12.41 µg/mL (MCF7; breast), 15.31 µg/mL (SKMEL-19; melanoma), 16.31 µg/mL (AGP01; gastric), and 20.8 µg/mL (MRC5; human fibroblast). The specimen (Pgui-1) of P. guineense presented inhibition potentials of 11.60 µg/mL (MCF7; breast), 11.10 µg/mL (SKMEL-19; melanoma), 8.21 µg/mL (AGP01; gastric), and 8.27 µg/mL (MRC5; human fibroblast). The Pgui-2 specimen presented inhibition potentials of: 18.21 µg/mL (MCF7; breast), 19.11 µg/mL (SKMEL-19; melanoma), 15.71 µg/mL (AGP01; gastric), and 24 µg/mL (MRC5; human fibroblast). The greatest cytotoxic activity was observed for the essential oil of E. patrisii (SKMEL-19; melanoma), (AGP01; gastric), and (HCT116; colon), whereas the essential oils of P. guajava and P. guineense, were more active against breast cancer cells (MCF7, IC_{50} 12.4 µg/mL and 11.6 µg/mL, respectively) [32].

The essential oil of four species of Eugenia (E. egensis, E. flavescens, E. polystachya, and E. patrisii) collected in Marabá-PA were tested against three types of cancer cells: HCT-116 (colon), SKMEL19 (melanoma), and AGP01 (gastric). The essential oil of E. egensis did not present a cytotoxic profile against the three types of cells, with IC_{50} > 25 µg/mL. At the same concentration where IC_{50} > 25 µg/mL, the essential oil of E. flavescens, E. polystachya, and E. patrisii did not present cytotoxic activity against the two cancer cells: SKMEL19 (melanoma) and AGP01 (gastric). On the other hand, the essential oils of E. flavescens, E. patrisii, and E. polystachya showed cytotoxic activity, with IC_{50} values of 13.9 µg/mL, 16.4 µg/mL, and 10.3 µg/mL, respectively, against HCT-116 (colon). According to the authors, this cytotoxic potential may be related to the presence of the main compound, germacrene D [30].

The essential oil of Myrcia splendens from the equatorial Amazon was assessed against A549 (human lung cancer), MCF-7 (human breast adenocarcinoma), and HaCaT (human keratinocytes) cells. All the results showed inhibition of cancer cell growth depending on the dose of α-bisabolol, which was the most active component. At a concentration of 10 µg/mL, α-bisabolol reduced the viability of A549 (human lung cancer), MCF-7 (human breast adenocarcinoma), and HaCaT (human keratinocytes) cells by 70, 10, and 50%, respectively, compared to the negative control. The growth of MCF-7 type cells was more strongly inhibited than that of the HaCaT cells 48 h after treatment with α-bisabolol (IC_{50} = 1.24 ± 0.03 µg/mL vs. 10.15 ± 0.35 µg/mL) and essential oil (IC_{50} = 5.59 ± 0.13 µg/mL vs. 21.58 ± 1.26 µg/mL). However, the HaCaT cells were more sensitive than the A549 cell line, with IC_{50} values varying from 10.15 ± 0.35 to 27.76 ± 2.76 µg/mL for the former, compared with values of 54.28 ± 2.39 to 100.99 ± 2.32 µg/mL for the latter. Therefore, the assessment of the cytotoxic activity showed promising results regarding the selectivity and efficacy of the essential oil of M. splendens against the cell line MCF-7 compared to that against A549 cells [46].

The essential oils from the leaves of five specimens of Eugenia uniflora were collected in Belém and Santarém, Pará, Brazil, and tested against HCT-116 (colon), AGP01 (malignant gastric ascites), SKMEL-19 (melanoma), and MRC-5 (human fibroblast). The essential oil of specimen E1 did not exhibit cytotoxic activity against the four types of cells, whereas samples E3 and E5 presented equal inhibition percentages (IC_{50} > 25 µg/mL) against the four cell types. In contrast, the essential oils of the specimens E2 and E4 showed cytotoxic activity against all the HCT-116 cell lines tested (IC_{50} E2: 16.26 µg/mL; E4: 9.28 µg/mL), AGP01, (IC_{50} E2:12.60 µg/mL; E4:8.73 µg / mL), SKMEL-19 (IC_{50} E2: 12.20 µg/mL; E4: 15.42 µg/mL), and MRC-5 (IC_{50} E2: 10.27 µg/mL; E4: 14.95 µg/mL) [90].
The cytotoxic potential of essential oils from the Piperaceae family, especially the genus piper [91], has been documented [12], in which three species of Piper (P. hispidum, P. aleyreanum, and P. anonifolium) collected in the national forest of Carajás, Pará state, Brazil were tested against three cancer cell lines: HCT-116 (colon), SKMEL19 (melanoma), and ACP-03 (gastric). The essential oils of these three species had low inhibitory effects on the growth of the HCT-116 (colon) and ACP-03 (gastric) cell lines (IC$_{50}$ > 25 µg/mL). The oils also had IC$_{50}$ > 25 µg/mL for the cell line SKMEL19 (melanoma), except for the essential oil of P. aleyreanum, which presented high in vitro cytotoxic activity (IC$_{50}$ = 7.4 µg/mL).

The essential oils of the family Lauraceae exhibit cytotoxic activity against some types of cell lines, as shown in a previous study [47], where the essential oils were taken from the leaves and branches of Nectandra puberula and only the leaves of N. Cuspidata. During this research, the cytotoxic activity of the essential oils from the leaf of N. puberula and N. cuspidata against MCF-7 breast tumor cells was evaluated, where the IC$_{50}$ was 64.5 ± 1.6 and 117.1 ± 11.9 µg/mL, respectively.

The Annonaceae family is characterized by a pantropical family of trees, bushes, and climbers, and is found especially in tropical lowlands [92]. This family is characterized by species rich in essential oils with potential in vitro inhibitory activity against cancer cells [36,92]. This biological activity was observed for the essential oil from the leaves of Anaxagorea brevipes collected in Manaus, Amazonas, Brazil. The essential oil showed cytotoxic activity against the MCF-7 (breast, TGI = 12.8 µg/mL), NCI-H460 (lung, TGI = 13.0 µg/mL), and PC-3 (prostate, TGI = 9.6 µg/mL) cell lines [15]. Other botanical families have been studied to prove their efficacy against cancer cells, such as the Myristicaceae family, which is recognized as a species that produces essential oils. The species Iryanthera polyneura (Myristicaceae) is commonly known as cumala-colorada, and can be found in the Amazon forest [93]. Studies on this species have shown cytotoxic activity [39] for the essential oil from the leaves of three specimens of Iryanthera polyneura collected in Amazonas, Brazil, which were tested against human breast (MCF-7) and prostate (PC-3) cells. In that study, thirty-six of the forty essential oils were more active against PC-3 than against MCF-7 cells, where the samples of the set 22EO, 80EO, and 53EO were particularly active, with inhibition values of IC$_{50}$ = 14.69 ± 4.33, 13.63 ± 3.23, and 12.48 ± 4.03 µg/mL, respectively. The essential oils of the leaves and bark of Virola surinamensis, native to the Amazon, Brazil, were tested against HCT116 (human colon carcinoma), MCF-7 (human breast adenocarcinoma), HL-60 (human promyelocytic leukemia), HepG2 (human hepatocellular carcinoma), B16–F10 (mouse melanoma), and MRC-5 (human pulmonary fibroblasts). The essential oil of the sample barks presented an inhibition percentage of IC$_{50}$ = 9.41 µg/mL against the respective cells. The cytotoxic activities of some essential oils from the Amazon are shown in Table 5.

| Species                  | Botanic Family | Methods            | Results                                                                 | References |
|-------------------------|----------------|--------------------|-------------------------------------------------------------------------|------------|
| Anaxagorea brevipes     | Anonaceae      | SRB assay          | MCF-7 = TGI 12.8 µg/mL                                                  | [15]       |
|                         |                |                    | NCI-H460 = (TGI 13.0 µg/mL)                                             |            |
|                         |                |                    | PC-3 = TGI 9.6 µg/mL                                                    |            |
|                         |                |                    | (MCF7) = IC$_{50}$ 18.11 µg mL$^{-1}$                                   |            |
|                         |                |                    | (HCT116) = IC$_{50}$ 15. 25 µg mL$^{-1}$                                 | [29]       |
|                         |                |                    | (SK-MEL-19) = IC$_{50}$ 26.17 µg mL$^{-1}$                              |            |
|                         |                |                    | (ACP02) = IC$_{50}$ > 50 µg mL$^{-1}$                                   |            |
|                         |                |                    | (MRC-5) = IC$_{50}$ 25.51 µg mL$^{-1}$                                  |            |

Table 5. Cytotoxic activity of essential oils from species found in the Amazon.
Table 5. Cont.

| Species             | Botanic Family | Methodos          | Results                                                                 | References |
|---------------------|----------------|-------------------|--------------------------------------------------------------------------|------------|
| E. egensis          | Myrtaceae      |                   | HCT-116 = IC<sub>50</sub> > 25 µg/mL                                    | [30]       |
|                     |                | SKMEL19 = IC<sub>50</sub> > 25 µg/mL                                 |             |
|                     |                | AGP-01 = IC<sub>50</sub> > 25 µg/mL                                  |             |
| E. flavescens       | Myrtaceae      |                   | SKMEL19 = ****                                                          | [30]       |
|                     |                | AGP-01 = ****                                                     |             |
|                     | Myrtaceae      | MTT colorimetric   | HCT-116 = IC<sub>50</sub> 13.9 µg/mL                                    | [30]       |
| E. patrisii         | Myrtaceae      |                   | SKMEL19 = ****                                                          | [30]       |
|                     | Myrtaceae      |                   | AGP-01 = ****                                                            | [30]       |
| E. polystachya      | Myrtaceae      |                   | HCT-116 = IC<sub>50</sub> 10.3 µg/mL                                    | [30]       |
| E. stipitata        | Myrtaceae      | MTT colorimetric   | HCT-116 = IC<sub>50</sub> 16.4 µg/mL                                    | [30]       |
| E. tapacumensis     | Myrtaceae      | Alamar blue assay    | (MCF) = IC<sub>50</sub> 24.35 µg mL<sup>-1</sup>                         | [29]       |
|                     |                |                   | (HCT116) = IC<sub>50</sub> 12.37 µg mL<sup>-1</sup>                    |             |
|                     |                |                   | (SK-MEL-19) = IC<sub>50</sub> 50 µg mL<sup>-1</sup>                     |             |
|                     |                |                   | (ACP02) IC<sub>50</sub> > 50 µg mL<sup>-1</sup>                         |             |
|                     |                |                   | (MRC-5) = IC<sub>50</sub> 36.12 µg mL<sup>-1</sup>                     |             |
| E. uniflora         | Myrtaceae      | MTT colorimetric   | HCT-116 (IC<sub>50</sub> E2: 16.26 µg/mL; IC<sub>50</sub> E4: 9.28 µg/mL) | [80]       |
|                     |                |                   | AGP-01, (IC<sub>50</sub> E2: 12.60 µg/mL; IC<sub>50</sub> E4: 8.73 µg/mL) |             |
|                     |                |                   | SKMEL-19 (IC<sub>50</sub> E2: 12.20 µg/mL; IC<sub>50</sub> E4: 15.42 µg/mL) |             |
|                     |                |                   | MRC-5 (IC<sub>50</sub> E2: 10.27 µg/mL; IC<sub>50</sub> E4: 14.95 µg/mL) |             |
| Iryanthera polyneura| Myristicaceae   | SRB assay          | PC-3 = IC<sub>50</sub> 14.69 ± 4.33 µg/mL                               | [39]       |
|                     |                |                   | MCF-7 = IC<sub>50</sub> 13.63 ± 3.23 µg/mL                             |             |
|                     |                |                   | SKMEL-19 = IC<sub>50</sub> 8.50 µg/mL                                  | [32]       |
|                     |                |                   | AGP-01 = IC<sub>50</sub> 4.70 µg/mL                                    |             |
|                     |                |                   | HCT116 = IC<sub>50</sub> 8.80 µg/mL                                    |             |
|                     |                |                   | MRC5 = IC<sub>50</sub> 6.5 µg/mL                                      |             |
| Myrcia splendens    | Myrtaceae      |                   | A549 = IC<sub>50</sub> 54.28 ± 2.39 µg/mL                              | [46]       |
|                     |                |                   | MCF-7 = IC<sub>50</sub> 12.4 ± 0.03 µg/mL                              |             |
|                     |                |                   | SKMEL-19 = IC<sub>50</sub> 8.50 µg/mL                                  | [32]       |
|                     |                |                   | AGP-01 = IC<sub>50</sub> 4.70 µg/mL                                    |             |
|                     |                |                   | HCT116 = IC<sub>50</sub> 8.80 µg/mL                                    |             |
|                     |                |                   | MRC5 = IC<sub>50</sub> 6.5 µg/mL                                      |             |
| Myrtaceae           | Myrtaceae      |                   | MCF-7 = IC<sub>50</sub> 12.4 ± 0.03 µg/mL                              | [46]       |
| M. splendens        | Myrtaceae      | MTT colorimetric   | HCT-116 = IC<sub>50</sub> 25 µg/mL                                    | [30]       |
|                     |                |                   | SKMEL-19 = IC<sub>50</sub> 20.01 µg/mL                                  |             |
|                     |                |                   | AGP-01 = IC<sub>50</sub> 17.31 µg/mL                                    |             |
|                     |                |                   | HCT116 = ****                                                            |             |
|                     |                |                   | MRC5 = IC<sub>50</sub> 23.3 µg/mL                                      |             |
| Nectandra cuspidata | Lauraceae       |                   | MCF-7 = IC<sub>50</sub> 117.1 ± 11.9 µg mL<sup>-1</sup>                | [47]       |
| N. puberula         |                |                   | MCF-7 = IC<sub>50</sub> 64.5 ± 1.6 µg mL<sup>-1</sup>                  |             |
Table 5. Cont.

| Species                  | Botanic Family | Methodos       | Results                                             | References |
|--------------------------|----------------|----------------|-----------------------------------------------------|------------|
| *Piper anonifolium*      | *Piperaceae*   | HCT-116 = IC₅₀ > 25 µg/mL | ACP-03 = IC₅₀ > 25 µg/mL | SKMEL19 = IC₅₀ > 25 µg/mL | [12] |
| *P. aleppenum*           | *Piperaceae*   | HCT-116 = IC₅₀ > 25 µg/mL | ACP-03 = IC₅₀ > 25 µg/mL | SKMEL19 = IC₅₀ = 7.4 µg/mL |          |
| *P. hydropium*           |                | HCT-116 = IC₅₀ > 25 µg/mL | ACP-03 = IC₅₀ > 25 µg/mL | SKMEL19 = IC₅₀ > 25 µg/mL |          |
| *Psidium guajava*        | *Myrtaceae*    | MCF7 = IC₅₀ 12.41 µg/mL | SKMEL19 = IC₅₀ 15.31 µg/mL | AGP01 = IC₅₀ 16.31 µg/mL | HCT116 = **** |
| *P. guineense* (Pgui-1) | *Myrtaceae*    | MCF7 = IC₅₀ 11.60 µg/mL | SKMEL19 = IC₅₀ 11.10 µg/mL | AGP01 = IC₅₀ 8.21 µg/mL | HCT116 = **** |
| *P. guineense* (Pgui-2) |                | MCF7 = IC₅₀ 11.00 µg/mL | SKMEL19 = IC₅₀ 19.11 µg/mL | AGP01 = IC₅₀ 15.71 µg/mL | HCT116 = **** |
| *Virola surinamensis*    | *Myristicaceae*| SRB assay      | Bark EO                                             | Leaves EO  | [62] |

**Table 5.** Cont...

MTT(3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide), **** = statistically similar at 95% confidence level by Tukey’s test.

### 4.4. Antiprotozal Activity

Diseases resulting from protozal infection have caused serious problems and have detrimental impacts on human health. Such diseases include leishmaniasis, which is considered one of the most neglected diseases resulting from the parasitic action of protozoans of the genus *Leishmania* [94]. Within this scope of parasitic diseases, *Trypanosoma cruzi* is predominant in the Americas [95].

The treatment of these diseases is based on highly toxic drugs with little efficacy [96], which cause serious side effects in the body [96]. However, some plants are considered potentially rich and promising for the development of drugs that act against leishmaniosis and Chagas disease [94,96]. In this context, it is important to emphasize that essential oils are substances extracted from aromatic plants and have biological potential against parasites [97]. The biological activity of natural products is related to the active chemical compounds in their composition [98].

Within the Amazon region, studies on the action of essential oils against protozoans are still lacking. However, studies have shown that the essential oils from plants of the Amazon have components that are active against leishmaniosis, as described in a study conducted with the essential oil of *Bocageopsis multiflora*, which presented significant activity (IC₅₀: 14.6 µg/mL) against promastigotes of *Leishmania amazonensis* [25]. The anti-Leishmania...
potential of the essential oil of *Syzygium cumini* and its major constituent, α-pinene, was tested, where α-pinene presented an inhibitory concentration of $IC_{50} = 19.7 \text{ mg/mL}$ against the promastigotes of *L. amazonenses*, and $IC_{50}$ value of 16.1 mg/mL and 15. mg/mL against axenic and intracellular amastigotes. On the other hand, the essential oil from *S. cumini* presented inhibitory concentrations of $IC_{50} = 43.9 \text{ mg/mL}$ and $IC_{50} = 38.1 \text{ mg/mL}$ against axenic and intracellular amastigotes. According to the authors, α-pinene was the most active substance [60].

The activity of essential oils from two species of Annonaceae, *Guatteria friesiana* (EOGF) and *G. pogonopus* (EOGP), against the protozoa causing malaria (*Plasmodium falciparum*) and Chagas disease (*Trypanosoma cruzi*) was tested. EOGF presented an inhibition potential of $IC_{50} = 0.53 \mu g/mL$ against *P. falciparum* and $IC_{50} = 10.7 \mu g/mL$ against *T. cruzi*. EOGP presented respective $IC_{50}$ values of 6.8 and 41.3 μg/mL against *P. falciparum* and *T. cruzi*. According to the authors, EOGF and EOGP presented potent antimalarial and trypanocidal activity [35]. The trypanocidal activity was assessed for essential oils of the leaves and rhizomes of a species of Zingiberaceae (*Renealmia chrysotricha*). At a concentration of 25 μg/mL, the essential oil of the rhizome of *R. chrysotricha* reduced the number of parasites by 50 and 61% after 24 and 48 h, respectively. Treatment with 100 μg/mL reduced the population of parasites by 56% after 24 h, with all parasites eliminated within 48 h. The essential oil of the leaves of *R. chrysotricha* reduced the population of parasites by 28–59% at concentrations of 25, 100, 400, and 800 μg/mL after 24 h, and by 2–53% at concentrations of 25, 100, and 400 μg/mL, with total death of the parasites at 800 μg/mL after 48 h [59].

The essential oil from the leaves and thin branches of three samples of *Aniba rosaeodora* (Lauraceae) and its major constituent linalool were tested against intracellular epimastigote and amastigote forms of *T. cruzi*. In the treatment with the essential oil of *A. rosaeodora*, the inhibitory concentration for the epimastigote forms was $IC_{50} = 150.5 \pm 1.08 \mu g/mL$, and $IC_{50} = 198.6 \pm 1.12 \mu g/mL$ for linalool. The essential oil and linalool presented respective inhibitory concentrations of $IC_{50} = 911.6 \pm 1.15$ and 249.6 ± 1.18 μg/mL for the intracellular amastigote forms. At higher concentrations, the essential oil and linalool both exhibited antitrypanosomal activity against the intracellular amastigote forms [19].

The activity of the essential oil from the leaves of *Ocimum canum* (Lamiaceae) against the intracellular promastigote and amastigote forms of *Leishmania amazonenses* was assessed. In this study, the essential oil presented respective inhibitory concentrations of $IC_{50} = 17.4 \mu g/mL$ and 13.1 μg/mL for the intracellular promastigote and amastigote forms [49]. In another study, the activity of the essential oils of two species of Piperaceae (*Piper duckei* and *P. demeraranum*) and their major compounds (limonene and E-caryophyllene) against strains of *L. amazonenses* and *L. guyanensis* was assessed. Both essential oils reduced the growth of the promastigote forms of two species of leishmania, where the essential oils of *P. duckei* and *P. demeraranum* presented respective inhibitory concentrations of $IC_{50} = 15.2 \mu g/mL$ and $IC_{50} = 22.7 \mu g/mL$ for the promastigote forms of *L. guyanensis*, whereas for the amastigote forms of *L. amazonenses*, the inhibitory concentrations were $IC_{50} = 46.0 \mu g/mL$ and $IC_{50} = 86.0 \mu g/mL$, respectively. For the amastigote forms of *L. guyanensis*, the essential oils presented inhibitory concentrations of $IC_{50} = 42.4 \mu g/mL$ for *P. duckei* and $IC_{50} = 78 \mu g/mL$ for *P. demeraranum*. The major compounds limonene and E-caryophyllene respectively exhibited inhibitory concentrations of $IC_{50} = 278 \mu M$ (limonene) and $IC_{50} = 96 \mu M$ (E-caryophyllene) against the promastigote forms of *L. amazonenses*. Thus, the major compounds presented lower inhibition percentages ($IC_{50}$) than the essential oils of *Piper* [58].

### 4.5. Larvicidal Activity and Toxicity

Toxicity studies of essential oils aim to discover new natural insecticidal and larvicidal agents that can fight against several vectors of public health concern [99]. It is important to highlight that these studies have increased steadily due to the strong resistance of microbes to synthetic insecticides that can cause serious problems to the environment, with risk of contamination of the air, soil, and water [65,100]. These problems have expanded the
search for and development of natural pesticides, especially aromatic plants in the Amazon region, as described in a study performed with the essential oil of the aerial parts of the species Mesophaerum suaveolens collected in three different periods (intermediate rainy, and dry). The activity of the essential oils against *Aedes aegypti* and *Artemia salina* Leach was tested, demonstrating that the essential oil extracted in the dry season showed greater activity \((LC_{50})\) against the larvae of *A. aegypti* (90.9 \(\mu\)g/mL), followed by that obtained in the rainy period (108.0 \(\mu\)g/mL), whereas low activity was observed for the oil acquired in the intermediary period (135.2 \(\mu\)g/mL). In relation to the *Artemia salina* Leach, the essential oil presented moderate toxicity \((LC_{50})\) 167.1 \(\mu\)g/mL (intermediary period), 202.6 \(\mu\)g/mL (rainy period), and 215.7 \(\mu\)g/mL (dry period) [45].

Some studies with essential oils of the family Piperaceae native to the Amazon region have demonstrated promising larvicidal activity and toxicity of the essential oil of *Piper capitatum* in the inflorescence vegetative period, which presented larvicidal potential against *Aedes aegypti* and *Aedes albopictus* \((LC_{50}) = 87.6 \mu\)g/mL and 76.1 \(\mu\)g/mL. Likewise, the essential oil obtained from the inflorescence was more active against *Artemia salina* Leach, with an \(LC_{50}\) of 465.30 \(\mu\)g/mL [57]. In another study, the activity of the essential oils of five species of *Piper* (*P. aduncum*, *P. gaudichaudianum*, *P. malacophyllum*, *P. marginatum*, and *P. tuberculatum*) against one type of rice blight (*Tribacta limbativentris*) was tested. The essential oils significantly reduced the hatching of *T. limbativentris* eggs, with \(LC_{50}\) = 2.49 \(\mu\)g/mL (\(P. aduncum\)), 4.243 \(\mu\)g/mL (\(P. gaudichaudianum\)), 6.073 \(\mu\)g/mL (\(P. malacophyllum\)), 1.968 \(\mu\)g/mL (\(P. marginatum\)), and 3.388 \(\mu\)g/mL (\(P. tuberculatum\)). The results demonstrate that essential oils are promising for use as botanical insecticides [101]. The essential oil of *Piper aduncum* presented insecticidal potential against one type of soybean pest, *Chrysodeixis includens* Walker, with \(LC_{50}\) = 3.5 \(\mu\)g/mL. According to the authors, further studies are necessary to confirm the use of this essential oil, rather than synthetic chemical products, to control this pest [55].

The insecticidal activity of the essential oils of *Piper* (\(P. aduncum\), \(P. marginatum\) (chomotypes A and B), \(P. divaricatum\), and \(P. callosum\)) against the termite *Solenopsis saevissima* was assessed. The activity values were \(LC_{50}\) = 114.4 \(\mu\)g/mL (\(P. aduncum\)), \(LC_{50}\) = 207.8 \(\mu\)g/mL (\(P. marginatum\) A), \(LC_{50}\) = 419.3 \(\mu\)g/mL (\(P. marginatum\) B), \(LC_{50}\) = 552.2 \(\mu\)g/mL (\(P. divaricatum\)), and \(LC_{50}\) = 571.1 \(\mu\)g/mL (\(P. callosum\)). The authors suggested new investigations of these essential oils for use in sustainable pest control in the Amazon region [53].

The larvicidal potential of essential oils from the leaves of three specimens of *Virola* (*V. calophylla*, *V. multinervia*, and *V. pavonis*) was tested to verify their activity against *A. aegypti*. The essential oil of *V. calophylla* presented \(LC_{50}\) = 179.6 \(\mu\)g/mL, followed by that of *V. pavonis* \(LC_{50}\) = 185.1 \(\mu\)g/mL and *V. multinervia* \(LC_{50}\) = 200.5 \(\mu\)g/mL. According to the authors, the essential oil of *Virola* had low larvicidal potential [61]. In contrast, the essential oil of *Bauhinia unguulata* (Fabaceae) presented high toxicity against *Artemia salina* Leach, with \(LC_{50}\) = 144.75 \(\mu\)g mL\(^{-1}\) [21].

Dias et al. [33] assessed the insecticidal potential of essential oils of *Eugenia piauiensis*, *Myrcia erythroxylon*, *Psidium myrsinoides*, *Siparuna camorum*, and *Lippia gracilis* against larvae of *A. aegypti* [33]. The essential oil of *M. erythroxylon* was inactive against *A. aegypti* larvae, with \(LC_{50}\) > 1000 mg/L, whereas the other essential oils were considered effective, with \(LC_{50}\) = 230, 251, 282, and 292 mg/L, respectively, for *E. piauiensis*, *S. camorum*, *L. gracilis*, and *P. myrsinoides*. The essential oil of the leaves and branches of *Aniba duckei* showed larvicidal activity against *A. aegypti*, with \(LC_{50}\) = 250.6 \(\mu\)g mL\(^{-1}\) [16]. Likewise, the essential oil of *Lippia origanoides* presented larvicidal potential against *Cerataphis lataniae* within 24 h of exposure, with \(LD_{50}\) = 6.6 \(\mu\)g/mL and \(LD_{90}\) = 41.9 \(\mu\)g/mL, and \(LD_{50}\) = 2.7 \(\mu\)g/mL and \(LD_{90}\) = 19.8 \(\mu\)g/mL within 48 h of exposure [41].

5. Conclusions

The Amazon flora has a wide range of aromatic plants with potential application in the international and national markets due to their fragrances and aromas and for their use in the traditional medicine for the treatment of several diseases. The essential oils and their compounds are directly related to the bioactive compounds found in the
essential oils of the Amazon biome. The chemical profile of the essential oils extracted from
amazon species is characterized specially by the terpenes, monoterpenes, sesquiterpenes,
and phenylpropanoids. Therefore, the essential oils listed in the present study show a great
potential for the development of natural pesticides, antioxidant products, and drugs with
antimicrobial and cytotoxic effect.

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