

Review

Chemical Variability and Biological Activities of *Eucalyptus* spp. Essential Oils

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Abstract: Many plant species produce mixtures of odorous and volatile compounds known as essential oils (EOs). These mixtures play important roles in Nature and have been utilized by mankind for different purposes, such as pharmaceuticals, agrochemicals, aromatherapy, and food flavorants. There are more than 3000 EOs reported in the literature, with approximately 300 in commercial use, including the EOs from *Eucalyptus* species. Most EOs from *Eucalyptus* species are rich in monoterpenes and many have found applications in pharmaceuticals, agrochemicals, food flavorants, and perfumes. Such applications are related to their diverse biological and organoleptic properties. In this study, we review the latest information concerning the chemical composition and biological activities of EOs from different species of *Eucalyptus*. Among the 900 species and subspecies of the *Eucalyptus* genus, we examined 68 species. The studies associated with these species were conducted in 27 countries. We have focused on the antimicrobial, acaricidal, insecticidal and herbicidal activities, hoping that such information will contribute to the development of research in this field. It is also intended that the information described in this study can be useful in the rationalization of the use of *Eucalyptus* EOs as components for pharmaceutical and agrochemical applications as well as food preservatives and flavorants.

Keywords: essential oils; monoterpenes; insecticidal activity; antimicrobial activity; acaricidal activity; herbicidal activity; *Eucalyptus*; 1,8-cineole

1. Introduction

Nature is a precious reservoir of substances that can be explored for developing new pharmaceuticals. Several drugs for treating a variety of diseases have been discovered via screening of natural compounds obtained from animals, microorganisms, marine organisms, and plants. These drugs can be natural products *per se* or semi-synthetic analogs derived from an active natural product. Furthermore, they can be entirely synthetic compounds designed using natural products as models [1–6].

Natural products have also been directly utilized as pest control agents. Moreover, they have served as models for the development of new pesticides with potential commercial applications [7–13].

Although there are a large number of plant species, only approximately 10% produce mixtures of odorous and volatile compounds, collectively called essential or volatile oils [14]. Such essential oils (EOs) can be produced from all parts of plants (buds, gums, blossoms, flowers, leaves, stems, twigs, seeds, fruits, roots, wood or bark), depending upon the producing species. EOs are stored in

several secretory structures such as epidermic cells, secretory hairs, secretory ducts, secretory cavities, glandular trichomes, or resin adducts [15–19]. EOs are generally hydrophobic liquids and soluble in alcohol, nonpolar or weakly polar solvents, waxes, and oils. They are slightly soluble in water and are usually colorless or pale yellow [15,17,20]. From a chemical standpoint, they are typically composed of hydrocarbons and oxygenated monoterpenes, sesquiterpenes and diterpenes, aromatic compounds (C6-C3 and C6-C1 compounds), and low molecular weight aliphatic compounds.

Some EOs play an important role in protecting plants against insect attack, fungi, bacteria and viruses and can also be important as a deterrent to herbivorous feeding [15,21–24]. EOs are also known to be involved in allelopathic interactions inhibiting seed germination and plant growth [25–28]. These properties have been investigated for the development of herbicides [29–31]. Within this context and considering the favorable biodegradability of essential oil components, they can be considered attractive alternative tools for controlling the growth of weeds [32]. EOs from a variety of plants are also endowed with antibacterial activities [33–36] as well as anti-inflammatory and antioxidant properties [37].

There are more than 3000 EOs described in the existing literature, with approximately 300 in commercial use, including those from various *Eucalyptus* species [15,17,38,39]. The *Eucalyptus* genus is represented by 900 species and subspecies. Based on morphological and molecular characteristics, *Eucalyptus* was reclassified in 1995 by Hill and Johnson [40]. According to these authors, the *Corymbia*, previously classified as a subgenus of *Eucalyptus*, has been elevated to the rank of a separate genus with 113 known *Corymbia* species. Among them, *Corymbia citriodora*, *C. maculata*, *C. ficifolia*, *C. ptychocarpa* and *C. torelliana* are the best-known. Despite this reclassification, the names originally found in the references were used for the preparation of this review to facilitate the discussion.

The *Eucalyptus* corresponds to one of the principal genera of the Myrtaceae family, native to Australia and cultivated worldwide [17,41–44]. *Eucalyptus* trees have perennial leaves that are odorous because of the presence of EOs that are produced and stored in secretory cells. These EOs are aromatic, spicy, and colorless or pale yellow, although there are studies that have reported the color as being brownish or greenish [44].

EOs obtained from *Eucalyptus* are usually rich in monoterpenes and in some cases sesquiterpenes. Many such EOs are used for pharmaceutical purposes and in perfumery [45]. The eucalyptus EOs utilized as pharmaceuticals are rich in 1,8-cineole, whereas those used in perfumery are rich in citronellal, citral and geranyl acetate [46].

Considering the versatility of *Eucalyptus* EOs in terms of bioactivities as well as their industrial importance, the purpose of this study is to provide the readers with the latest information concerning the chemical composition and biological activities of EOs from different species of *Eucalyptus*. Two reviews about *Eucalyptus* EOs and biological activities have been recently published. One of them by Vuong et al. [47] that focused on anticancer properties of *Eucalyptus* EOs; the other by Zhang et al. [48] that described advances up to 2010 in terms of several biological activities. In this paper, from the 900 species and subspecies of the *Eucalyptus* genus, we have examined 68 species (three of them are hybrids). The studies associated with these species were conducted in 27 countries and the literature survey covers recent developments in the field. The review focused on the antimicrobial, acaricidal, insecticidal and herbicidal properties of *Eucalyptus* species. The information described can be useful in the rationalization of the use of *Eucalyptus* EOs as source of constituents for pharmaceutical and agrochemical applications as well as food preservatives.

2. Chemical Variability of *Eucalyptus* EOs

Although the EOs are found in the leaves of more than 300 species of *Eucalyptus*, fewer than 20 species have been commercially explored for EO production [46,49]. In terms of the chemical composition of these EOs, they are complex mixtures of substances, generally containing 20 to 80 compounds, differing in their concentrations. Terpenes and terpenoids are the major components found in EOs obtained from the leaves of *Eucalyptus* [38,50–55] as illustrated in Figure 1.

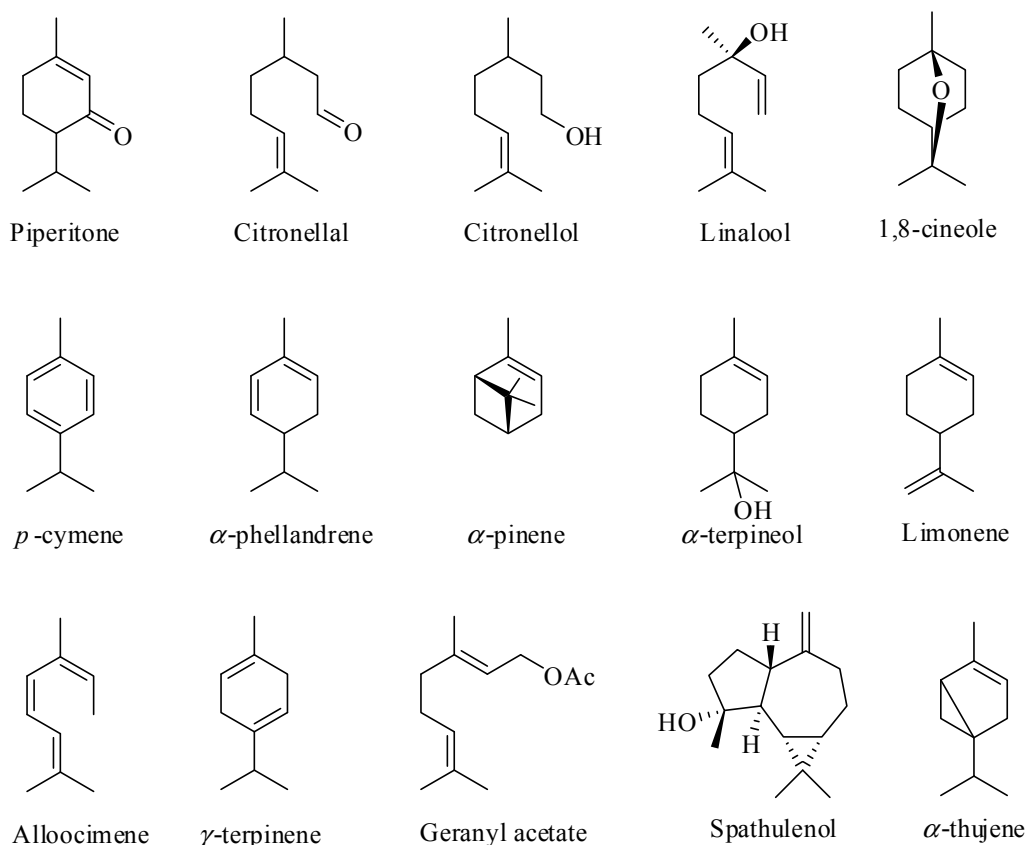


Figure 1. Some of the major constituents of the essential oils of *Eucalyptus* leaves.

The International Standard Organization (ISO) defines EOs as products obtained from parts of plants through hydrodistillation, steam distillation or dry distillation, as well as products obtained by a suitable mechanical process (for *Citrus* fruits). The definition of an essential oil excludes other aromatic/volatile products obtained by different extractive techniques such as extraction with solvents (concretes, absolutes), supercritical fluid extraction, and microwave-assisted extraction.

The composition of the EOs can vary according to the method and drying conditions applied to the vegetal material prior to extraction, and also according to the storage conditions [56–59]. The method of choice for a particular application depends on the material from which the EOs are to be extracted and also the type of application itself.

Concerning the extraction of EOs from *Eucalyptus*, hydrodistillation is typically the method of choice. The extraction yields range from 0.06% to 7% [60], and the chemical composition of the resulting EOs depends on the plant species and varieties. Within the same variety, the essential oil composition can vary according to geographical region, as reported in several studies [15,17,39,61,62] (Table 1).

From Table 1, it can be noticed that the species *E. camaldulensis*, *E. cinerea*, *E. citriodora*, *E. globulus*, *E. grandis*, *E. saligna* and *E. tereticornis* are the ones which have received more attention in terms of their essential oil composition. A more detailed discussion regarding chemical aspects of EOs of these species is described below.

Table 1. Some common chemical components of essential oils extracted from leaves of *Eucalyptus* spp. ^a.

<i>Eucalyptus</i> spp.	Origin	Components of <i>Eucalyptus</i> EOs	EOs Yields (%)	Reference
<i>E. camaldulensis</i>	Argentina	1,8-cineole (19.1%), <i>p</i> -cymene (17.9%), β -phellandrene (16.3%)	0.38	[63–65]
	Brazil	1,8-cineole (52.8%), limonene (14.2%), γ -terpinene (6.8%), α -pinene (6.1%)	0.63	[66,67]
	Brazil	1,8-cineole (44.8%), α -phellandrene (22.9%), <i>p</i> -cymene (9.8%)	3.00	[68]
	Democratic Republic of the Congo	1,8-cineole (58.9%), myrtenol (4.3%), myrtenal (3.5%)	0.30 ^b	[53]
	Egypt	1,8-cineole (60.3%), α -pinene (13.6%), γ -terpinene (8.8%)	-	[69]
	India	α -phellandrene (27.5%), β -pinene (23.5%), <i>m</i> -cymene (9.5%), 1,8-cineole (8.7%)	1.97 ^b	[70]
	Iran	1,8-cineole (74.7%)	-	[71]
	Kenya	1,8-cineole (18.9%), α -cadinol (6.4%), β -phellandrene (2.6%)	-	[72]
	Nigeria	1,8-cineole (70.4%), β -pinene (9.0%), α -pinene (8.8%)	0.26	[73]
	Northern Cyprus	1,8-cineole (19.0%), β -caryophyllene (11.6%), carvacrol (9.1%)	-	[74]
	Pakistan	linalool (17.0%), 1,8-cineole (16.1%), <i>p</i> -cymene (12.2%)	1.90	[75]
	Spain	spathulenol (41.5%), <i>p</i> -cymene (21.9%)	0.71	[76]
	Taiwan	1,8-cineole (29.6%), limonene (15.2%), β -pinene (9.9%), α -pinene (9.7%)	3.48	[77]
	Taiwan	α -pinene (22.5%), <i>p</i> -cymene (21.7%), α -phellandrene (20.1%), 1,8-cineole (9.5%)	0.57	[78]
	Tunisia	1,8-cineole (20.6%), α -pinene (16.5%)	0.76–1.42	[79,80]
<i>E. cinerea</i>	Argentina	1,8-cineole (88.5%), α -terpineol (9.0%), α -pinene (2.0%)	-	[81]
	Argentina	1,8-cineole (79.8%), α -terpinyl acetate (8.2%)	2.48	[63,64]
	Argentina	1,8-cineole (62.1%), <i>p</i> -cymene (11.2%)	-	[82]
	Argentina	1,8-cineole (56.9%), α -pinene (6.4%)	-	[83]
	Brazil	1,8-cineole (83.6%), α -terpinyl acetate (5.4%), α -pinene (5.0%)	3.56–5.02	[84]
	Brazil	1,8-cineole (75.7%), α -terpineol (9.7%), α -pinene (6.2%)	6.07	[85]
	Tunisia	1,8-cineole (79.2%), α -terpinyl acetate (5.4%), α -pinene (4.1%)	3.00	[86]
Tunisia	1,8-cineole (70.4%), α -terpineol (10.3%)	3.90	[87]	
<i>E. citriodora</i>	Argentina	citronellal (76.0%), iso-isopulegol (9.0%), citronellyl acetate (7.3%)	-	[82]
	Australia	citronellal (68.9%), citronellol (7.6%), isopulegol (7.4%)	-	[88]
	Benin	citronellal (52.8%), citronellol (20.0%), citronellyl acetate (9.0%)	4.60	[89,90]
	Brazil	citronellal (94.9%), citronellyl acetate (2.6%), <i>trans</i> caryophyllene (2.5%)	-	[91]
	Brazil	citronellal (89.6%), citronellyl acetate (3.3%), 1,8-cineole (2.9%)	-	[92]
	Brazil	citronellal (82.3%), citronellyl acetate (7.8%), neothujan-3-ol (6.8%)	4.00	[93]
	Brazil	citronellal (76.0%), <i>neo-iso</i> -3-thujanol (11.8%)	0.66	[66,67]
	Brazil	β -citronellal (71.8%), (–)-isopulegol (7.3%), isopulegol (4.3%)	-	[94]
	Brazil	citronellal (71.8%), isopulegol (4.3%)	-	[95]
	Brazil	citronellal (71.1%), citronellol (8.8%)	-	[96]
	Brazil	citronellal (67.5%), citronellol (6.9%), menthol (6.1%)	-	[97]
	Brazil	citronellal (61.8%), isopulegol (15.5%), β -citronellol (7.9%)	-	[98]
	Brazil	citronellal (64.9%), <i>iso</i> -isopulegol (10.2%), citronellol (8.3%)	2.10	[99]
	China	citronellal (65.9%), citronellol (10.5%), 1,8-cineole (3.0%)	-	[100,101]
China	citronellal (55.3%), citronellol (8.3%)	-	[102]	

Table 1. Cont.

<i>Eucalyptus</i> spp.	Origin	Components of <i>Eucalyptus</i> EOs	EOs Yields (%)	Reference
<i>E. citriodora</i>	Colombia	citronellal (49.3%), citronellol (13.0%), isopulegol (12.9%)	0.70	[103]
	Colombia	citronellal (40.0%), isopulegol (14.6%), citronellol (13.0%)	-	[104,105]
	Democratic Republic of the Congo	citronellal (72.7%), citronellol (6.3%), eugenol (3.5%)	1.63 ^b	[53]
	India	citronellal (52.2%), citronellol (12.3%), isopulegol (11.9%)	0.60	[26]
	India	citronellal (48.3%), citronellol (21.9%), <i>iso</i> -isopulegol (12.7%)	2.36–4.80	[54]
	Indonesia	citronellal (90.1%), citronellol (4.3%)	-	[106]
	Kenya	1,8-cineole (11.2%), β -pinene (3.2%), terpinen-4-ol (3.1%)	-	[72]
	Pakistan	citronellal (22.3%), citronellol (20.0%)	1.82	[75]
	South Korea	citronellal (73.0%), isopulegol (6.7%)	-	[107]
	Taiwan	citronellal (49.5%), citronellol (11.9%), <i>iso</i> -isopulegol (10.4%)	1.89	[77]
Tunisia	1,8-cineole (54.1%), α -pinene (23.6%)	3.30	[49,108]	
<i>E. globulus</i>	Algeria	1,8-cineole (55.3%), spathulenol (7.4%), α -terpineol (5.5%)	2.53	[109]
	Argentina	1,8-cineole (77.9%), α -terpineol (6.0%)	2.25	[63,64]
	Argentina	1,8-cineole (76.7%), α -pinene (11.1%)	1.66	[63,110]
	Argentina	1,8-cineole (52.3%–62.1%)	1.31–1.49	[111]
	Australia	1,8-cineole (90.0%), α -pinene (2.2%)	-	[112]
	Australia	1,8-cineole (81.1%), limonene (7.6%), α -pinene (4.0%)	-	[113]
	Brazil	1,8-cineole (90.0%), tricyclene (3.0%)	-	[114]
	Brazil	1,8-cineole (85.8%), α -pinene (9.9%)	-	[91]
	Brazil	1,8-cineole (83.9%), limonene (8.2%), α -pinene (4.2%)	-	[95,115]
	Brazil	1,8-cineole (77.5%), α -pinene (14.2%)	3.10	[116]
	Democratic Republic of the Congo	1,8-cineole (44.3%), camphene (23.1%), α -pinene (9.3%), globulol (7.3%)	1.87 ^b	[53]
	Egypt	1,8-cineole (21.4%), <i>o</i> -cimene (21.4%), α -pinene (6.7%), spathulenol (6.3%)	-	[117]
	Ethiopia	1,8-cineole (63.0%), α -pinene (16.1%)	-	[118]
	India	1,8-cineole (81.9%), limonene (6.6%)	-	[119]
	India	1,8-cineole (68.8%), α -pinene (2.8%)	-	[120]
	India	1,8-cineole (66.3%), <i>cis</i> -ocymene (21.3%), α -terpinyl acetate (3.4%)	-	[121]
	India	1,8-cineole (44.4%), limonene (17.8%), <i>p</i> -cymene (9.5%)	-	[43]
	India	1,8-cineole (33.6%), α -pinene (14.2%), limonene (10.1%)	-	[122]
	Indonesia	1,8-cineole (86.5%), α -pinene (4.7%)	-	[106]
	Iran	1,8-cineole (84.5%), limonene (8.50%)	-	[123]
	Iran	1,8-cineole (47.2%), spathulenol (18.1%), α -pinene (9.6%)	-	[124]
	Italy	1,8-cineole (84.9%), α -pinene (5.6%), <i>p</i> -cymene (5.3%)	-	[125]
	Kenya	1,8-cineole (17.2%), α -pinene (7.1%), spathulenol (6.5%)	-	[72]
	Montenegro	1,8-cineole (85.8%), α -pinene (7.2%), β -myrcene (1.5%)	1.80 ^b	[126]
	Morocco	1,8-cineole (22.4%), limonene (7.0%), solanone (6.1%), β -pinene (5.2%)	1.21	[127]
	Pakistan	1,8-cineole (56.5%), limonene (28.0%)	1.89	[75]
	Spain	1,8-cineole (63.8%), α -pinene (16.1%)	-	[128]

Table 1. Cont.

<i>Eucalyptus</i> spp.	Origin	Components of <i>Eucalyptus</i> EOs	EOs Yields (%)	Reference
<i>E. grandis</i>	Argentina	α -pinene (52.7%), 1,8-cineole (18.4%), <i>p</i> -cymene (8.7%)	0.36	[65,129,130]
	Brazil	<i>p</i> -cymene (59.6%), γ -terpinene (29.2%)	0.26	[68]
	Brazil	α -pinene (40.6%), γ -terpinene (16.3%), <i>p</i> -cymene (13.1%)	0.31	[66,67]
	Brazil	γ -terpinene (16.8%), <i>o</i> -cymene (16.7%), β -pinene (11.5%)	2.00	[93]
	Taiwan	1,8-cineole (19.8%), α -terpinyl acetate (12.8%), α -pinene (11.4%)	3.01	[77]
<i>E. saligna</i>	Argentina	1,8-cineole (93.2%)	-	[131]
	Argentina	1,8-cineole (93.2%), limonene (3.3%)	-	[82]
	Argentina	1,8-cineole (34.0%), <i>p</i> -cymene (21.3%), γ -terpinene (20.10%), α -pinene (13.0%)	0.36	[63,64]
	Brazil	1,8-cineole (45.2%), <i>p</i> -cymene (34.4%), α -pinene (12.8%)	0.50	[116]
	Brazil	<i>p</i> -cymene (25.6%), α -terpineol (9.3%), α -camphonellal (8.0%), 1,8-cineole (6.2%)	0.50	[93]
	Brazil	α -pinene (92.3%)	1.42	[68]
	Brazil	α -pinene (45.1%), <i>p</i> -cymene (22.5%), α -pinene oxide (11.3%)	0.40	[132]
	Brazil	α -pinene (25.9%), <i>p</i> -cymene (24.4%), γ -terpinene (24.6%)	0.19	[66,67]
	Democratic Republic of the Congo	1,8-cineole (61.3%), limonene (10.1%), <i>p</i> -cymene (7.2%)	0.78 ^b	[53]
	Kenya	α -pinene (24.4%), 1,8-cineole (24.3%), <i>o</i> -cimene (9.9%), α -terpineol (8.8%)	0.38	[133]
Nigeria	α -thujene (63.8%), 1,8-cineole (12.3%)	0.30	[73]	
<i>E. tereticornis</i>	Argentina	1,8-cineole (37.5%), <i>p</i> -cymene (22.0%), γ -terpinene (10.8%)	-	[82]
	Argentina	β -phellandrene (22.6%), 1,8-cineole (18.6%), <i>p</i> -cymene (14.5%), α -phellandrene (9.4%)	0.60	[63–65]
	Benin	<i>p</i> -cymene (31.1%), β -phellandrene (9.7%)	-	[134]
	Benin	<i>p</i> -cymene (16.7%), caryophyllene oxide (14.2%), spathulenol (13.5%), cryptone (11.4%)	1.00	[89]
	Brazil	β -pinene (22.4), 1,8-cineole (19.3%), α -pinene (13.6%), α -phellandrene (10.3%)	2.30	[68]
Democratic Republic of the Congo	<i>p</i> -cymene (28.6%), cryptone (17.8%), α -pinene (8.3%)	0.45 ^b	[53]	

^a The compounds are listed according to their decreasing quantities; ^b Fresh leaves; (-): not reported. A complete Table of common chemical components of essential oils extracted from leaves of *Eucalyptus* spp. is in Supplementary Materials.

2.1. *Eucalyptus camaldulensis* Dehnh

The reported yields of EOs for *E. camaldulensis* range from 0.26% to 3.48% being the highest value found for plants cultivated in Taiwan [77]. In most *E. camaldulensis* EOs, 1,8-cineole is the major constituent, usually found in quantities above 50% in EOs extracted from plants cultivated in Egypt [69], the Democratic Republic of the Congo [53], Nigeria [73], Brazil [66,67] and Iran [71]. Different chemotypes of *E. camaldulensis* were identified for plants cultivated in Spain and Taiwan. Plants from Spain showed spathulenol and *p*-cymene as the major components [76], while for the species from Taiwan the principal constituents were α -pinene, *p*-cymene and α -phellandrene [78]. Plants cultivated in different countries produces EOs with variable composition as can be seen from Table 1.

2.2. *Eucalyptus cinerea* F. Muell. ex Benth

The leaves of *E. cinerea* are aromatic, with great potential for EO production, and are used for ornamental purposes. There are few reports of its use in folk medicine [135]. Among all herein described *Eucalyptus* species, *E. cinerea* is the one that produces the highest amount of EOs, as illustrated by plants cultivated in Argentina that afford 2.48% [63,64] and those from Paraná state in Brazil with 6.07% [85]. As observed from Table 1, the EOs produced by *E. cinerea* usually contain more than 80% of 1,8-cineole [81,84] and such oils may serve as a source of this important compound for industrial applications.

2.3. *Eucalyptus citriodora* Hook

The EOs extracted from *E. citriodora* is the most important in terms of worldwide trading volume [99,136]. This species constitutes the richest and most economical known source of citronellal, a substance widely used in the manufacture of cosmetics and aromatization of cleaning products such as soaps and detergents. This compound also has antiseptic properties, which justifies its use as a cleaning agent and disinfectant of floors and toilets [137]. In terms of chemical composition, the EOs produced by *E. citriodora* are the most widely investigated among all eucalyptus species. In general, this species affords high yields of EOs, as observed in the studies from some plants cultivated in India [54] and in Benin [89] (4.8% and 4.6% yields, respectively). Lower EOs yielding species were found, however, among plants cultivated in India (0.6%) [26], in São Paulo state, Brazil (0.66%) [66,67] and Colombia (0.70%) [103].

As observed from the data presented in Table 1, plants cultivated in several states in Brazil usually produce EOs with high (>70%) citronellal content [66,67,91–96]. Other examples of plants that produce EOs with citronellal content above 70% are those from the Democratic Republic of the Congo [53]; South Korea [107] and Argentina [82]. Analysis of the data presented in Table 1 reveals that yields of EOs produced by these species and also their citronellal contents are influenced by the plant cultivation location.

As reported to date, only plants cultivated in Tunisia [49,108] and Kenya [72] do not present citronellal as the major component in their EOs. Therefore, these *E. citriodora* species represent different chemotypes producing EOs rich in 1,8-cineole and α -pinene (the Tunisian species) and 1,8-cineole for species cultivated in Kenya.

2.4. *Eucalyptus globulus* Labill

The EOs produced by *E. globulus*, cultivated in several places, are the major commercial source of 1,8-cineole. The highest content of 1,8-cineole (>80%) in EOs of *E. globulus* was reported in studies carried out in Brazil in São Paulo state [114,115], in Minas Gerais state [91], and in Ceará state [95]. High 1,8-cineole content was also found in EOs from Australia (81.1%–90.0%) [112,113]; Indonesia (86.5%) [106]; Montenegro (85.8%) [126]; Italy (84.9%) [125]; India (81.9%) [119]; Iran [123].

A severe limitation on several studies with *E. globulus* EOs is the lack of information on the extraction yields. This fact precludes us from evaluating the potential commercial application of such

plants as a source of 1,8-cineole. Therefore, the plants that produce EOs with high 1,8-cineole content should be further investigated in more details in case of a commercial interest.

2.5. *Eucalyptus grandis* W. Hill ex Maiden

As described for other eucalyptus species, different chemotypes were also reported for *E. grandis*. Thus, plants cultivated in Goiás state (Brazil) are representative of chemotypes with γ -terpinene, *o*-cymene and β -pinene as the major components of their EOs [93]. In another study conducted in Botucatu (São Paulo state, Brazil) the identified chemotype was characterized by large quantities of α -pinene, γ -terpinene and *p*-cymene [66,67]. The main components in the EOs from plants found in the Taiwan chemotype [77] were 1,8-cineole, α -terpinyl acetate and α -pinene, while the same chemotypes cultivated in Argentina [130] showed the presence of 52.7% of α -pinene, 18.4% of 1,8-cineole and 8.7% of *p*-cymene. Concerning EO extraction yields, species cultivated in Botucatu and in Argentina are low yielding (0.31% and 0.36%, respectively) while good extraction yields were observed for plants from Goiás state (Brazil) and Taiwan (2.0% and 3.01%, respectively).

In Brazil *E. grandis* is widely cultivated and used for cellulose pulp and paper production. Since its leaves have a high EO content (2.0%), further investigation to evaluate the use of such an industrial residue for EO production could constitute in a good business opportunity for the companies involved.

2.6. *Eucalyptus saligna* Smith

The species *E. saligna* is widely cultivated in Brazil for cellulose pulp production and is constituted of several chemotypes, some of them rich in 1,8-cineole. Another example of the 1,8-cineole chemotype is found in plants cultivated in the Democratic Republic of the Congo [53] which EO contained 61.3% of this component. Two studies conducted in Argentina [63,64,82] found the same chemotypes producing EOs with 1,8-cineole contents equal to 93.2% and 34.0%, respectively. Several studies carried out in Brazil, in different states, have revealed different EO compositions of *E. saligna*. A 1,8-cineole chemotype was found in plants cultivated in Rio Grande do Sul state [116]. Chemotypes presenting α -pinene as major component were found in plants cultivated in Minas Gerais state [68], which presented 92.3% of this compound, and in São Paulo state [66,67,132]. Finally, species cultivated in Nigeria [73] constituted a chemotype rich in α -thujene. In all the aforementioned studies of *E. saligna* EOs, the best extraction yields (1.42%) were obtained in the state of Minas Gerais [68].

2.7. *Eucalyptus tereticornis* Smith

The yields of EOs from *E. tereticornis* cultivated in different places varied from 0.45% to 2.3%. Two studies conducted in Benin found EOs presenting *p*-cymene as the main component [89,134]. The EOs of *E. tereticornis* cultivated in the Democratic Republic of the Congo also revealed *p*-cymene as the major component [53]. Lucia et al. [63,64] reported that *E. tereticornis* EOs are rich in β -phellandrene, 1,8-cineole and *p*-cymene. Toloza and co-workers [82] examined EOs containing 1,8-cineole, *p*-cymene, and γ -terpinene as the major components. A recent work by Filomeno and co-workers [68] reported that *E. tereticornis*, cultivated in Minas Gerais state in Brazil, produces high quantities (2.3%) of EOs rich in β -pinene, 1,8-cineole and α -pinene. This plant has a potential to be commercially explored as a source of EOs.

Based on the data described above, a large chemical variability is observed among *Eucalyptus* EO species. Such variation can be attributed to several factors including climate, soil type, plant age, nature (wet or dried) of the material used in the extraction, vegetative cycle stage, and time of the day when harvesting is done [35,95,99,138–141].

Since the chemical composition of the *Eucalyptus* EOs is directly associated with their biological activities, the following discussion will be focused on such activities and on the multiple applications of such EOs.

3. Biological Activities of *Eucalyptus* EOs

Several studies on antioxidant and antimicrobial activities of EOs from eucalyptus have been published in recent years [14,15,17,21,49,142–148]. Significant insecticide, antibacterial and fungicide effects have also been observed for EOs produced by *Eucalyptus* species [53,63,66,75,106]. Antimicrobial, acaricidal, insecticidal and herbicidal activities associated with EOs from the leaves of *Eucalyptus* are reported in several articles each year, demonstrating the importance of this research field. Such bioactivities are highly dependent on the EOs chemical composition, as discussed and illustrated in the following discussion.

3.1. Antimicrobial Activity

Eucalyptus EOs were evaluated against several Gram-positive and Gram-negative bacterial strains (Table 2) as well as against various fungal species (Table 3). The EOs showed different degrees of efficiency against the evaluated species. Among the bacterial strains, the pathogenic Gram-positive *Staphylococcus aureus* was most sensitive to EOs obtained from several *Eucalyptus* species. From the data available, *Pseudomonas aeruginosa* corresponded to the most resistant bacterial species. The yeast species *Candida albicans* also exhibited high sensitivity to the EOs.

3.1.1. Antibacterial Activity

The EOs from *E. staigeriana* presented high antimicrobial activity against all evaluated microorganisms (Table 2). By using the agar diffusion method, *E. staigeriana* EOs presented the highest activity against *S. aureus* with inhibition zone diameter (izd) superior to 90 mm (the growth of the microorganism was inhibited over the entire Petri dish). This value was four times superior to the inhibition zone diameter caused by chloramphenicol, the commercial antibiotic used as positive control in the biological assays [17]. In the same investigation, it was demonstrated that *E. dives* EOs were also very effective against *S. aureus* (izd 52.3 mm in diameter, a value approximately two times higher than the izd observed for chloramphenicol).

Derwich et al. [127] have demonstrated the efficiency of *E. globulus* EOs against Gram-negative *E. coli* and Gram-positive *S. aureus* and *S. intermedius*. These authors found that *E. globulus* EOs presented excellent activity on *E. coli* in the agar disc diffusion assay (izd = 48.15 mm) compared to *S. aureus* (izd = 13.5 mm) and *S. intermedius* (izd = 10.26). The minimum inhibitory concentration (MIC) for *E. coli* corresponded to 0.15 mg/mL while for *S. aureus* and *S. intermedius* the values corresponded to 0.75 mg/mL and 1.08 mg/mL, respectively.

The effects of *E. globulus* EOs on 14 food spoilage microorganisms have been investigated using liquid and vapour phase agar dilution/well diffusion method and disc volatilization method [43]. The MIC found from such methods varied in the range of 2.25–9.0 mg/mL for bacterial and fungal strains. It was observed that MIC obtained for Gram-positive *B. subtilis* and *S. aureus* were lower than MIC values found for Gram-negative *E. coli*, *P. aeruginosa*, and *P. fluorescens* [43]. In general, significantly higher antimicrobial activities were observed in the vapour phase. As previously mentioned, 1,8-cineole is the main component of *E. globulus* EOs. It has been demonstrated that this compound has antimicrobial activity against several microorganisms including *S. aureus* [149], *E. coli* and *B. subtilis* [150,151].

Table 2. *Eucalyptus* spp. essential oils with antibacterial activities.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. alba</i>	<i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella typhimurium</i> , <i>Staphylococcus aureus</i>	[53,73]
<i>E. astringens</i>	<i>Bacillus cereus</i> , <i>Escherichia coli</i> , <i>Listeria ivanovii</i>	[86]
<i>E. bicostata</i>	<i>Bacillus cereus</i> , <i>Listeria ivanovii</i> , <i>Staphylococcus aureus</i> , <i>Streptococcus pneumoniae</i>	[86,152]
<i>E. botryoides</i>	<i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[49]
<i>E. camaldulensis</i>	<i>Bacillus cereus</i> , <i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Listeria monocytogenes</i> , <i>Proteus vulgaris</i> , <i>Pseudomonas aeruginosa</i> , <i>Shigella flexneri</i> , <i>Staphylococcus aureus</i>	[53,70,73–75]
<i>E. cinerea</i>	<i>Bacillus cereus</i> , <i>Escherichia coli</i> , <i>Listeria ivanovii</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i> , <i>Staphylococcus epidermidis</i> , <i>Streptococcus pyogenes</i>	[84–87]
<i>E. citriodora</i>	<i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella choleraesuis</i> , <i>Salmonella typhimurium</i> , <i>Shigella flexneri</i> , <i>Staphylococcus aureus</i>	[49,53,75,93,106]
<i>E. cloeziana</i>	<i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[93]
<i>E. crebra</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[75]
<i>E. deglupta</i>	<i>Bacillus cereus</i> , <i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella typhimurium</i> , <i>Shigella flexneri</i> , <i>Staphylococcus aureus</i>	[53,73]
<i>E. diversifolia</i>	<i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[153]
<i>E. dives</i>	<i>Escherichia coli</i> , <i>Listeria monocytogenes</i> , <i>Pseudomonas fragi</i> , <i>Salmonella typhimurium</i> , <i>Staphylococcus aureus</i>	[17,154]
<i>E. globulus</i>	<i>Acinetobacter baumannii</i> , <i>Bacillus cereus</i> , <i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Fusobacterium nucleatum</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Porphyromonas gingivalis</i> , <i>Pseudomonas aeruginosa</i> , <i>Pseudomonas fluorescens</i> , <i>Salmonella paratyphi</i> , <i>Salmonella typhi</i> , <i>Salmonella typhimurium</i> , <i>Shigella</i> , <i>Staphylococcus aureus</i> , <i>Staphylococcus intermedius</i> , <i>Staphylococcus sciuri</i> , <i>Staphylococcus warneri</i> , <i>Streptococcus pyogenes</i>	[43,53,75,106,109,118,123–128]
<i>E. gracilis</i>	<i>Klebsiella pneumoniae</i> , <i>Listeria monocytogenes</i>	[155]
<i>E. grandis</i>	<i>Escherichia coli</i> , <i>Salmonella choleraesuis</i> , <i>Staphylococcus aureus</i>	[93]
<i>E. lehmannii</i>	<i>Bacillus cereus</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i>	[86,152]
<i>E. leucoxydon</i>	<i>Bacillus cereus</i> , <i>Escherichia coli</i>	[86]
<i>E. maidenii</i>	<i>Bacillus cereus</i> , <i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Listeria ivanovii</i> , <i>Staphylococcus aureus</i>	[86,152]
<i>E. melanophloia</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[75]
<i>E. microcorys</i>	<i>Staphylococcus aureus</i>	[93]

Table 2. Cont.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. microtheca</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	[75]
<i>E. odorata</i>	<i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Haemophilus influenzae</i> , <i>Streptococcus agalactiae</i> , <i>Staphylococcus aureus</i> , <i>Streptococcus pneumoniae</i> , <i>Streptococcus pyogenes</i>	[152]
<i>E. oleosa</i>	<i>Klebsiella pneumoniae</i> , <i>Listeria monocytogenes</i>	[155]
<i>E. radiata</i>	<i>Acinetobacter baumannii</i> , <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella typhimurium</i>	[128]
<i>E. robusta</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella typhimurium</i> , <i>Shigella flexneri</i> , <i>Staphylococcus aureus</i>	[53,132]
<i>E. saligna</i>	<i>Bacillus cereus</i> , <i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>Salmonella choleraesuis</i> , <i>Staphylococcus aureus</i>	[53,73,93,132]
<i>E. olida</i>	<i>Staphylococcus aureus</i>	[17]
<i>E. ovata</i>	<i>Escherichia coli</i>	[49]
<i>E. pellita</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i>	[156]
<i>E. platypus</i>	<i>Enterococcus faecalis</i>	[152]
<i>E. propinqua</i>	<i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Salmonella typhimurium</i> , <i>Shigella flexneri</i> , <i>Staphylococcus aureus</i>	[53]
<i>E. radiata</i>	<i>Enterococcus faecalis</i> , <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i>	[106]
<i>E. salmonophloia</i>	<i>Klebsiella pneumoniae</i> , <i>Listeria monocytogenes</i>	[155]
<i>E. salubris</i>	<i>Klebsiella pneumoniae</i> , <i>Listeria monocytogenes</i>	[155]
<i>E. sargentii</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> , <i>Pseudomonas aeruginosa</i> , <i>Shigella dysenteriae</i> , <i>Staphylococcus aureus</i> , <i>Staphylococcus epidermidis</i>	[157]
<i>E. sideroxylon</i>	<i>Bacillus cereus</i> , <i>Listeria ivanovii</i>	[86]
<i>E. staigeriana</i>	<i>Enterococcus faecalis</i> , <i>Staphylococcus aureus</i>	[17]
<i>E. tereticornis</i>	<i>Bacillus subtilis</i> , <i>Citrobacter diversus</i> , <i>Corynebacteriaceae</i> spp., <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus vulgaris</i> , <i>Pseudomonas aeruginosa</i> , <i>Shigella flexneri</i>	[53,134]
<i>E. urophylla</i>	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i>	[53]

Table 3. *Eucalyptus* spp. essential oils with antifungal activities.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. astringens</i>	<i>Candida albicans</i> , <i>Microsporium canis</i>	[152]
<i>E. bicostata</i>	<i>Candida albicans</i>	[152]
<i>E. camaldulensis</i>	<i>Alternaria alternata</i> , <i>Aspergillus clavatus</i> , <i>Aspergillus niger</i> , <i>Candida albicans</i> , <i>Chaetomium globosum</i> , <i>Cladosporium cladosporioides</i> , <i>Lenzites sulphureus</i> , <i>Myrothecium verrucaria</i> , <i>Penicillium citrinum</i> , <i>Phanerochaete chrysosporium</i> , <i>Phaeolus schweintizii</i> , <i>Rhizopus solani</i> , <i>Trametes versicolor</i> , <i>Trichoderma viride</i>	[69,73,75,77]
<i>E. cinerea</i>	<i>Candida albicans</i>	[84,85]
<i>E. citriodora</i>	<i>Aspergillus clavatus</i> , <i>Aspergillus niger</i> , <i>Aspergillus</i> spp., <i>Botrytis cinerea</i> , <i>Chaetomium globosum</i> , <i>Cladosporium cladosporioides</i> , <i>Colletotrichum gloeosporioides</i> , <i>Colletotrichum musae</i> , <i>Cryphonectria parasitica</i> , <i>Fusarium oxysporum</i> , <i>Lenzites sulphureus</i> , <i>Myrothecium verrucaria</i> , <i>Penicillium citrinum</i> , <i>Phaeolus schweintizii</i> , <i>Phanerochaete chrysosporium</i> , <i>Phytophthora cactorum</i> , <i>Pyricularia grisea</i> , <i>Pythium ultimum</i> , <i>Rhizoctonia solani</i> , <i>Rhizopus solani</i> , <i>Trametes versicolor</i> , <i>Trichoderma viride</i>	[75,77,88,98,107]
<i>E. crebra</i>	<i>Aspergillus niger</i> , <i>Rhizopus solani</i>	[75]
<i>E. deglupta</i>	<i>Candida albicans</i>	[73]
<i>E. dives</i>	<i>Candida albicans</i> , <i>Saccharomyces cerevisiae</i>	[17]
<i>E. erythrocorys</i>	<i>Bipolaris sorokiniana</i> , <i>Botrytis cinerea</i>	[158]
<i>E. globulus</i>	<i>Aspergillus flavus</i> , <i>Aspergillus niger</i> , <i>Aspergillus parasiticus</i> , <i>Aspergillus</i> spp., <i>Candida albicans</i> , <i>Fusarium oxysporum</i> , <i>Mucor</i> spp., <i>Penicillium digitatum</i> , <i>Rhizopus nigricans</i> , <i>Rhizopus solani</i> , <i>Saccharomyces cerevisiae</i> , <i>Trichophyton</i> spp.	[43,75,114,118,126]
<i>E. gracilis</i>	<i>Aspergillus ochraceus</i> , <i>Candida albicans</i> , <i>Mucor ramannianus</i> , <i>Saccharomyces cerevisiae</i>	[155]
<i>E. grandis</i>	<i>Aspergillus clavatus</i> , <i>Aspergillus niger</i> , <i>Chaetomium globosum</i> , <i>Cladosporium cladosporioides</i> , <i>Lenzites sulphureus</i> , <i>Myrothecium verrucaria</i> , <i>Penicillium citrinum</i> , <i>Phaeolus schweintizii</i> , <i>Phanerochaete chrysosporium</i> , <i>Trametes versicolor</i> , <i>Trichoderma viride</i>	[77]
<i>E. maidenii</i>	<i>Candida albicans</i> , <i>Trichophyton soudanense</i>	[152]
<i>E. melanophloia</i>	<i>Aspergillus niger</i> , <i>Rhizopus solani</i>	[75]
<i>E. microtheca</i>	<i>Aspergillus niger</i> , <i>Rhizopus solani</i>	[75]
<i>E. odorata</i>	<i>Candida albicans</i> , <i>Microsporium canis</i> , <i>Scopulariopsis brevicaulis</i> , <i>Trichophyton rubrum</i> , <i>Trichophyton soudanense</i>	[152]
<i>E. oleosa</i>	<i>Aspergillus ochraceus</i> , <i>Candida albicans</i> , <i>Mucor ramannianus</i> , <i>Saccharomyces cerevisiae</i>	[155]
<i>E. robusta</i>	<i>Candida albicans</i>	[132]
<i>E. saligna</i>	<i>Candida albicans</i>	[73,132]
<i>E. olida</i>	<i>Candida albicans</i>	[17]
<i>E. platyphylla</i>	<i>Deightoniella torulosa</i>	[159]
<i>E. salmonophloia</i>	<i>Aspergillus ochraceus</i> , <i>Candida albicans</i> , <i>Mucor ramannianus</i> , <i>Saccharomyces cerevisiae</i>	[155]
<i>E. salubris</i>	<i>Aspergillus ochraceus</i> , <i>Candida albicans</i> , <i>Mucor ramannianus</i> , <i>Saccharomyces cerevisiae</i>	[155]
<i>E. sargentii</i>	<i>Aspergillus niger</i> , <i>Candida albicans</i>	[157]
<i>E. sideroxylon</i>	<i>Microsporium canis</i>	[152]
<i>E. smithii</i>	<i>Microsporium canis</i> , <i>Microsporium gypseum</i> , <i>Trichophyton mentagnophytes</i> , <i>Trichophyton rubrum</i>	[160]
<i>E. staigeriana</i>	<i>Candida albicans</i>	[17]
<i>E. tereticornis</i>	<i>Hansenula</i> spp., <i>Saccharomyces</i> spp., <i>Sporobolomyces</i> , <i>Torulopsis candida</i>	[134]
<i>E. urophylla</i>	<i>Aspergillus clavatus</i> , <i>Aspergillus niger</i> , <i>Chaetomium globosum</i> , <i>Cladosporium cladosporioides</i> , <i>Lenzites sulphureus</i> , <i>Myrothecium verrucaria</i> , <i>Penicillium citrinum</i> , <i>Phanerochaete chrysosporium</i> , <i>Phaeolus schweintizii</i> , <i>Trametes versicolor</i> , <i>Trichoderma viride</i>	[77]

Vratnica and co-workers [126] investigated the antimicrobial effects of *E. globulus* EOs against 17 microorganisms, including food poisoning and spoilage bacteria and human pathogens. In general, the EOs were highly active against the evaluated microorganisms. The agar disc diffusion method was utilized and filter paper discs were impregnated with *E. globulus* EOs (5, 10, 15, 20 and 30 μ L). In these assays, the highest inhibition zone diameter (izd) values were observed for *S. pyogenes* (25–51 mm), *S. aureus* (22–48 mm), and *E. coli* (23–47 mm). The broth microdilution method was used to determine MIC which ranged from 0.09 mg/mL to 3.13 mg/mL. The highest MIC values were found for *P. aeruginosa* and *Salmonella infantis* (3.13 mg/mL) and the lowest for *S. aureus*, *E. coli* and *S. pyogenes* (0.09 mg/mL). In this work, no information about the compounds possibly responsible for the biological activity was provided.

The EOs from *E. camaldulensis* were tested against a panel of 12 bacteria strains, and the most sensitive microorganism was *B. subtilis*. For this microorganism, the EOs caused izds in the range of 19.3 mm to 29.3 mm at different volumes (20, 30, 40, 50 and 100 μ L) in the agar diffusion method. When tested against *L. monocytogenes* and *S. aureus*, the EOs caused significant growth inhibition of the microorganisms, as attested by the corresponding izds ranging from 14.6 to 25.0 mm [70].

The biological assays conducted with EOs of *E. odorata* displayed the best results against *S. aureus* (izd = 27.4 mm) as determined in the agar diffusion method, followed by *S. agalactiae* (izd = 19.4 mm), *H. influenzae* (izd = 19.2 mm), *S. pyogenes* (izd = 19.0 mm) and *S. pneumoniae* (izd = 17.4 mm). Moreover, *E. maidenii* exhibited good activity against *S. aureus* (izd = 22.8 mm) [87,152].

Antimicrobial activities of *Eucalyptus* spp. EOs against resistant bacterial strains have also been described. For instance, *P. aeruginosa* is known for its high intrinsic resistance against antibiotics. This fact has been attributed to the very restrictive outer membrane barrier of the bacteria, being highly resistant even to synthetic drugs [17,49]. The EOs of *E. camaldulensis* and *E. tereticornis* exhibited relevant activity against *P. aeruginosa* (izd ~16.0 mm) [53]. The EOs from *E. cinerea* were less active (izd = 7.0 mm) when tested against *P. aeruginosa* [84].

In general, Gram-positive bacterial strains are more sensitive to *Eucalyptus* EOs than the Gram-negative ones [17,43,84]. This can be rationalized considering that Gram-negative bacteria possess a lipopolysaccharide membrane which is restrictive to the diffusion of hydrophobic compounds. In addition, the direct contact between the hydrophobic components of the EOs and the phospholipid bilayer of the cell membrane can occur in Gram-positive bacteria. As a consequence, the components exert their effects such as increase in the permeability to ions, leakage of vital intracellular components or compromise bacterial enzymes [43,84].

3.1.2. Antifungal Activity

Eucalyptus EOs also cause growth inhibition of some fungal species (Table 3), as in the case of *C. albicans*. Vratnica and co-workers [126] reported that *E. globulus* EOs were two times more effective (izd = 14–46 mm) than nystatin, a drug used to treat fungal infections on the skin, mouth, vagina, and intestinal tract. The authors attributed this effect to the high content of 1,8-cineole in *E. globulus* EOs (85.8%). This information should be taken with caution since in another study the correlation between 1,8-cineole content and antifungal activity was not confirmed [77]. Gilles and co-workers [17] reported the effect of *E. staigeriana* (izd = 26.7 mm), *E. dives* (izd = 15.4 mm) and *E. olida* (izd = 12.6 mm) EOs on *C. albicans*. In this study, the superior antifungal activity of *E. staigeriana* EOs was attributed to the presence of 1,8-cineole (34.8%). Low activity against *C. albicans* was observed for EOs extracted from *E. robusta* and *E. saligna*, both without 1,8-cineole [132]. It should be noted that in the above cited studies no bioassays were conducted with pure 1,8-cineole, which could evaluate if 1,8-cineole has synergistic or antagonistic effect with other components of the EOs.

Tyagi and Malik [43] investigated the effect of EOs from *E. globulus* on several fungal species and reported MIC values ranging from 2.25 to 9 mg/mL. The superior limit value was observed for *P. digitatum* and *A. niger*. For *A. flavus*, *R. nigricans* and *F. oxysporum* a MIC of 4.5 mg/mL was found, while for *Mucor* spp. and *C. albicans* MIC of 2.25 mg/mL was reported.

In a recent study, it has been found that EOs from *E. erythrocoris* significantly reduced the growth of fungal species *B. sorokiniana* (79.6%) and *B. cinerea* (78.5%) [158].

The evaluation of antifungal activity of *E. citriodora* EOs, in concentration of 10 mg/disc, revealed that these EOs completely inhibit the growth of *C. cladosporioides*, *M. verrucaria* and *T. viride*. On the contrary, the growth of *A. clavatus*, *A. niger* and *P. citrinum* were partially inhibited (90.7%, 54.6% and 86.0%, respectively). Such antifungal activities were ascribed to the main components of *E. citriodora* EOs, namely citronellal (49.5%) and citronellol (11.9%) [77].

Lipid peroxidation and microbial contamination are two problems related to deterioration of food, an important issue for the food industry [39]. The addition of antioxidants is a well known strategy used to retard or even stop oxidation processes in food. Due to the carcinogenicity associated with some synthetic antioxidants, their use is restricted. In this context, an increased interest in the use of natural additives to control food oxidation has been observed. The use of EOs has been considered by the food industries as an alternative to overcome food deterioration [161,162]. Natural products presenting antioxidant activity has also been taken into consideration since some compounds with antioxidant activity can also be utilized as antimicrobials [37,163].

Infections caused by fungi and bacteria represent an important issue due to development of species resistant to well known fungicides and antibiotics [164]. Considering the relevant information available in the literature concerning the antimicrobial activity of *Eucalyptus* EOs, the employment of such can also be considered a viable alternative to overcome the resistance problem.

Synthetic fungicides are typically employed to prevent the contamination of food commodities from fungal deterioration as well as from mycotoxin contaminations. However, the use of such substances is not free from side effects, as residual toxicity that contributes to the development of fungal resistance. This is particularly true when the fungi are exposed to fungicide sub-lethal concentrations. The use of EOs has been considered as an alternative to overcome the reported problems associated with synthetic fungicides and protection of food commodities [159,165]. Although a promising strategy, further investigation in this area is still required to achieve a commercial product.

3.2. Acaricidal Activity

An acaricide can be defined as any substance or mixture of substances intended to prevent, destroy, repel, or mitigate ticks and mites. A number of studies have demonstrated the acaricidal effects of EOs obtained from different species of *Eucalyptus* (Table 4).

Table 4. *Eucalyptus* spp. essential oils with acaricidal activities.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. approximans</i>	<i>Tetranychus urticae</i>	[166]
<i>E. bicostata</i>	<i>Tetranychus urticae</i>	[166]
<i>E. camaldulensis</i>	<i>Varroa destructor</i>	[71]
<i>E. citriodora</i>	<i>Boophilus microplus</i> , <i>Dermanyssus gallinae</i> , <i>Neoseiulus californicus</i> , <i>Tetranychus urticae</i>	[91,100–102]
<i>E. globulus</i>	<i>Boophilus microplus</i>	[91]
<i>E. maidenii</i>	<i>Tetranychus urticae</i>	[166]
<i>E. sideroxylon</i>	<i>Tetranychus urticae</i>	[166]
<i>E. staigeriana</i>	<i>Boophilus microplus</i> , <i>Dermanyssus gallinae</i>	[91,102]
<i>E. tereticornis</i>	<i>Amblyoma variegatum</i>	[134]

The effects of EOs from *E. citriodora*, *E. globulus* and *E. staigeriana* on the tick species *B. microplus* were evaluated at several doses (1%, 5%, 10%, 20% and 30% in methanol). The EOs from *E. citriodora* and *E. staigeriana* were the most active, causing 100% mortality of the larvae at 10% concentration. To achieve the same 100% mortality, it was required 20% of the EOs of *E. globulus* [91].

The EOs from *E. citriodora* are also toxic to the mite species *T. urticae* and *N. californicus*. A mortality bioassay was used to determine the LD₅₀ of EOs (LD stands for lethal dose; LD₅₀ denotes the dose likely to cause death in 50% of mites). The determined LD₅₀ values were 19.3 µg/cm³ for *T. urticae* and 21.4 µg/cm³ for *N. californicus* [100].

Acaricidal effects were observed for EOs of *E. approximans*, *E. bicostata*, *E. maidenii* and *E. sideroxylon* on *T. urticae* females. At the concentrations of 0.5% and 1.0%, the reported observed mortalities were as follows: *E. approximans* (67% at 0.5%; 83.1% at 1.0%), *E. bicostata* (67.8% at 0.5% and 82.5% at 1.0%), *E. maidenii* (82.2% at 0.5% and 100.0% at 1.0%), *E. sideroxylon* (78.8% at 0.5% and 79.4% at 1.0%) [166].

The contact toxicity assay was used to evaluate the effects of *E. citriodora* EOs on the mite species *D. gallinae*. Using a dose of 0.21 mg/cm² and after 24 h of exposure, 85% mortality was observed [102]. The effect of *E. citriodora* EOs was tested on larvae of the mite species *Amblyomma cajennense* and *Anocentor nitens*. In the biological evaluation, the concentrations ranged from 6.25% to 50%. For *A. cajennense*, the acaricidal effect varied from 10.8% to 53.1% mortality; for *A. nitens*, a more sensitive species, the mortality ranged from 20.1% to 100% [167].

The acaricidal activity of EOs from *E. camaldulensis* on *V. destructor* mite was also investigated and a LD₅₀ of 1.74 µL/L of air was found [71].

From the surveyed literature, it was clear that the acaricidal effects of EOs from eucalyptus in some cases are high and could lead to the development of an environmental friendly commercial products to control such parasites. However, the works reported are limited to nine species of eucalyptus, concentrated in five countries. Therefore, considering the large disponibility and diversity in chemical composition of EOs from eucalyptus, we believe that EOs endowed with more potent and specific acaricidal activities are still to be discovered and converted into commercial products.

3.3. Insecticidal Activity

There are more than 1,000,000 reported species of insects, with approximately 10,000 of them showing crop-eating behavior; of these, approximately 700 species cause the majority of global pest-related damage to crops. Moreover, several diseases that affect man are transmitted by insects [168]. Therefore, controlling insects is highly desirable and necessary to improve human quality of life and health. Compounds obtained from natural sources have been investigated for their insecticidal activities [169–171]. Many such compounds have been used as models for the development of active ingredients to control insects [172–185]. In this regard, EOs have attracted the attention of researchers as an alternative to synthetic chemical-based insect control [186–193]. As shown in Table 5, EOs from many *Eucalyptus* species show positive results in controlling a variety of insect species.

The insecticidal activity of EOs from *E. globulus* was evaluated against the larvae and pupae stages of house fly *M. domestica* (Diptera: Muscidae). The effects of the EOs were assessed via fumigation and contact bioassays. Considering the larvae stage, in the contact assay the observed lethal concentration (LC₅₀) ranged from 2.73 to 0.60 µL/cm² for different days of observation, while the 50% lethality time (LT₅₀) varied from 1.7 to 6 days. The observed LC₅₀ values in the fumigation test were 66.1 and 50.1 µL/L after 24 and 48 h, respectively. Pupicidal activity was reported in terms of inhibition percentage rate (IPR) which was 36.0% to 93.0% for contact assay and 67.9% to 100% for fumigation test [122]. In another investigation, the EOs of *E. cinerea* were evaluated against adult stage of *M. domestica* via fumigation assays. An LC₅₀ of 5.5 mg/dm³ was found and the mortality of the insects was observed in a period of time of less than 15 min [81]. The major component in the oil used in this work was 1,8-cineole (56.9%), a component of several other EOs with insecticidal activity.

Table 5. *Eucalyptus* spp. essential oils with insecticidal activities.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. astringens</i>	<i>Callosobruchus maculatus</i> , <i>Ephestia cautela</i> , <i>Ephestia kuehniella</i> , <i>Rhyzopertha dominica</i> , <i>Tribolium castaneum</i>	[79,194]
<i>E. badjensis</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. badjensis</i> x <i>E. nitens</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. benthamii</i>	<i>Sitophilus zeamais</i>	[116]
<i>E. botryoides</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. camaldulensis</i>	<i>Aedes aegypti</i> , <i>Aedes albopictus</i> , <i>Atta sexdens rubropilosa</i> , <i>Ectomyelois ceratoniae</i> , <i>Ephestia cautela</i> , <i>Ephestia kuehniella</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus zeamais</i> , <i>Thyrinteina arnobia</i>	[63–67,72,78–80]
<i>E. cinerea</i>	<i>Aedes aegypti</i> , <i>Musca domestica</i> , <i>Pediculus humanus capitis</i>	[63,64,81–83]
<i>E. citriodora</i>	<i>Aedes aegypti</i> , <i>Anopheles gambia</i> , <i>Atta sexdens rubropilosa</i> , <i>Callosobruchus maculatus</i> , <i>Lutzomyia longipalpis</i> , <i>Nasutitermes corniger</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus zeamais</i> , <i>Thyrinteina arnobia</i> , <i>Tribolium castaneum</i>	[66,67,72,82,89,90,92,95,96,103–105]
<i>E. cloeziana</i>	<i>Atta sexdens rubropilosa</i> , <i>Thyrinteina arnobia</i>	[66,67]
<i>E. darlympleana</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. dorrigoensis</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. dundasii</i>	<i>Oryzaephilus surinamensis</i> , <i>Rhyzopertha dominica</i>	[197]
<i>E. dun nii</i>	<i>Aedes aegypti</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus zeamais</i>	[63,64,110,116,129]
<i>E. elata</i>	<i>Haematobia irritans</i>	[195]
<i>E. fastigata</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. fraxinoides</i>	<i>Haematobia irritans</i>	[195]
<i>E. floribundi</i>	<i>Oryzaephilus surinamensis</i> , <i>Rhyzopertha dominica</i>	[198]
<i>E. globulus</i>	<i>Aedes aegypti</i> , <i>Lutzomyia longipalpis</i> , <i>Musca domestica</i> , <i>Odontotermes assamensis</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus oryzae</i> , <i>Sitophilus zeamais</i> , <i>Tribolium castaneum</i> , <i>Tribolium confusum</i>	[63,64,72,95,110–113,116,117,120–122]
<i>E. grandis</i>	<i>Aedes aegypti</i> , <i>Atta sexdens rubropilosa</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i> , <i>Thyrinteina arnobia</i>	[65–67,129,130]
<i>E. grandis</i> x <i>E. camaldulensis</i>	<i>Aedes aegypti</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i>	[63–65,129]
<i>E. grandis</i> x <i>E. tereticornis</i>	<i>Aedes aegypti</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i>	[63–65,129]
<i>E. gunnii</i>	<i>Aedes aegypti</i> , <i>Pediculus humanus capitis</i>	[63,64,110]

Table 5. Cont.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. lehmannii</i>	<i>Callosobruchus maculatus</i> , <i>Ephestia cautela</i> , <i>Ephestia kuehniella</i> , <i>Rhyzopertha dominica</i> , <i>Tribolium castaneum</i>	[79,194]
<i>E. leucoxydon</i>	<i>Ectomyelois ceratoniae</i> , <i>Ephestia cautela</i> , <i>Ephestia kuehniella</i>	[79,80]
<i>E. maculata</i>	<i>Atta sexdens rubropilosa</i> , <i>Thyreoxena arnobia</i>	[66,67]
<i>E. nobilis</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. oblicua</i>	<i>Haematobia irritans</i>	[195]
<i>E. polybractea</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. radiata</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. resinifera</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. robertsonii</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. rubida</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. rudis</i>	<i>Ectomyelois ceratoniae</i> , <i>Ephestia cautela</i> , <i>Ephestia kuehniella</i>	[79]
<i>E. saligna</i>	<i>Acanthoscelides obtectus</i> , <i>Aedes aegypti</i> , <i>Atta sexdens rubropilosa</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus zeamais</i> , <i>Sitotroga cerealella</i> , <i>Tribolium castaneum</i> , <i>Thyreoxena arnobia</i>	[63,64,66,67,82,116,131,133]
<i>E. sideroxydon</i>	<i>Aedes aegypti</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i>	[63,64,110,129]
<i>E. smithii</i>	<i>Aedes aegypti</i> , <i>Haematobia irritans</i>	[195,196]
<i>E. staigeriana</i>	<i>Callosobruchus maculatus</i> , <i>Lutzomyia longipalpis</i>	[92,95]
<i>E. tereticornis</i>	<i>Aedes aegypti</i> , <i>Anopheles gambia</i> , <i>Pediculus humanus capitis</i>	[63–65,82,89]
<i>E. urophylla</i>	<i>Atta sexdens rubropilosa</i> , <i>Thyreoxena arnobia</i>	[66,67]
<i>E. viminalis</i>	<i>Aedes aegypti</i> , <i>Blattella germanica</i> , <i>Pediculus humanus capitis</i> , <i>Sitophilus zeamais</i>	[63,64,82,116,129]

The effects of EOs from *E. gunnii*, *E. tereticornis*, *E. grandis*, *E. camaldulensis*, *E. dunnii*, *E. cinerea*, *E. saligna*, *E. sideroxylon*, *E. globulus* ssp. *globulus*, *E. globulus* ssp. *maidenii*, *E. viminalis* and the hybrids *E. grandis* × *E. tereticornis* and *E. grandis* × *E. camaldulensis* were tested on *A. aegypti* larvae. The best results were observed for *E. dunnii*, *E. gunnii*, *E. tereticornis*, *E. camaldulensis* and *E. saligna* which presented, respectively, LC₅₀s of 25.2, 21.1, 22.1, 26.8 and 22.2 mg/L. In this work, a correlation between the toxicity effect and the EOs contents of 1,8-cineole and *p*-cymene was found. However, other *Eucalyptus* species producing EOs with high content of 1,8-cineole and low concentration of *p*-cymene (*E. cinerea*, *E. globulus* ssp. *maidenii*, *E. globulus* ssp. *globulus*, *E. sideroxylon*, *E. viminalis*, *E. grandis*, *E. tereticornis*, *E. grandis*, and *E. camaldulensis*) had a lower effect on *A. aegypti* (larval mortality < 50% after 24 h at 40 ppm) [63,64]. The vapor of the EOs of the aforementioned *Eucalyptus* species were also tested on *A. aegypti* adults. The toxicity was determined as the number of knockdown mosquitoes as a function of time. The fumigation toxicity was expressed as knockdown effect time (KT₅₀) which varied from 4.2 to 12.0 min. The best result was observed for *E. viminalis* EOs. In this case, a direct correlation was found between the EO 1,8-cineole contents and toxicity level [64].

The investigation carried out by Cheng and co-workers [78] demonstrated larvicidal activity of *E. camaldulensis* and *E. urophylla* EOs against *A. aegypti* and *A. albopictus*. The EOs from *E. camaldulensis* presented the best results with LC₅₀ of 31.0 and 55.3 µg/mL, respectively (the corresponding LC₉₀ were 71.8 and 192.4 µg/mL for *A. aegypti* and *A. albopictus*, respectively). The larvicidal activity of individual components of *E. camaldulensis* EOs was also assessed. It was observed that α-terpinene caused the highest larvicidal activity (LC₅₀ of 14.7 µg/mL and LC₉₀ of 39.3 µg/mL for *A. aegypti*; LC₅₀ of 25.2 µg/mL and LC₉₀ > 50.0 µg/mL for *A. albopictus*). The EOs from *E. citriodora* were toxic to third and fourth instar of *A. aegypti* (LC₅₀ 71.2 ppm) [103].

L. longipalpis is the vector of *Leishmania chagasi*, a protozoan species which is responsible for 90% of visceral leishmaniasis in Brazil. The effects of EOs of *E. staigeriana*, *E. citriodora* and *E. globulus* were evaluated on eggs, larva and adult phases of *L. longipalpis*. All EOs were active on the evaluated phases being *E. staigeriana* the most effective one, followed by *E. citriodora* and *E. globulus* [95]. Although the authors have not assessed individual essential oil components for their activities, it is worth pointing out that the EOs had citronellal as major component (71.8%), a compound known for its insecticidal activity.

The major pest of maize *S. zeamais* is known to attack both standing crop and the stored cereal. Investigations on the insecticidal and repellent effects of *E. dunnii*, *E. saligna*, *E. benthamii*, *E. globulus* and *E. viminalis* EOs on *S. zeamais* were carried out. By using the contact cytotoxicity assay on filter paper, EOs from *E. globulus* and *E. viminalis* caused 100% mortality at concentrations of 0.16 and 0.23 µL/cm² after 24 h of exposure, respectively. Considering this parameter, the concentration values for other EOs were as follows: 0.42 µL/cm² for *E. dunnii*, 0.65 µL/cm² for *E. saligna* and 2.60 µL/cm² *E. benthamii*. A regression analysis allowed the calculation of LC₅₀ values: *E. viminalis* (0.08 µL/cm²); *E. globulus* (0.10 µL/cm²); *E. dunnii* (0.16 µL/cm²); *E. saligna* (0.25 µL/cm²) and *E. benthamii* (0.79 µL/cm²). The analysis of essential oil content and mortality activity resulted in a correlation between 1,8-cineole content and LC₅₀. Thus, it is plausible to consider this compound responsible for the observed activity. Using the calculated LC₅₀, it was possible to determine the repellency activity for all *Eucalyptus* EOs [116].

Among the components of EOs, monoterpenoids have contributed to fumigant activity against storage product pests [199], and it has been shown that they are lethal to insects by inhibiting the enzyme acetylcholinesterase activity (AChE) [200]. The repellent activity of *E. saligna*, *E. camaldulensis*, *E. globulus* and *E. citriodora* EOs were also assayed against *S. zeamais*. Y-shape olphatometer bioassay was utilized and the concentration tested range from 0.002 to 2 µL/µL. EOs were dissolved in hexane and at the highest concentration, *E. camaldulensis* and *E. citriodora* EOs presented the best repellent activity (74.35% and 69.15%, respectively), followed by *E. globulus* (53.68%) and *E. saligna* (40.5%). The repellent activity observed for *E. camaldulensis* EOs was higher than that observed for the positive

control *N-N*-diethyl *m*-toluamide (DEET). Some individual constituents of the EOs were assayed and the highest repellent activity was associated with 1,8-cineole content (70.87%) [72].

The fumigant toxicity of several EOs was evaluated on *S. oryzae* (also known as the rice weevil). The best activity was associated with *E. globulus* EOs (LD₅₀ of 28.9 µL/L of air). Individual assessment of 1,8-cineole, the major component of *E. globulus* EOs, revealed a LD₅₀ of 23.5 µL/L of air for the fumigant toxicity [113].

The EOs from *E. globulus*, rich in 1,8-cineole, had their antitermite activity evaluated against *O. assamensis*. At the concentration of 2.5 mg/g, *E. globulus* EOs caused 80% mortality while 70% was observed for pure 1,8-cineole [120]. These results suggest that other compounds present in the oil might be enhancing the effect of 1,8-cineole.

P. humanus capitis (head louse) is an obligate ectoparasite responsible for the head lice infestation, also known as pediculosis capitis, nits or cooties. Several reports have described the effects of *Eucalyptus* EOs on *P. humanus capitis*. The fumigant toxicity assay was utilized to evaluate the effect of EOs from *E. sideroxylon*, *E. globulus* ssp. *globulus*, *E. globulus* ssp. *maidenii*, *E. dunnii*, and *E. gunnii* on head lice resistant to permethrin. Among the evaluated EOs, the most efficient ones were *E. sideroxylon*, *E. globulus* ssp. *globulus* and *E. globulus* ssp. *maidenii* presenting, respectively, KT₅₀ of 24.75, 27.73, and 31.39 min [110]. A similar investigation conducted with EOs from *E. cinerea*, *E. viminalis* and *E. saligna* revealed KT₅₀ values of 12.0, 14.9, and 17.4 min [82]. A comparative investigation on the effect of EOs from hybrids (*E. grandis* × *E. camaldulensis* and *E. grandis* × *E. tereticornis*) and non-hybrids (*E. grandis*, *E. camaldulensis*, and *E. tereticornis*) eucalyptus species on *P. humanus capitis* was carried out. The fumigant activity of hybrids was higher than non-hybrid ones. The observed KT₅₀ values for the hybrid were *E. grandis* × *E. tereticornis* (12.99 min) and *E. grandis* × *E. camaldulensis* (13.63 min). For the non-hybrid, the values for KT₅₀ parameter were *E. grandis* (25.57 min), *E. camaldulensis* (35.01 min) and *E. tereticornis* (31.31 min) [65].

E. citriodora leaves has been traditionally used as insecticide repellent, especially by low income families to protect themselves against mosquitoes [201].

The red flour beetle *T. castaneum* is a worldwide pest of stored products, particularly food grains. The EOs of *E. citriodora*, rich in citronellal, citronellol and isopulegol, presents repellent activity against this beetle species (0.084 mL/L dose repellent media after 4 h of exposure). The observed activity was higher than the commercial product ethyl 3-(*N*-acetyl-*N*-butylamino) propionate used as positive control [104].

The evaluation of fumigant activity of EOs from *E. camaldulensis*, *E. astringens*, *E. leucoxydon*, *E. lehmannii* and *E. rudis* against the pests of stored products *E. kuehniella*, *E. cautella* and *E. ceratoniae* showed that *E. camaldulensis* EOs present high toxicity on *E. cautella* and *E. kuehniella* (LC₅₀ = 11.07 and 26.73 µL/L of air, respectively). Considering *E. ceratoniae*, the most effective EOs were extracted from *E. rudis* (LC₅₀ = 31.4 µL/L of air) [79]. In another study, the effects of *E. camaldulensis* and *E. leucoxydon* EOs on larvae and adult stages of *E. ceratoniae* were investigated. The EOs presented bioactivity on both stages of the insect development. For adult stage, 100% mortality was achieved for both EOs after 120 h of exposure at 26.31 µL/L of air; at higher concentration (131.58 µL/L of air) the exposure time was reduced to 48 h. The LC₅₀ after 24 h of exposure corresponded to 12.07 µL/L of air and 21.75 µL/L of air for *E. camaldulensis* and *E. leucoxydon*, respectively. Considering the larvae stage, 100% mortality was observed at 131.58 µL/L of air after 264 h of exposure [80].

The EOs from *E. tereticornis*, at the concentration of 160 ppm, caused 100% mortality on the larvae of *Anopheles stephensi* [202]. The observed insecticidal activity of *E. tereticornis* EOs on *A. gambiae* was associated to *p*-cymene and 1,8-cineole as demonstrated by the biological assays conducted with these individual components [89].

3.4. Herbicidal Activity

Weeds compete with crops for water, nutrients and light, and controlling their growth is of fundamental importance in modern agriculture. It is estimated that approximately 10% of all plant

species are weeds, corresponding to approximately 30,000 species. Among them, some 1800 cause serious economic losses in crop production [203].

The observation of plant growth regulation effects caused by EOs has attracted the attention of researchers toward the possibility of utilizing these natural sources for weed control [136,204]. Such investigations are important from the viewpoint of evolution of resistance of weeds to traditional herbicides. There is a constant need for the development of weed control agents that are environmentally benign, present low toxicity to mammals, less recalcitrant, and can be applied in less quantity [205–207]. In this regard, nature has been considered an important source of compounds that can be explored to provide herbicides that can meet the aforementioned criteria [206,208,209].

As shown in Table 6, several studies have been conducted on the phytotoxic effects of *Eucalyptus* EOs on weeds [31,136,210,211]. It has been demonstrated that these EOs inhibit and/or retard the germination of seeds. Effects on crop species have also been described [18].

Table 6. *Eucalyptus* spp. essential oils with herbicidal activities.

<i>Eucalyptus</i> spp.	Target Species	Reference
<i>E. brockwayii</i>	<i>Solanum elaeagnifolium</i>	[212,213]
<i>E. camaldulensis</i>	<i>Amaranthus hybridus</i> , <i>Portulaca oleracea</i>	[76]
<i>E. citriodora</i>	<i>Amaranthus viridis</i> , <i>Cassia occidentalis</i> , <i>Cucumis sativus</i> , <i>Echinochloa crus-galli</i> , <i>Oryza sativa</i> , <i>Sorghum bicolor</i> , <i>Triticum aestivum</i>	[26,54,99]
<i>E. dundasii</i>	<i>Solanum elaeagnifolium</i>	[212,213]
<i>E. erythrocorys</i>	<i>Phalaris canariensis</i> , <i>Sinapis arvensis</i>	[158]
<i>E. melliodora</i>	<i>Solanum elaeagnifolium</i>	[213]
<i>E. salubris</i>	<i>Solanum elaeagnifolium</i>	[212,213]
<i>E. spathulata</i>	<i>Solanum elaeagnifolium</i>	[212,213]
<i>E. urophylla</i>	<i>Lactuca sativa</i>	[214]

The phytotoxic effect of *E. citriodora* EOs collected from leaves at different stages (juvenile and adult leaves) and fallen (senescent leaves and brown leaf litter) has been investigated on two weed species (*E. crus-galli* and *A. viridis*) and two crops (*T. aestivum* and *O. sativa*). As a general trend, the adult leaf EOs presented superior phytotoxicity compared to leaf litter EOs. In a subsequent investigation, Batish and co-workers [26] examined the phytotoxic effects of EOs extracted from decaying leaves of *E. citriodora* against weed species *C. occidentalis* and *E. crus-galli*. Also, the phytotoxicity of EOs major components, i.e., citronellal and citronellol, were also assessed. The EOs exhibited superior effect on the germination of *C. occidentalis* ($I_{50} = 1.09$ mg/mL) compared to *E. crus-galli* ($I_{50} = 1.49$ mg/mL). The EOs presented similar effects on root elongation ($I_{50} = 0.31$ mg/mL for *C. occidentalis* and 0.35 mg/mL for *E. crus-galli*). Comparing the effect of the major components on germination, citronellal was more effective in inhibiting the germination ($I_{50} = 0.55$ mg/mL and 0.14 mg/mL for *C. occidentalis* and *E. crus-galli*, respectively). On the contrary, citronellol caused a more pronounced effect on root elongation ($I_{50} = 0.13$ mg/mL and 0.09 mg/mL for *C. occidentalis* and *E. crus-galli*, respectively).

Silverleaf nightshade (*S. elaeagnifolium*) is a perennial and aggressive weed species common in Australia. The effect of five selected *Eucalyptus* EOs from Australia, namely *E. brockwayii*, *E. dundasii*, *E. melliodora*, *E. salubris* and *E. spathulata*, on germination and root elongation of *S. elaeagnifolium* was evaluated. The EOs from *E. salubris* caused the highest (73%) inhibitory effect on germination. This effect was superior to that observed by commercial eucalyptus EOs (38% of inhibition index) purchased from the market and used as positive control. In terms of root growth inhibition, *E. salubris* was again the most effective EOs (reduction of 84% of root elongation when applied at 10 μ L/dish). At the same dose, commercial eucalyptus EOs caused only 41% decrease in root length [212]. The phytotoxic effects of aqueous volatile fractions of the aforementioned EOs, i.e., the water soluble volatile fractions obtained along with the EOs (water insoluble fractions) during the steam distillation process were also assessed. It was also observed strong phytotoxic effects on germination, shoot length and root elongation of *S. elaeagnifolium* [213].

Shingh and co-workers [31] investigated the herbicidal effect of EOs produced by *E. citriodora* against the weed species *Parthenium hysterophorus*. They found that germination has been fully inhibited by the EOs (dose used 5.0 nL/mL). Plants of *P. hysterophorus* (4-week-old) were sprayed with different concentrations of EOs (0–100 µL/mL). A week after spraying, damage and decreased chlorophyll content and respiratory activity as the EOs concentration increased was noticed. When sprayed with concentrations up to 50 µL/mL, plants showed recovery over time. However, when the weed species were sprayed with 75 µL/mL and 100 µL/mL, plants died after two weeks. Moreover, plants sprayed with 50 µL/mL and concentrations higher than that were desiccated and wilted. *E. citriodora* EOs caused rapid electrolyte leakage at concentrations of 5–75 µL/mL indicating an effect on membrane integrity.

Phytotoxic effects of *E. citriodora* EOs on the crops *S. bicolor* L. (sorghum) and *C. sativus* L. (cucumber) have been reported. From the biological essays, an allelopathic effect was observed mainly causing germination and radicle growth inhibition of *S. bicolor* and *C. sativus* seeds. It was also observed that the increase of EOs concentration (0 to 5000 ppm) leads to a linear decrease in the germination as well as in the radicle length of *S. bicolor* [99].

4. Concluding Remarks

The world production and trade of EOs from several *Eucalyptus* species is dominated by China which is the biggest producer of EOs rich in 1,8-cineole [215]. Other important producers include South Africa, Portugal, Spain, Brazil, Australia, Chile and Swaziland [45]. There are important aspects to be considered with respect to cultivation of *Eucalyptus* spp. aimed for production of EOs such as environmental, genetic variation and leaf type.

The majority of EOs produced by *Eucalyptus* are rich in monoterpenes. For medicinal purposes, the value of *Eucalyptus* EOs is directly associated to its content of 1,8-cineole that should be at least 70% in mass. It should be mentioned that medicinal EOs are designated in terms of 1,8-cineole content. Typical descriptions for such oils are: “*Eucalyptus* oil China 80%”, “*Eucalyptus* oil 70/75% Spain/Portugal” and “*Eucalyptus* oil 80/85% Spain/Portugal”. The highest price is associated with an essential oil known as ‘eucalyptol’ which contains about 98% 1,8-cineole [45,216]. In Table 7 the main *Eucalyptus* species that have been used for the extraction of medicinal essential oils are listed [217,218].

Table 7. *Eucalyptus* species typically used to produce medicinal essential oils.

<i>Eucalyptus</i> spp.	1,8-Cineole (%)	Reference
<i>E. camaldulensis</i>	80–90	[217,218]
<i>E. cineorifolia</i>	40–90	[217,218]
<i>E. dumosa</i>	33–70	[217,218]
<i>E. elaeophora</i>	60–80	[217,218]
<i>E. globulus</i>	60–85	[217,218]
<i>E. leucoxydon</i>	65–75	[217,218]
<i>E. oleosa</i>	45–52	[217,218]
<i>E. polybractea</i>	60–93	[217,218]
<i>E. radiata</i> subsp. <i>radiata</i> var. <i>cineole</i>	65–75	[217,218]
<i>E. sideroxydon</i>	60–75	[217,218]
<i>E. smithii</i>	70–80	[217,218]

In several cases according to the source, after extraction certain crude EOs have to be rectified to increase the percentage of 1,8-cineole required for medicinal purposes.

The EOs intended for use in perfumery are rich in citronellal, citronellol and geranyl acetate. One important source of perfumery *Eucalyptus* EOs is *E. citriodora* in which the major component is citronellal and its content should be in the range 65%–85%. The essential oils of *E. citriodora* are used in whole form for fragrance purposes, usually in lower-cost soaps, perfumes and disinfectants, but their main use is as a source of citronellal for the chemical industry [45,216,219].

The term industrial oil is commonly used to describe the use of the EOs as raw materials for the isolation of their chemical constituents. The industrial EOs are characterized by high levels of phellandrene and piperitone, and mainly obtained from *E. dives* species [216].

As described by Coppen [220] “any attempt to accurately quantify and analyse production and consumption trends for *Eucalyptus* oil is fraught with difficulties. Unlike some other commodities, or some other EOs such as the citrus oils, quantitative information is not always available or accessible”.

Research on EOs is of fundamental importance considering the current applications of natural extracts and EOs in the food, cosmetic, perfume, pharmaceutical, and agrochemical industries. In this review, the large chemical variability that exists among EOs from several species of *Eucalyptus* was demonstrated. In addition, the usefulness of those EOs in terms of their antimicrobial, insecticidal, acaricidal, and phytotoxic activity was described. In some cases, the observed biological activity of the EOs is superior to that of the products available in the market, but there is very limited research about the mechanism of action of the biological activities of such EOs. Considering all such aspects, and taking into consideration that several species of *Eucalyptus* are still unexplored in terms of their essential oil content and composition, we envisage that investigations in this field will continue to be active in the future. New activities will be reported for *Eucalyptus* EOs and further details on their mechanisms of action will also appear in the future.

Supplementary Materials: Supplementary materials can be accessed at: <http://www.mdpi.com/1420-3049/21/12/1671/s1>. Table S1. Major chemical components for *Eucalyptus* spp. essential oils.

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References

1. Paterson, I.; Anderson, E.A. The renaissance of natural products as drug candidates. *Science* **2005**, *310*, 451–453. [CrossRef] [PubMed]
2. Koehn, F.E.; Carter, G.T. The evolving role of natural products in drug discovery. *Nat. Rev. Drug Discov.* **2005**, *4*, 206–220. [CrossRef] [PubMed]
3. Newman, D.J.; Cragg, G.M. Natural product as sources of new drugs over the last 25 years. *J. Nat. Prod.* **2007**, *70*, 461–477. [CrossRef] [PubMed]
4. Harvey, A.L.; Edrada-Ebel, R.A.; Quinn, R.J. The re-emergence of natural products for drug discovery in the genomics era. *Nat. Rev. Drug Discov.* **2015**, *14*, 111–129. [CrossRef] [PubMed]
5. Newman, D.J.; Cragg, G.M. Natural products as sources of new drugs over the 30 years from 1981 to 2010. *J. Nat. Prod.* **2012**, *75*, 311–335. [CrossRef] [PubMed]
6. Gbenou, J.D.; Ahounou, J.F.; Akakpo, H.B.; Laleye, A.; Yayi, E.; Gbaguidi, F.; Baba-Moussa, L.; Darboux, R.; Dansou, P.; Moudachirou, M.; et al. Phytochemical composition of *Cymbopogon citratus* and *Eucalyptus citriodora* EOs and their anti-inflammatory and analgesic properties on Wisstar rats. *Mol. Biol. Rep.* **2013**, *40*, 1127–1134. [CrossRef] [PubMed]
7. Arantes, F.F.P.; Barbosa, L.C.A.; Maltha, C.R.A.; Demuner, A.J.; Costa, P.M.; Ferreira, J.R.O.; Costa-Lotufo, L.V.; Moraes, M.O.; Pessoa, C. Synthesis of novel α -santonin derivatives as potential cytotoxic agents. *Eur. J. Med. Chem.* **2010**, *45*, 6045–6051. [CrossRef] [PubMed]
8. Paula, V.F.; Barbosa, L.C.A.; Demuner, A.J.; Veloso, D.P.; Picanço, M.C. Synthesis and insecticidal activity of new amide derivatives of piperine. *Pest Manag. Sci.* **2000**, *56*, 168–174. [CrossRef]
9. Barbosa, L.C.A.; Alvarenga, E.S.; Demuner, A.J.; Virtuoso, L.S.; Silva, A.A. Synthesis of new phyto-growth-inhibitory substituted aryl-*p*-benzoquinones. *Chem. Biodivers.* **2006**, *3*, 553–567. [CrossRef] [PubMed]
10. Cantrell, C.L.; Dayan, F.E.; Duke, S.O. Natural Products as sources of new pesticides. *J. Nat. Prod.* **2012**, *75*, 1231–1242. [CrossRef] [PubMed]
11. Copping, L.G.; Duke, S.O. Natural products that have been used commercially as crop protection agents. *Pest Manag. Sci.* **2007**, *63*, 524–554. [CrossRef] [PubMed]

12. Gerwick, B.C.; Sparks, T.C. Natural products for pest control: An analysis of their role, value and future. *Pest Manag. Sci.* **2014**, *70*, 1169–1185. [[CrossRef](#)] [[PubMed](#)]
13. Lima, L.S.; Barbosa, L.C.A.; Alvarenga, E.S.; Demuner, A.J.; Silva, A.A. Synthesis and phytotoxicity evaluation of substituted *para*-benzoquinones. *Aust. J. Chem.* **2003**, *36*, 625–630. [[CrossRef](#)]
14. Kalembe, D.; Kunicka, A. Antibacterial and antifungal properties of EOs. *Curr. Med. Chem.* **2003**, *10*, 813–829. [[CrossRef](#)] [[PubMed](#)]
15. Bakkali, F.; Averbeck, S.; Averbeck, D.; Idaomar, M. Biological effects of EOs—A review. *Food Chem. Toxicol.* **2008**, *46*, 446–475. [[CrossRef](#)] [[PubMed](#)]
16. Silva, C.J.; Barbosa, L.C.A.; Demuner, A.J.; Montanari, R.M.; Francino, D.; Meira, R.M.S.A.; Souza, A.O. Chemical composition and histochemistry of *Sphagneticola trilobata* essential oil. *Rev. Bras. Farmacogn.* **2012**, *22*, 482–489. [[CrossRef](#)]
17. Gilles, M.; Zhao, J.; An, M.; Agboola, S. Chemical composition and antimicrobial properties of EOs of three Australian *Eucalyptus* species. *Food Chem.* **2010**, *119*, 731–737. [[CrossRef](#)]
18. Ens, E.J.; Bermner, J.B.; French, K.; Korth, J. Identification of volatile compounds released by roots of an invasive plant, bitou bush (*Chrysanthemoides monilifera* spp. *rotundata*), and their inhibition of native seedling growth. *Biol. Invasions* **2009**, *11*, 275–287. [[CrossRef](#)]
19. Passos, J.L.; Meira, R.M.S.A.; Barbosa, L.C.A.; Barreto, R.W. Foliar anatomy of the species *Lantana camara* and *L. radula* (Verbenaceae). *Planta Daninha* **2009**, *27*, 689–700. [[CrossRef](#)]
20. Sefidkon, F.; Assareh, M.H.; Abravesh, Z.; Barazandeh, M.M. Chemical composition of the EOs of four cultivated *Eucalyptus* species in Iran as medicinal plants (*E. microtheca*, *E. spathulata*, *E. largiflorens* and *E. torquata*). *Iran. J. Pharm. Res.* **2007**, *6*, 135–140.
21. Si, W.; Gong, J.; Tsao, R.; Zhou, T.; Yu, H.; Poppe, C.; Johnson, R.; Du, Z. Antimicrobial activity of EOs and structurally related synthetic food additives towards selected pathogenic and beneficial gut bacteria. *J. Appl. Microbiol.* **2006**, *100*, 296–305. [[CrossRef](#)] [[PubMed](#)]
22. Langenheim, J.H. Higher plant terpenoids: Phyto-centric overview of their ecological roles. *J. Chem. Ecol.* **1994**, *20*, 1223–1280. [[CrossRef](#)] [[PubMed](#)]
23. Holopainen, J.L. Multiple functions of inducible plant volatiles. *Trends Plant Sci.* **2004**, *9*, 529–533. [[CrossRef](#)] [[PubMed](#)]
24. Penuelas, J.; Llusà, J. Plant VOC emissions: Making use of the unavoidable. *Trends Ecol. Evol.* **2004**, *19*, 402–404. [[CrossRef](#)] [[PubMed](#)]
25. Barbosa, L.C.A.; Demuner, A.J.; Dumont, A.C.; Paula, V.F.; Ismail, F.M.D. Seasonal variation in the composition of volatile oils from *Schinus terebinthifolius* Raddi. *Quím. Nova* **2007**, *30*, 1959–1965. [[CrossRef](#)]
26. Batish, D.R.; Singh, H.P.; Setia, N.; Kaur, S.; Kohli, R.K. Chemical composition and inhibitory activity of essential oil from decaying leaves of *Eucalyptus citriodora*. *Z. Naturforsch.* **2006**, *61*, 52–56. [[CrossRef](#)]
27. Angelini, L.G.; Carpanese, G.; Cioni, P.L.; Morelli, I.; Macchia, M.; Flamni, G. EOs from Mediterranean Lamiaceae as weed germination inhibitors. *J. Agric. Food Chem.* **2003**, *51*, 6158–6164. [[CrossRef](#)] [[PubMed](#)]
28. Barney, J.N.; Hay, A.G.; Weston, L.A. Isolation and characterization of volatiles from mugwort. *J. Chem. Ecol.* **2005**, *31*, 247–265. [[CrossRef](#)] [[PubMed](#)]
29. Dudai, N.; Mayer, A.M.; Putievsky, E.; Lerner, H.R. Essential oil as allelochemicals and their potential use as bioherbicides. *J. Chem. Ecol.* **1999**, *25*, 1079–1089. [[CrossRef](#)]
30. Tworzoski, T. Herbicide effects of essential oil. *Weed Sci.* **2002**, *50*, 425–431. [[CrossRef](#)]
31. Singh, H.P.; Batish, D.R.; Setia, N.; Kohli, R.K. Herbicidal activity of volatile oils from *Eucalyptus citriodora* against *Parthenium hysterophorus*. *Ann. Appl. Biol.* **2005**, *146*, 89–94. [[CrossRef](#)]
32. Isman, M.B. Plant EOs for pest and disease management. *Crop Prot.* **2000**, *19*, 603–608. [[CrossRef](#)]
33. Montanari, R.M.; Barbosa, L.C.A.; Demuner, A.J.; Silva, C.J.; Carvalho, L.S.; Andrade, N.J. Chemical composition and antibacterial activity of essential oils from Verbenaceae species: Alternative sources of (*E*)-caryophyllene and germacrene-D. *Quím. Nova* **2011**, *34*, 1550–1555. [[CrossRef](#)]
34. Nascimento, J.C.; Barbosa, L.C.A.; Paula, V.F.; David, J.M.; Fontana, R.; Silva, L.A.M.; França, R.S. Chemical composition and antimicrobial activity of essential oils of *Ocimum canum* Sims. and *Ocimum selloi* Benth. *Ann. Acad. Bras. Cienc.* **2011**, *83*, 787–799. [[CrossRef](#)]
35. Demuner, A.J.; Barbosa, L.C.A.; Magalhães, C.G.; Silva, C.J.; Maltha, C.R.A.; Pinheiro, A.L. Seasonal variation in the chemical composition and antimicrobial activity of volatile oils of three species of *Leptospermum* (Myrtaceae) grown in Brazil. *Molecules* **2011**, *16*, 1181–1191. [[CrossRef](#)] [[PubMed](#)]

36. Silva, C.J.; Barbosa, L.C.A.; Demuner, A.J.; Montanari, R.M.; Pinheiro, A.L.; Dias, I.; Andrade, N.J. Chemical composition and antibacterial activities from the essential oils of Myrtaceae species planted in Brazil. *Quím. Nova* **2010**, *33*, 104–108. [[CrossRef](#)]
37. Martins, F.T.; Doriguetto, A.C.; Souza, T.C.; Souza, K.R.D.; Santos, M.H.; Moreira, M.E.C.; Barbosa, L.C.A. Composition, and anti-inflammatory and antioxidant activities of the volatile oil from the fruit peel of *Garcinia brasiliensis*. *Chem. Biodivers.* **2008**, *5*, 251–258. [[CrossRef](#)] [[PubMed](#)]
38. Burt, S. EOs: Their antibacterial properties and potential applications in foods—A review. *Int. J. Food Microbiol.* **2004**, *94*, 223–253. [[CrossRef](#)] [[PubMed](#)]
39. Stefanakis, M.K.; Touloupakis, E.; Anastasopoulos, E.; Ghanotakis, D.; Katerinopoulos, H.E.; Makridis, P. Antibacterial activity of EOs from plants of the genus *Origanum*. *Food Control* **2013**, *34*, 539–546. [[CrossRef](#)]
40. Hill, K.D.; Johnson, L.A.S. Systematic studies in the eucalypts. 7. A revision of the bloodwoods, genus *Corymbia* (Myrtaceae). *Telopea* **1995**, *6*, 185–504. [[CrossRef](#)]
41. Pereira, V.; Dias, C.; Vasconcelos, M.C.; Rosa, E.; Saavedra, M.J. Antibacterial activity and synergistic effects between *Eucalyptus globulus* leaf residues (EOs and extracts) and antibiotics against several isolates of respiratory tract infections (*Pseudomonas aeruginosa*). *Ind. Crops Prod.* **2014**, *52*, 1–7. [[CrossRef](#)]
42. Bello, M.O.; Olabanji, I.O.; Ibrahim, A.O.; Yekeen, T.A.; Oboh, L.M. Nutraceuticals in leaves of *Eucalyptus citriodora* and *Eucalyptus camandulensis*. *Food Sci.* **2013**, *62*, 17873–17876.
43. Tyagi, A.K.; Malik, A. Antimicrobial potential and chemical composition of *Eucalyptus globulus* oil in liquid and vapour phase against food spoilage microorganisms. *Food Chem.* **2011**, *126*, 228–235. [[CrossRef](#)]
44. Araujo, F.O.L.; Rietzler, A.C.; Duarte, L.P.; Silva, G.D.F.; Carazza, F.; Filho, S.A.V. Constituintes químicos e efeito ecotoxicológico do óleo volátil de folhas de *Eucalyptus urograndis* (Mirtaceae). *Quím. Nova* **2010**, *33*, 1510–1513. [[CrossRef](#)]
45. Bizzo, H.R.; Hovell, A.M.C.; Rezende, C.M. Óleos essenciais no Brasil: Aspectos gerais, desenvolvimento e perspectivas. *Quím. Nova* **2009**, *32*, 588–594. [[CrossRef](#)]
46. Pino, J.A.; Marbot, R.; Quert, R.; Garcia, H. Study of EOs of *Eucalyptus resinifera* Smith, *E. tereticornis* Smith and *Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson, grown in Cuba. *Flavour Frag. J.* **2002**, *17*, 1–4.
47. Vuong, Q.V.; Chalmers, A.C.; Bhuyan, D.J.; Bowyer, M.C.; Scarlett, C.J. Botanical, phytochemical, and anticancer properties of the *Eucalyptus* species. *Chem. Biodivers.* **2015**, *12*, 907–924. [[CrossRef](#)] [[PubMed](#)]
48. Zhang, J.; An, M.; Wu, H.; Stanton, R.; Lemerle, D. Chemistry and bioactivity of *Eucalyptus* essential oils. *Allelopathy J.* **2010**, *25*, 313–330.
49. Elaissi, A.; Salah, K.H.; Mabrouk, S.; Larbi, K.M.; Chemli, R.; Harzallah-Skhiri, F. Antibacterial activity and chemical composition of 20 *Eucalyptus* species' EOs. *Food Chem.* **2011**, *129*, 1427–1434. [[CrossRef](#)]
50. Watanabe, K.; Shono, Y.; Kakimizu, A.; Okada, A.; Matsuo, N.; Satoh, A.; Nishimura, H. New mosquito repellent from *Eucalyptus camaldulensis*. *J. Agric. Food Chem.* **1993**, *41*, 2164–2166. [[CrossRef](#)]
51. Li, H.; Madden, J.L.; Potts, B.M. Variation in volatile leaf oils of the Tasmanian *Eucalyptus* species I. Subgenus *Monocalyptus*. *Biochem. Syst. Ecol.* **1995**, *23*, 299–318. [[CrossRef](#)]
52. Li, H.; Madden, J.L.; Potts, B.M. Variation in volatile leaf oils of the Tasmanian *Eucalyptus* species II. Subgenus *Symphomyrtus*. *Biochem. Syst. Ecol.* **1996**, *24*, 547–569. [[CrossRef](#)]
53. Cimanga, K.; Kambu, K.; Tona, L.; Apers, S.; de Bruyne, T.; Hermans, N.; Totté, J.; Pieters, L.; Vlietinck, A.J. Correlation between chemical composition and antibacterial activity of EOs of some aromatic medicinal plants growing in the Democratic Republic of the Congo. *J. Ethnopharmacol.* **2002**, *79*, 213–220. [[CrossRef](#)]
54. Batish, D.R.; Singh, H.P.; Setia, N.; Kaur, S.; Kohli, R.K. Chemical composition and phytotoxicity of volatile essential oil from intact and fallen leaves of *Eucalyptus citriodora*. *Z. Naturforsch.* **2006**, *61*, 465–471. [[CrossRef](#)]
55. Quereshi, S.; Upadhyay, A.; Singh, R.; Khan, N.A.; Mani, A.; Patel, J. GC Analysis of EOs, TLC Profiling of Pigments and DNA Extraction from *Eucalyptus* Species. *Curr. Bot.* **2011**, *2*, 23–26.
56. Silva, F.; Santos, R.H.S.; Andrade, N.J.; Barbosa, L.C.A.; Casali, V.W.D.; Lima, R.R.; Passarinho, R.V.M. Basil conservation affected by cropping season, harvest time and storage period. *Pesq. Agropec. Bras.* **2005**, *40*, 323–328. [[CrossRef](#)]
57. Barbosa, F.F.; Barbosa, L.C.A.; Melo, E.C.; Botelho, F.M.; Santos, R.H.S. Influência da temperatura do ar de secagem sobre o teor e a composição química do óleo essencial de *Lippia alba* (Mill) N. E. Brown. *Quím. Nova* **2006**, *29*, 1221–1225. [[CrossRef](#)]
58. Lemos, D.R.H.; Melo, E.C.; Rocha, R.P.; Barbosa, L.C.A.; Pinheiro, A.L. Influence of drying air temperature on the chemical composition of the essential oil of melaleuca. *Eng. Agric.* **2012**, *20*, 5–11. [[CrossRef](#)]

59. Pimentel, F.A.; Cardoso, M.G.; Guimarães, L.G.L.; Queiroz, F.; Barbosa, L.C.A.; Morais, A.R.; Nelson, D.L.; Andrade, M.A.; Zacaroni, L.M.; Pimentel, S.M.N.P. Extracts from the leaves of *Piper piscatorum* (Trel. Yunc.) obtained by supercritical extraction of with CO₂, employing ethanol and methanol as co-solvents. *Ind. Crops Prod.* **2013**, *43*, 490–495. [[CrossRef](#)]
60. Bignell, C.M.; Dunlop, P.J.; Brophy, J.J.; Fookes, C.J.R. Volatile leaf oils of some South-western and Southern Australian species of the genus *Eucalyptus* (Series I). Part XIV. Subgenus *Monocalyptus*. *Flavour Frag. J.* **1997**, *12*, 177–183. [[CrossRef](#)]
61. Gonçalves, L.A.; Barbosa, L.C.A.; Azevedo, A.A.; Casali, V.W.D.; Nascimento, E.A. Produção e composição do óleo essencial de alfavaquinha (*Ocimum selloi* Benth.) em resposta a dois níveis de radiação solar. *Rev. Bras. Plantas Med.* **2003**, *6*, 8–14.
62. Silva, A.F.; Barbosa, L.C.A.; Silva, E.A.M.; Casali, V.W.D.; Nascimento, E.A. Composição química do óleo essencial de *Hyptis suaveolens* (L.) Poit. (Lamiaceae). *Rev. Bras. Plantas Med.* **2003**, *6*, 1–7.
63. Lucia, A.; Licastro, S.; Zerba, E.; Masuh, H. Yield, chemical composition, and bioactivity of EOs from 12 species of *Eucalyptus* on *Aedes aegypti* larvae. *Entomol. Exp. Appl.* **2008**, *129*, 107–114. [[CrossRef](#)]
64. Lucia, A.; Licastro, S.; Zerba, E.; Gonzalez, A.P.; Masuh, H. Sensitivity of *Aedes aegypti* adults (Diptera: Culicidae) to the vapors of *Eucalyptus* EOs. *Bioresour. Technol.* **2009**, *100*, 6083–6087. [[CrossRef](#)] [[PubMed](#)]
65. Toloza, A.; Lucia, A.; Zerba, E.; Masuh, H.; Picollo, M.I. Interspecific hybridization of *Eucalyptus* as a potential tool to improve the bioactivity of EOs against permethrin-resistant head lice from Argentina. *Bioresour. Technol.* **2008**, *99*, 7341–7347. [[CrossRef](#)] [[PubMed](#)]
66. Batista-Pereira, L.G.; Fernandes, J.B.; Silva, M.F.G.F.; Vieira, P.C.; Bueno, O.C.; Correia, A.G. Electrophysiological responses of *Atta sexdens rubropilosa* workers to EOs of *Eucalyptus* and its chemical composition. *Z. Naturforsch.* **2006**, *61*, 749–755.
67. Batista-Pereira, L.G.; Fernandes, J.B.; Correa, A.G.; da Silva, M.F.G.F.; Vieira, P.C. Electrophysiological responses of *Eucalyptus* brown looper *Thyrintina arnobia* to EOs of seven *Eucalyptus* species. *J. Braz. Chem. Soc.* **2006**, *17*, 555–561. [[CrossRef](#)]
68. Filomeno, C.A.; Barbosa, L.C.A.; Pereira, J.L.; Pinheiro, A.L.; Fidencio, P.H.; Montanari, R.M. The chemical diversity of *Eucalyptus* spp. essential oils from plants grown in Brazil. *Chem. Biodivers.* **2008**. [[CrossRef](#)] [[PubMed](#)]
69. Salem, M.Z.M.; Zidan, Y.E.; Mansour, M.M.A.; El Hadidi, N.M.N.; Abo Elgat, W.A.A. Antifungal activities of two essential oils used in the treatment of three commercial woods deteriorated by five common mold fungi. *Int. Biodeterior. Biodegrad.* **2016**, *106*, 88–96. [[CrossRef](#)]
70. Debbarma, J.; Kishore, P.; Nayak, B.B.; Kannuchamy, N.; Gudipati, V. Antibacterial activity of ginger, *Eucalyptus* and sweet orange peel EOs on fish-borne bacteria. *J. Food Process. Preserv.* **2013**, *37*, 1022–1030.
71. Ghasemi, V.; Moharramipour, S.; Tahmasbi, G. Biological activity of some plant EOs against *Varroa destructor* (Acari: Varroidae), an ectoparasitic mite of *Apis mellifera* (Hymenoptera: Apidae). *Exp. Appl. Acarol.* **2011**, *55*, 147–154. [[CrossRef](#)] [[PubMed](#)]
72. Karemu, C.K.; Ndung'u, M.W.; Githua, M. Repellent effects of EOs from selected *Eucalyptus* species and their major constituents against *Sitophilus zeamais* (Coleoptera: Curculionidae). *Int. J. Trop. Insect Sci.* **2013**, *33*, 188–194. [[CrossRef](#)]
73. Oyediji, A.O.; Ekundayo, O.; Olawore, O.N.; Adeniyi, B.A.; Koenig, W.A. Antimicrobial activity of the EOs of five *Eucalyptus* species growing in Nigeria. *Fitoterapia* **1999**, *70*, 526–528. [[CrossRef](#)]
74. Akin, M.; Aktumsek, A.; Nostro, A. Antibacterial activity and composition of the EOs of *Eucalyptus camaldulensis* Dehn. and *Myrtus communis* L. growing in Northern Cyprus. *Afr. J. Biotechnol.* **2010**, *9*, 531–535.
75. Ghaffar, A.; Yameen, M.; Kiran, S.; Kamal, S.; Jalal, F.; Munir, B.; Saleem, S.; Rafiq, N.; Ahmad, A.; Saba, I.; et al. Chemical composition and in-vitro evaluation of the antimicrobial and antioxidant activities of essential oils extracted from seven *Eucalyptus* species. *Molecules* **2015**, *20*, 20487–20498. [[CrossRef](#)] [[PubMed](#)]
76. Verdeguer, M.; Blazquez, M.A.; Boira, H. Phytotoxic effects of *Lantana camara*, *Eucalyptus camaldulensis* and *Eriocephalus africanus* EOs in weeds of Mediterranean summer crops. *Biochem. Syst. Ecol.* **2009**, *37*, 362–369. [[CrossRef](#)]
77. Su, Y.C.; Ho, C.L.; Wang, E.I.; Chang, S.T. Antifungal activities and chemical compositions of EOs from leaves of four *Eucalyptus*. *Taiwan J. Sci.* **2006**, *21*, 49–61.
78. Cheng, S.S.; Huang, C.G.; Chen, Y.J.; Yu, J.J.; Chen, W.J.; Chang, S.T. Chemical compositions and larvicidal activities of leaf EOs from two *Eucalyptus* species. *Bioresour. Technol.* **2009**, *100*, 452–456. [[CrossRef](#)] [[PubMed](#)]

79. Jemaa, J.M.B.; Haouel, S.; Bouaziz, M.; Khouja, M.L. Seasonal variations in chemical composition and fumigant activity of five *Eucalyptus* EOs against three moth pests of stored dates in Tunisia. *J. Stored Prod. Res.* **2012**, *48*, 61–67. [[CrossRef](#)]
80. Jemaa, J.M.B.; Haouel, S.; Khouja, M.L. Efficacy of *Eucalyptus* EOs fumigant control against *Ectomyelois ceratoniae* (Lepidoptera: Pyralidae) under various space occupation conditions. *J. Stored Prod. Res.* **2013**, *53*, 67–71. [[CrossRef](#)]
81. Rossi, Y.E.; Palacios, S.M. Insecticidal toxicity of *Eucalyptus cinerea* essential oil and 1,8-cineole against *Musca domestica* and possible uses according to the metabolic response of flies. *Ind. Crops Prod.* **2015**, *63*, 133–137. [[CrossRef](#)]
82. Toloza, A.C.; Zygadlo, J.; Mougabure, C.G.; Biurrun, F.; Zerba, E.; Picollo, M.I. Fumigant and repellent properties of EOs and component compounds against permethrin-resistant *Pediculus humanus capitis* (Anoplura: Pediculidae) from Argentina. *J. Med. Entomol.* **2006**, *43*, 889–895. [[CrossRef](#)]
83. Palacios, S.M.; Bertoni, A.; Rossi, T.; Santander, R.; Urzúa, A. Efficacy of EOs from edible plants as insecticides against the house fly, *Musca Domestica* L. *Molecules* **2009**, *14*, 1938–1947. [[CrossRef](#)] [[PubMed](#)]
84. Silva, S.M.; Abe, S.Y.; Murakami, F.S.; Frensch, G.; Marques, F.A.; Nakashima, T. EOs from different plant parts of *Eucalyptus cinerea* F. Muell. ex Benth. (Myrtaceae) as a source of 1,8-cineole and their bioactivities. *Pharmaceuticals* **2011**, *4*, 1535–1550. [[CrossRef](#)] [[PubMed](#)]
85. Franco, J.; Nakashima, T.; Franco, L.; Boller, C. Composição química e atividade antimicrobiana *in vitro* do óleo essencial de *Eucalyptus cinerea* F. Mull. Ex Benth., Myrtaceae, extraído em diferentes intervalos de tempo. *Rev. Bras. Farmacogn.* **2005**, *15*, 191–194. [[CrossRef](#)]
86. Sebei, K.; Sakouhi, F.; Herchi, W.; Khouja, M.L.; Boukhchina, S. Chemical composition and antibacterial activities of seven *Eucalyptus* species EOs leaves. *Biol. Res.* **2015**, *48*, 7. [[CrossRef](#)] [[PubMed](#)]
87. Elaissi, A.; Marzouki, H.; Medini, H.; Khouja, M.L.; Farhat, F.; Lynene, F.; Harzallah-Skhiri, F.; Chemli, R. Variation in volatile leaf oils of 13 *Eucalyptus* species harvested from Souinet Arboreta (Tunisia). *Chem. Biodivers.* **2010**, *7*, 909–921. [[CrossRef](#)] [[PubMed](#)]
88. Lee, Y.-S.; Kim, J.; Shin, S.-C.; Lee, S.-G.; Park, I.-K. Antifungal activity of Myrtaceae EOs and their components against three phytopathogenic fungi. *Flavour Fragr. J.* **2008**, *23*, 23–28. [[CrossRef](#)]
89. Bossou, A.D.; Mangelinckx, S.; Yedomonhan, H.; Boko, P.M.; Akogbeto, M.C.; Kimpe, N.; Avlessi, F.; Sohounhloué, D.C.K. Chemical composition and insecticidal activity of plant EOs from Benin against *Anopheles gambiae* (Giles). *Parasit. Vectors* **2013**, *6*, 337. [[CrossRef](#)] [[PubMed](#)]
90. Bossou, A.D.; Ahoussi, E.; Ruysbergh, E.; Adams, A.; Smagghe, G.; De Kimpe, N.; Avlessi, F.; Sohounhloué, D.C.K.; Mangelinckx, S. Characterization of volatile compounds from three *Cymbopogon* species and *Eucalyptus citriodora* from Benin and their insecticidal activities against *Tribolium castaneum*. *Ind. Crops Prod.* **2015**, *76*, 306–317. [[CrossRef](#)]
91. Chagas, A.C.S.; Passos, W.M.; Prates, H.T.; Leitem, R.C.; Furlong, J.; Fortes, I.C.P. Acaricide effect of *Eucalyptus* spp. EOs and concentrated emulsion on *Boophilus microplus*. *Braz. J. Vet. Res. Anim. Sci.* **2002**, *39*, 247–253.
92. Gusmao, N.M.S.; Oliveira, J.V.; Navarro, D.M.A.F.; Dutra, K.A.; Silva, W.A.; Wanderley, M.J.A. Contact and fumigant toxicity and repellency of *Eucalyptus citriodora* Hook., *Eucalyptus staigeriana* F., *Cymbopogon winterianus* Jowitt and *Foeniculum vulgare* Mill. EOs in the management of *Callosobruchus maculatus* (FABR.) (Coleoptera: Chrysomelidae, Bruchinae). *J. Stored Prod. Res.* **2013**, *54*, 41–47.
93. Estanislau, A.A.; Barros, F.A.S.; Peña, A.P.; Santos, S.C.; Ferri, P.H.; Paula, J.R. Composição química e atividade antibacteriana dos óleos essenciais de cinco espécies de *Eucalyptus* cultivadas em Goiás. *Rev. Bras. Farmacogn.* **2001**, *11*, 95–100.
94. Macedo, I.T.F.; Bevilaqua, C.M.L.; Oliveira, L.M.B.; Camurça-Vasconcelos, A.L.F.; Vieira, L.S.; Amóra, S.S.A. Evaluation of *Eucalyptus citriodora* essential oil on goat gastrointestinal nematodes. *Rev. Bras. Parasitol. Vet.* **2011**, *20*, 223–227. [[CrossRef](#)] [[PubMed](#)]
95. Maciel, M.V.; Morais, S.M.; Bevilaqua, C.M.L.; Silva, R.A.; Barros, R.S.; Sousa, R.N.; Sousa, L.C.; Brito, E.S.; Souza-Neto, M.A. Chemical composition of *Eucalyptus* spp. EOs and their insecticidal effects on *Lutzomyia longipalpis*. *Vet. Parasitol.* **2010**, *167*, 1–7. [[CrossRef](#)] [[PubMed](#)]
96. Lima, J.K.A.; Albuquerque, E.L.D.; Santos, A.C.C.; Oliveira, A.P.; Araujo, A.P.A.; Blank, A.F.; Arrigoni-Blank, M.F.; Alves, P.B.; Santos, D.A.; Bacci, L. Biototoxicity of some plant EOs against the termite *Nasutitermes corniger* (Isoptera: Termitidae). *Ind. Crops Prod.* **2013**, *47*, 246–251. [[CrossRef](#)]

97. Ribeiro, J.C.; Ribeiro, W.L.C.; Camurça-Vasconcelos, A.L.F.; Macedo, I.T.F.; Santos, J.M.L.; Paula, H.C.B.; Araujo Filho, J.V.; Magalhães, R.D.; Bevilaqua, C.M.L. Efficacy of free and nanoencapsulated *Eucalyptus citriodora* EOs on sheep gastrointestinal nematodes and toxicity for mice. *Vet. Parasitol.* **2014**, *204*, 243–248. [[CrossRef](#)] [[PubMed](#)]
98. Aguiar, R.W.S.; Ootani, M.A.; Ascencio, S.D.; Ferreira, T.P.S.; Santos, M.M.; Santos, G.R. Fumigant antifungal activity of *Corymbia citriodora* and *Cymbopogon nardus* EOs and citronellal against three fungal species. *Sci. World J.* **2014**, *2014*, 149–168. [[CrossRef](#)] [[PubMed](#)]
99. Tomaz, M.A.; Costa, A.V.; Rodrigues, W.N.; Pinheiro, P.F.; Parreira, L.A.; Rinaldo, D.; Queiroz, V.T. Chemical composition and allelopathic activity of the *Eucalyptus* essential oil. *Biosci. J.* **2014**, *30*, 475–483.
100. Han, J.; Choi, B.R.; Lee, S.G.; Kim, S.I.; Ahn, Y.J. Toxicity of plant EOs to acaricide-susceptible and -resistant *Tetranychus urticae* (Acari: Tetranychidae) and *Neoseiulus californicus* (Acari: Phytoseiidae). *J. Econ. Entomol.* **2010**, *103*, 1293–1298. [[CrossRef](#)] [[PubMed](#)]
101. Han, J.; Kim, S.I.; Choi, B.R.; Lee, S.G.; Ahn, Y.J. Fumigant toxicity of lemon *Eucalyptus* oil constituents to acaricide-susceptible and acaricide-resistant *Tetranychus urticae*. *Pest Manag. Sci.* **2011**, *67*, 1583–1588. [[CrossRef](#)] [[PubMed](#)]
102. George, D.R.; Masic, D.; Sparagano, O.A.E.; Guy, J.H. Variation in chemical composition and acaricidal activity against *Dermanyssus gallinae* of four *Eucalyptus* EOs. *Exp. Appl. Acarol.* **2009**, *48*, 43–50. [[CrossRef](#)] [[PubMed](#)]
103. Vera, S.S.; Zambrano, D.F.; Méndez-Sánchez, S.C.; Rodríguez-Sanabria, F.; Stashenko, E.E.; Luna, J.E.D. EOs with insecticidal activity against larvae of *Aedes aegypti* (Diptera: Culicidae). *Parasitol. Res.* **2014**, *113*, 2647–2654. [[CrossRef](#)] [[PubMed](#)]
104. Olivero-Verbel, J.; Nerio, L.S.; Stashenko, E.E. Bioactivity against *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) of *Cymbopogon citratus* and *Eucalyptus citriodora* EOs grown in Colombia. *Pest Manag. Sci.* **2010**, *66*, 664–668. [[PubMed](#)]
105. Olivero-Verbel, J.; Tirado-Ballestas, I.; Caballero-Gallardo, K.; Stashenko, E.E. EOs applied to the food act as repellents toward *Tribolium castaneum*. *J. Stored Prod. Res.* **2013**, *55*, 145–147. [[CrossRef](#)]
106. Mulyaningsih, S.; Sporer, F.; Reichling, J.; Wink, M. Antibacterial activity of EOs from *Eucalyptus* and of selected components against multidrug-resistant bacterial pathogens. *Pharm. Biol.* **2011**, *49*, 893–899. [[CrossRef](#)] [[PubMed](#)]
107. Lee, S.O.; Choi, G.J.; Jang, K.S.; Lim, H.K.; Cho, K.Y.; Kim, J. Antifungal activity of five plant EOs as fumigant against postharvest and soilborne plant pathogenic fungi. *Plant Pathol. J.* **2007**, *23*, 97–102. [[CrossRef](#)]
108. Elaissi, A.; Medini, H.; Simmonds, M.; Lynen, F.; Farhat, F.; Chemli, R.; Harzallah-Skhiri, F.; Khouja, M.L. Variation in volatile leaf oils of seven *Eucalyptus* species harvested from Zerniza Arboreta (Tunisia). *Chem. Biodivers.* **2011**, *8*, 362–372. [[CrossRef](#)] [[PubMed](#)]
109. Harkat-Madouri, L.; Asma, B.; Madani, K.; Said, Z.B.S.; Rigou, P.; Grenier, D.; Allalou, H.; Remini, H.; Adjaoud, A.; Boulekbache-Makhlouf, L. Chemical composition, antibacterial and antioxidant activities of essential oil of *Eucalyptus globulus* from Algeria. *Ind. Crops Prod.* **2015**, *78*, 148–153. [[CrossRef](#)]
110. Toloza, A.C.; Lucia, A.; Zerba, E.; Masuh, H.; Picollo, M.I. *Eucalyptus* essential oil toxicity against permethrin-resistant *Pediculus humanus capitis* (Phthiraptera: Pediculidae). *Parasitol. Res.* **2010**, *106*, 409–414. [[CrossRef](#)] [[PubMed](#)]
111. Russo, S.; Cabrera, N.; Chludil, H.; Yaber-Grass, M.; Leicach, S. Insecticidal activity of young and mature leaves essential oil from *Eucalyptus globulus* Labill. against *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). *Chil. J. Agric. Res.* **2015**, *75*, 375–379. [[CrossRef](#)]
112. Yang, Y.; Choi, H.; Choi, W.; Clark, J.M.; Ahn, Y. Ovicidal and adulticidal activity of *Eucalyptus globulus* leaf oil terpenoids against *Pediculus humanus capitis* (Anoplura: Pediculidae). *J. Agric. Food Chem.* **2004**, *52*, 2507–2511. [[CrossRef](#)] [[PubMed](#)]
113. Lee, B.; Choi, W.; Lee, S.; Park, B. Fumigant toxicity of EOs and their constituent compounds towards the rice weevil, *Sitophilus oryzae* (L.). *Crop Prot.* **2001**, *20*, 317–320. [[CrossRef](#)]
114. Vilela, G.R.; Almeida, G.S.; D’Arce, M.A.B.R.; Moraes, M.H.D.; Brito, J.O.; Silva, M.F.G.F.; Silva, S.C.; Piedade, S.M.S.; Calori-Domingues, M.A.; Gloria, E.M. Activity of essential oil and its major compound, 1,8-cineole, from *Eucalyptus globulus* Labill., against the storage fungi *Aspergillus flavus* Link and *Aspergillus parasiticus* Speare. *J. Stored Prod. Res.* **2009**, *45*, 108–111. [[CrossRef](#)]

115. Macedo, I.T.F.; Bevilaqua, C.M.L.; Oliveira, L.M.B.; Camurça-Vasconcelos, A.L.F.; Vieira, L.S.; Oliveira, F.R.; Queiroz-Junior, E.M.; Portela, B.G.; Barros, R.S.; Chagas, A.C.S. Ovicidal and larvicidal activity in vitro of *Eucalyptus globulus* EOs on *Haemonchus contortus*. *Rev. Bras. Parasitol. Vet.* **2009**, *18*, 62–66. [[CrossRef](#)] [[PubMed](#)]
116. Mossi, A.J.; Astolfi, V.; Kubiak, G.; Lerin, L.; Zanella, C.; Toniazzo, G.; Oliveira, D.; Treichel, H.; Devilla, I.A.; Cansiana, R.; Restello, R. Insecticidal and repellency activity of essential oil of *Eucalyptus* sp. against *Sitophilus zeamais* Motschulsky (Coleoptera, Curculionidae). *J. Sci. Food Agric.* **2011**, *91*, 273–277. [[CrossRef](#)] [[PubMed](#)]
117. Yones, D.A.; Bakir, H.Y.; Bayoumi, S.A.L. Chemical composition and efficacy of some selected plant oils against *Pediculus humanus capitis* in vitro. *Parasitol. Res.* **2016**, *115*, 3209–3218. [[CrossRef](#)] [[PubMed](#)]
118. Mekonnen, A.; Yitayew, B.; Tesema, A.; Taddese, S. In Vitro Antimicrobial activity of essential oil of *Thymus schimperi*, *Matricaria chamomilla*, *Eucalyptus globulus*, and *Rosmarinus officinalis*. *Int. J. Microbiol.* **2016**, *2016*, 9545693. [[CrossRef](#)] [[PubMed](#)]
119. Gupta, A.; Sharma, S.; Naik, S.N. Biopesticidal value of selected EOs against pathogenic fungus, termites, and nematodes. *Int. Biodeterior. Biodegrad.* **2011**, *65*, 703–707. [[CrossRef](#)]
120. Pandey, A.; Chattopadhyay, P.; Banerjee, S.; Pakshirajan, K.; Singh, L. Antitermitic activity of plant EOs and their major constituents against termite *Odontotermes assamensis* Holmgren (Isoptera: Termitidae) of North East India. *Int. Biodeterior. Biodegrad.* **2012**, *75*, 63–67. [[CrossRef](#)]
121. Pant, M.; Dubey, S.; Patanjali, P.K.; Naik, S.N.; Sharma, S. Insecticidal activity of *Eucalyptus* oil nanoemulsion with karanja and jatropa aqueous filtrates. *Int. Biodeterior. Biodegrad.* **2014**, *91*, 119–127. [[CrossRef](#)]
122. Kumar, P.; Mishra, S.; Malik, A.; Satya, S. Compositional analysis and insecticidal activity of *Eucalyptus globulus* (family: Myrtaceae) essential oil against housefly (*Musca domestica*). *Acta Trop.* **2012**, *122*, 212–218. [[CrossRef](#)] [[PubMed](#)]
123. Golestani, M.R.; Rad, M.; Bassami, M.; Afkhami-Goli, A. Analysis and evaluation of antibacterial effects of new herbal formulas, AP-001 and AP-002, against *Escherichia coli* O157:H7. *Life Sci.* **2015**, *135*, 22–26. [[CrossRef](#)] [[PubMed](#)]
124. Tohidpour, A.; Sattari, M.; Omidbaigi, R.; Yadegar, A.; Nazemi, J. Antibacterial effect of EOs from two medicinal plants against Methicillin-resistant *Staphylococcus aureus* (MRSA). *Phytomedicine* **2010**, *17*, 142–145. [[CrossRef](#)] [[PubMed](#)]
125. Fratini, F.; Casella, S.; Leonardi, M.; Pisseri, F.; Ebani, V.V.; Pistelli, L.; Pistelli, L. Antibacterial activity of EOs, their blends and mixtures of their main constituents against some strains supporting livestock mastitis. *Fitoterapia* **2014**, *96*, 1–7. [[CrossRef](#)] [[PubMed](#)]
126. Vratnica, B.D.; Đakov, T.; Šuković, D.; Damjanović, J. Antimicrobial effect of essential oil isolated from *Eucalyptus globulus* Labill. from Montenegro. *Czech J. Food Sci.* **2011**, *29*, 277–284.
127. Derwich, E.; Benziane, Z.; Boukir, A. GC/MS analysis of volatile constituents and antibacterial activity of the essential oil of the leaves of *Eucalyptus globulus* in Atlas Median from Morocco. *Adv. Nat. Appl. Sci.* **2009**, *3*, 305–313.
128. Luis, A.; Duarte, A.; Gominho, J.; Domingues, F.; Duarte, A.P. Chemical composition, antioxidant, antibacterial and anti-quorum sensing activities of *Eucalyptus globulus* and *Eucalyptus radiata* essential oils. *Ind. Crops Prod.* **2016**, *79*, 274–282. [[CrossRef](#)]
129. Alzogaray, R.A.; Lucia, A.; Zerba, E.N.; Masuh, H.M. Insecticidal activity of EOs from eleven *Eucalyptus* spp. and two hybrids: Lethal and sublethal effects of their major components on *Blattella germanica*. *J. Econ. Entomol.* **2011**, *104*, 595–600. [[CrossRef](#)] [[PubMed](#)]
130. Lucia, A.; Gonzalez, A.P.; Seccacini, E.; Licastro, S.; Zerba, E.; Masuh, H.M. Larvicidal effect of *Eucalyptus grandis* essential oil and turpentine and their major components on *Aedes aegypti* larvae. *J. Am. Mosq. Control Assoc.* **2007**, *23*, 299–303. [[CrossRef](#)]
131. Gillij, Y.G.; Gleiser, R.M.; Zygadlo, J.A. Mosquito repellent activity of EOs of aromatic plants growing in Argentina. *Bioresour. Technol.* **2008**, *99*, 2507–2515. [[CrossRef](#)] [[PubMed](#)]
132. Sartorelli, P.; Marquiere, A.D.; Amaral-Baroli, A.; Lima, M.E.L.; Moreno, P.R.H. Chemical composition and antimicrobial activity of the EOs from two species of *Eucalyptus*. *Phytotherapy* **2007**, *21*, 231–233. [[CrossRef](#)] [[PubMed](#)]

133. Bett, P.K.; Deng, A.L.; Ogendob, J.O.; Kariuki, S.T.; Kamatenesi-Mugisha, M.; Mihale, J.M.; Torto, B. Chemical composition of *Cupressus lusitanica* and *Eucalyptus saligna* leaf essential oils and bioactivity against major insect pests of stored food grains. *Ind. Crops Prod.* **2016**, *82*, 51–62. [[CrossRef](#)]
134. Alitonou, G.; Avlessi, F.; Wotto, V.D.; Ahoussi, E.; Dangou, J.; Sohounhloué, D.C.K. Composition chimique, propriétés antimicrobiennes et activités sur les tiques de l'huile essentielle d'*Eucalyptus tereticornis* Sm. *C. R. Chim.* **2004**, *7*, 1051–1055. [[CrossRef](#)]
135. Silva, S.M.; Abe, S.Y.; Bueno, F.G.; Lopes, N.P.; Mello, J.C.P.; Nakashima, T. Direct proof by ¹³C-nuclear magnetic resonance of semi-purified extract and isolation of *ent*-Catechin from leaves of *Eucalyptus cinerea*. *Pharmacogn. Mag.* **2014**, *10*, 191–194. [[PubMed](#)]
136. Batish, D.R.; Singh, H.P.; Kohli, R.K.; Kaur, S. *Eucalyptus* essential oil as a natural pesticide. *For. Ecol. Manag.* **2008**, *256*, 2166–2174. [[CrossRef](#)]
137. Castro, N.E.A.; Carvalho, G.J.; Cardoso, M.G.; Pimentel, F.A.; Correa, R.M.; Guimaraes, L.G.L. Avaliação de rendimento e dos constituintes químicos do óleo essencial de folhas de *Eucalyptus citriodora* Hook. colhidas em diferentes épocas do ano em municípios de Minas Gerais. *Rev. Bras. Med.* **2008**, *10*, 70–75.
138. Martins, F.T.; Santos, M.H.; Polo, M.; Barbosa, L.C.A. Chemical variation in the essential oil of *Hyptis suaveolens* (L.) Poit., under cultivation condition. *Quím. Nova* **2006**, *29*, 1203–1209. [[CrossRef](#)]
139. Martins, F.T.; Santos, M.H.; Polo, M.; Barbosa, L.C.A. Effects of the interactions among macronutrients, plant age and photoperiod in the composition of *Hyptis suaveolens* (L.) Poit essential oil from Alfenas (MG), Brazil. *Flavour Fragr. J.* **2007**, *22*, 123–129. [[CrossRef](#)]
140. Castro, H.G.; Oliveira, L.O.; Barbosa, L.C.A.; Ferreira, F.A.; Silva, D.J.H.; Mosquim, P.R.; Nascimento, E.A. Teor e composição do óleo essencial de cinco acessos de mentrasto. *Quím. Nova* **2004**, *27*, 55–57. [[CrossRef](#)]
141. Silva, C.J.; Barbosa, L.C.A.; Maltha, C.R.A.; Pinheiro, A.L.; Ismail, F.M.D. Comparative study of the essential oils of seven *Melaleuca* (Myrtaceae) species grown in Brazil. *Flavour Fragr. J.* **2007**, *22*, 474–478. [[CrossRef](#)]
142. Bayala, B.; Bassole, I.H.N.; Gnoula, C.; Nebie, R.; Yonli, A.; Morel, L.; Figueredo, G.; Nikiema, J.; Lobaccaro, J.A.; Simpore, J. Chemical composition, antioxidant, anti-inflammatory and anti-proliferative activities of EOs of plants from Burkina Faso. *PLoS ONE* **2014**, *9*, e92122. [[CrossRef](#)] [[PubMed](#)]
143. Deba, F.; Xuan, T.D.; Yasuda, M.; Tawata, S. Chemical composition and antioxidant, antibacterial and antifungal activities of the EOs from *Bidens pilosa* Linn. var. *Radiata*. *Food Control* **2008**, *19*, 346–352. [[CrossRef](#)]
144. Pauli, A. Anticandidal low molecular compounds from higher plants with special reference to compounds from EOs. *Med. Res. Rev.* **2006**, *26*, 223–268. [[CrossRef](#)] [[PubMed](#)]
145. Sacchetti, G.; Maietti, S.; Muzzoli, M.; Scaglianti, M.; Manfredini, S.; Radice, M.; Bruni, R. Comparative evaluation of 11 EOs of different origin as functional antioxidants, antiradicals and antimicrobials in foods. *Food Chem.* **2005**, *91*, 621–632. [[CrossRef](#)]
146. Thuille, N.; Fille, M.; Nagl, M. Bactericidal activity of herbal extracts. *Int. J. Hyg. Envir. Health* **2003**, *206*, 217–221. [[CrossRef](#)] [[PubMed](#)]
147. Valero, M.; Salmeron, M.C. Antibacterial activity of 11 EOs against *Bacillus cereus* in tyndallized carrot broth. *Int. J. Food Microbiol.* **2003**, *85*, 73–81. [[CrossRef](#)]
148. Bugarin, D.; Grbovic, S.; Orcic, D.; Mitic-Culafic, D.; Knezevic-Vukcevic, J.; Mimica-Dukic, N. Essential oil of *Eucalyptus gunnii* Hook. as a novel source of antioxidant, antimutagenic and antibacterial agents. *Molecules* **2014**, *19*, 19007–19020. [[CrossRef](#)] [[PubMed](#)]
149. Rosato, A.; Vitali, C.; Laurentis, N.; Armenise, D.; Milillo, M.A. Antibacterial effect of some EOs administered alone or in combination with Norfloxacin. *Phytomedicine* **2007**, *14*, 727–732. [[CrossRef](#)] [[PubMed](#)]
150. Sonboli, A.; Babakhani, B.; Mehrabian, A.R. Antimicrobial activity of six constituents of essential oil from *Salvia*. *Z. Naturforsch. C* **2006**, *61*, 160–164. [[CrossRef](#)] [[PubMed](#)]
151. Ghalem, B.R.; Mohamed, B. Antibacterial activity of leaf EOs of *Eucalyptus globulus* and *Eucalyptus camaldulensis*. *Afr. J. Pharm. Pharmacol.* **2008**, *2*, 211–215.
152. Elaissi, A.; Rouis, Z.; Salem, N.A.B.; Mabrouk, S.; Salem, Y.B.; Salah, K.B.H.; Aouni, M.; Farhat, F.; Chemli, R.; Harzallah-Skhiri, F.; et al. Chemical composition of 8 *Eucalyptus* species' EOs and the evaluation of their antibacterial, antifungal and antiviral activities. *Complement. Altern. Med.* **2012**, *12*, 81. [[CrossRef](#)] [[PubMed](#)]

153. Elaissi, A.; Rouis, Z.; Mabrouk, S.; Salah, K.B.H.; Aouni, M.; Khouja, M.L.; Farhat, F.; Chemli, R.; Harzallah-Skhiri, F. Correlation between chemical composition and antibacterial activity of EOs from fifteen *Eucalyptus* species. Growing in the Korbous and Jbel Abderrahman Arboreta (North East Tunisia). *Molecules* **2012**, *17*, 3044–3057. [[CrossRef](#)] [[PubMed](#)]
154. Delaquis, P.J.; Stanich, K.; Girard, B.; Mazza, G. Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and *Eucalyptus* EOs. *Int. J. Food Microbiol.* **2002**, *74*, 101–109. [[CrossRef](#)]
155. Marzoug, H.N.B.; Bouajila, J.; Ennajar, M.; Lebrihi, A.; Mathieu, F.; Couderc, F.; Abderraba, M.; Romdhane, M. *Eucalyptus* (*gracilis*, *oleosa*, *salubris*, and *salmonophloia*) EOs: Their chemical composition and antioxidant and antimicrobial activities. *J. Med. Food* **2010**, *13*, 1005–1012. [[CrossRef](#)] [[PubMed](#)]
156. Proenza, Y.G.; Álvarez, R.Q.; Tamayo, Y.V.; Saavedra, M.A.; García, Y.S.; Espinosa, R.H. Chemical composition and antibacterial activity of the essential oil from *Eucalyptus pellita* F. Muell. *J. Med. Plants Res.* **2013**, *7*, 1979–1983.
157. Safaei-Ghomi, J.; Batooli, H. Chemical composition and antimicrobial activity of the volatile oil of *Eucalyptus sargentii* Maiden cultivated in central Iran. *Int. J. Green Pharm.* **2010**, *4*, 174–177. [[CrossRef](#)]
158. Ghnaya, A.B.; Hanana, M.; Amri, I.; Balti, H.; Gargouri, S.; Jamoussi, B.; Hamrouni, L. Chemical composition of *Eucalyptus erythrocorys* EOs and evaluation of their herbicidal and antifungal activities. *J. Pest Sci.* **2013**, *86*, 571–577. [[CrossRef](#)]
159. Camara, B.; Dick, E.; Sako, A.; Kone, D.; Kanko, C.; Boye, M.A.D.; Ake, S.; Anno, A. Lutte biologique contre *Deightoniella torulosa* (Syd.) Ellis, par l'application des huiles essentielles d'*Eucalyptus platyphylla* F. Muell. et de *Melaleuca quinquenervia* L. *Phytothérapie* **2010**, *8*, 240–244. [[CrossRef](#)]
160. Baptista, E.B.; Zimmermann-Franco, D.C.; Lataliza, A.A.B.; Raposo, N.R.B. Chemical composition and antifungal activity of essential oil from *Eucalyptus smithii* against dermatophytes. *Rev. Soc. Bras. Med. Trop.* **2015**, *48*, 746–752.
161. Ye, C.L.; Dai, D.H.; Hu, W.L. Antimicrobial and antioxidant activities of the essential oil from onion (*Allium cepa* L.). *Food Control* **2013**, *30*, 48–53. [[CrossRef](#)]
162. Singh, N.; Rajini, P.S. Free radical scavenging activity of an aqueous extract of potato peel. *Food Chem.* **2004**, *85*, 611–616. [[CrossRef](#)]
163. Puupponen-Pimiä, R.; Nohynek, L.; Meier, C.; Kähkönen, M.; Heinonen, M.; Hopia, A. Antimicrobial properties of phenolic compounds from berries. *J. Appl. Microbiol.* **2001**, *90*, 494–507. [[CrossRef](#)] [[PubMed](#)]
164. Cermelli, C.; Fabio, A.; Fabio, G.; Quaglio, P. Effect of *Eucalyptus* essential oil on respiratory bacteria and viruses. *Curr. Microbiol.* **2008**, *56*, 89–92. [[CrossRef](#)] [[PubMed](#)]
165. Srivastava, B.; Singh, P.; Shukla, R.; Dubey, N.K. A novel combination of the EOs of *Cinnamomum camphora* and *Alpinia galanga* in checking aflatoxin B1 production by a toxigenic strain of *Aspergillus flavus*. *World J. Microbiol. Biotechnol.* **2008**, *24*, 693–697. [[CrossRef](#)]
166. Roh, H.S.; Lee, B.H.; Park, C.G. Acaricidal and repellent effects of myrtacean EOs and their major constituents against *Tetranychus urticae* (Tetranychidae). *J. Asia-Pac. Entomol.* **2013**, *16*, 245–249. [[CrossRef](#)]
167. Clemente, M.A.; Monteiro, C.M.O.; Scoralik, M.G.; Gomes, F.T.; Prata, M.C.A.; Daemon, E. Acaricidal activity of the EOs from *Eucalyptus citriodora* and *Cymbopogon nardus* on larvae of *Amblyomma cajennense* (Acari: Ixodidae) and *Anocentor nitens* (Acari: Ixodidae). *Parasitol. Res.* **2010**, *107*, 987–992. [[CrossRef](#)] [[PubMed](#)]
168. Ware, G.W. *The Pesticide Book*, 5th ed.; Thomson Publications: Fresno, CA, USA, 1999.
169. Moreira, M.D.; Picanço, M.C.; Barbosa, L.C.A.; Guedes, R.N.C.; Silva, E.M. Toxicity of leaf extracts of *Ageratum conyzoides* to lepidoptera pests of horticultural crops. *Biol. Agric. Hort.* **2004**, *22*, 251–260. [[CrossRef](#)]
170. Moreira, M.D.; Picanço, M.C.; Barbosa, L.C.A.; Guedes, R.N.C.; Barros, E.C.; Campos, M.R. Compounds from *Ageratum conyzoides*: Isolation, structural elucidation and insecticide activity. *Pest Manag. Sci.* **2007**, *63*, 615–621. [[CrossRef](#)] [[PubMed](#)]
171. Moreira, M.D.; Picanço, M.C.; Barbosa, L.C.A.; Guedes, R.N.C.; Campos, M.R.; Silva, G.A.; Martins, J.C. Plant Compounds insecticide activity against Coleoptera pests of stored products. *Pesq. Agropec. Bras.* **2007**, *42*, 909–915. [[CrossRef](#)]
172. Tjahjani, S. Efficacy of several EOs as *Culex* and *Aedes* repellents. *Proc. ASEAN Congress Trop. Med. Parasitol.* **2008**, *3*, 33–37.
173. Sophia, N.; Pandian, R.S. Screening of the efficacy of phytochemical repellents against the filarial vector mosquito, *Culex quinquefasciatus* Say. *Curr. Biot.* **2009**, *3*, 14–31.

174. Govindarajan, M. Larvicidal and repellent properties of some EOs against *Culex tritaeniorhynchus* Giles and *Anopheles subpictus* Grassi (Diptera: Culicidae). *Asian Pac. J. Trop. Med.* **2011**, *4*, 106–111. [[CrossRef](#)]
175. Mandal, S. Repellent activity of *Eucalyptus* and *Azadirachta indica* seed oil against the filarial mosquito *Culex quinquefasciatus* Say. (Diptera: Culicidae) in India. *Asian Pac. J. Trop. Biomed.* **2011**, *1*, S109–S112. [[CrossRef](#)]
176. Tennyson, S.; Ravindran, J.; Eapen, A.; Willian, J. Repellent activity of *Ageratum houstonianum* Mill. (Asteraceae) leaf extracts against *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae). *Asian Pac. J. Trop. Dis.* **2012**, *6*, 478–480. [[CrossRef](#)]
177. Gokulakrishnan, J.; Kuppusamy, E.; Shanmugam, D.; Appavu, A.; Kaliyamoorthi, K. Pupicidal and repellent activities of *Pogostemon cablin* essential oil chemical compounds against medically important human vector mosquitoes. *Asian Pac. J. Trop. Dis.* **2013**, *3*, 26–31. [[CrossRef](#)]
178. Nerio, L.S.; Olivero-Verbel, J.; Stashenko, E. Repellent activity of EOs: A review. *Bioresour. Technol.* **2010**, *101*, 372–378. [[CrossRef](#)] [[PubMed](#)]
179. Murugan, K.; Murugan, P.; Noortheen, A. Larvicidal and repellent potential of *Albizzia amara* Boivin and *Ocimum basilicum* Linn against dengue vector, *Aedes aegypti* (Insecta: Diptera: Culicidae). *Bioresour. Technol.* **2007**, *98*, 198–201. [[CrossRef](#)] [[PubMed](#)]
180. Choochote, W.; Chaithong, U.; Kamsuk, K.; Jitpakdi, A.; Tippawangkosol, P.; Tueton, B.; Champakaew, D.; Pitasawat, B. Repellent activity of selected EOs against *Aedes aegypti*. *Fitoterapia* **2007**, *78*, 359–364. [[CrossRef](#)] [[PubMed](#)]
181. Phasomkusolsil, S.; Soonwera, M. Efficacy of herbal EOs as insecticide against *Aedes aegypti* (Linn.), *Culex quinquefasciatus* (Say.) and *Anopheles dirus* (Peyton and Harrison). *Southeast Asian J. Trop. Med. Public Health* **2011**, *42*, 1083–1092. [[PubMed](#)]
182. Krishnappa, K.; Elumalai, K. Toxicity of *Aristolochia bracteata* methanol leaf extract against selected medically important vector mosquitoes (Diptera: Culicidae). *Asian Pac. J. Trop. Dis.* **2012**, *2*, S553–S557. [[CrossRef](#)]
183. Govindarajan, M. Chemical composition and larvicidal activity of leaf essential oil from *Clausena anisata* (Willd.) Hook. f. ex Benth (Rutaceae) against three mosquito species. *Asian Pac. J. Trop. Med.* **2010**, *3*, 874–877. [[CrossRef](#)]
184. Govindarajan, M.; Sivakumar, R. Repellent properties of *Cardiospermum halicacabum* Linn. (Family: Sapindaceae) plant leaf extracts against three important vector mosquitoes. *Asian Pac. J. Trop. Biomed.* **2012**, *8*, 602–607. [[CrossRef](#)]
185. Aarathi, N.; Murugan, K. Larvicidal and repellent activity of *Vetiveria zizanioides* L, *Ocimum basilicum* Linn and the microbial pesticide spinosad against malarial vector, *Anopheles stephensi* Liston (Insecta: Diptera: Culicidae). *J. Biopestic.* **2010**, *3*, 199–204.
186. Ali, A.; Murphy, C.C.; Demirci, B.; Wedge, D.W.; Sampson, B.J.; Khan, I.A.; Baser, K.H.C.; Tabanca, N. Insecticidal and biting deterrent activity of rose-scented geranium (*Pelargonium* spp.) EOs and individual compounds against *Stephanitis pyrioides* and *Aedes aegypti*. *Pest Manag. Sci.* **2013**, *69*, 1385–1392. [[CrossRef](#)] [[PubMed](#)]
187. Ali, A.; Tabanca, N.; Demirci, B.; Baser, K.H.C.; Ellis, J.; Gray, S.; Lackey, B.R.; Murphy, C.; Khan, I.A.; Wedge, D.E. Composition, mosquito larvicidal, biting deterrent and antifungal activity of EOs of different plant parts of *Cupressus arizonica* var. *glabra* ('Carolina Sapphire'). *Nat. Prod. Commun.* **2013**, *8*, 257–260. [[PubMed](#)]
188. Hoel, D.; Pridgeon, J.W.; Bernier, U.R.; Chauhan, K.; Meepagala, K.; Cantrell, C. Departments of Defense and Agriculture team up to develop new insecticides for mosquito control. *Wing Beats* **2010**, *21*, 19–34.
189. Nascimento, J.C.; David, J.M.; Barbosa, L.C.A.; Paula, V.F.; Demuner, A.J.; David, J.P.; Conserva, L.M.; Ferreira, J.C.; Guimarães, E.F. Larvicidal activities and chemical composition of essential oils from *Piper klotzschianum* (Kunth) C. DC. (Piperaceae). *Pest Manag. Sci.* **2013**, *69*, 1267–1271. [[PubMed](#)]
190. Pavela, R. Larvicidal property of EOs against *Culex quinquefasciatus* Say. (Diptera: Culicidae). *Ind. Crops Prod.* **2009**, *30*, 311–315. [[CrossRef](#)]
191. Pavela, R. Larvicidal effects of some Euro-Asiatic plants against *Culex quinquefasciatus* Say larvae (Diptera: Culicidae). *Parasitol. Res.* **2009**, *105*, 887–892. [[CrossRef](#)] [[PubMed](#)]
192. Tabanca, N.; Bernier, U.R.; Ali, A.; Wang, M.; Demirci, B.; Blythe, E.K.; Khan, S.I.; Baser, K.H.C.; Khan, I.A. Bioassay-guided investigation of two *Monarda* EOs as repellents of yellow fever mosquito *Aedes aegypti*. *J. Agric. Food Chem.* **2013**, *61*, 8573–8580. [[CrossRef](#)] [[PubMed](#)]

193. Wedge, D.E.; Klun, J.A.; Tabanca, N.; Demirci, B.; Ozek, T.; Baser, K.H.C.; Liu, Z.; Zhang, S.; Cantrell, C.L.; Zhan, J. Bioactivity-guided fractionation and GC/MS fingerprinting of *Angelica sinensis* and *Angelica archangelica* root components for antifungal and mosquito deterrent activity. *J. Agric. Food Chem.* **2009**, *57*, 464–470. [[CrossRef](#)] [[PubMed](#)]
194. Hamdi, S.H.; Hedjal-Chebheb, M.; Kellouche, A.; Khouja, M.L.; Boudabous, A.; Jemaa, J.M.B. Management of three pests' population strains from Tunisia and Algeria using *Eucalyptus* essential oils. *Ind. Crops Prod.* **2015**, *74*, 551–556. [[CrossRef](#)]
195. Juan, L.; Lucia, A.; Zerba, E.; Harrand, L.; Marco, M.; Masuh, H. Chemical composition and fumigant toxicity of the EOs from 16 species of *Eucalyptus* against *Haematobia irritans* (L.) (Diptera: Muscidae) adults. *J. Econ. Entomol.* **2011**, *104*, 1087–1092. [[CrossRef](#)] [[PubMed](#)]
196. Lucia, A.; Juan, L.W.; Zerba, E.N.; Harrand, L.; Marcó, M.; Masuh, H.M. Validation of models to estimate the fumigant and larvicidal activity of *Eucalyptus* EOs against *Aedes aegypti* (Diptera: Culicidae). *Parasitol. Res.* **2012**, *110*, 1675–1686. [[CrossRef](#)] [[PubMed](#)]
197. Aref, S.P.; Valizadegan, O.; Farashiani, M.E. *Eucalyptus dundasii* Maiden essential oil, chemical composition and insecticidal values against *Rhyzopertha dominica* (F.) and *Oryzaephilus surinamensis* (L.). *J. Plant Prot. Res.* **2015**, *55*, 35–41. [[CrossRef](#)]
198. Aref, S.P.; Valizadegan, O.; Farashiani, M.E. The insecticidal effect of essential oil of *Eucalyptus floribundi* against two major stored product insect pests; *Rhyzoperth dominica* (F.) and *Oryzaephilus surinamensis* (L.). *J. Essent. Oil Bear. Plants* **2016**, *19*, 820–831. [[CrossRef](#)]
199. Rajendran, S.; Sriranjini, V. Plant products as fumigants for stored-product insect control. *J. Stored Prod. Res.* **2008**, *44*, 126–135. [[CrossRef](#)]
200. Houghton, P.J.; Ren, Y.; Howes, M.J. Acetylcholinesterase inhibitors from plants and fungi. *Nat. Prod. Rep.* **2006**, *23*, 181–199. [[CrossRef](#)] [[PubMed](#)]
201. Seyoum, A.; Killeen, G.F.; Kabiru, E.W.; Knols, B.G.J.; Hassanali, A. Field efficacy of thermally expelled or live potted repellent plants against African malaria vectors in western Kenya. *Trop. Med. Int. Health* **2003**, *8*, 1005–1011. [[CrossRef](#)] [[PubMed](#)]
202. Nathan, S.S. The use of *Eucalyptus tereticornis* Sm: (Myrtaceae) oil (leaf extract) as a natural larvicidal agent against the malaria vector *Anopheles stephensi* Liston (Diptera: Culicidae). *Bioresour. Technol.* **2007**, *98*, 1856–1860.
203. Coob, A.H.; Reade, J.P.H. *Herbicides and Plant Physiology*, 2nd ed.; Wiley-Blackwell: Chichester, UK, 2010; p. 286.
204. Dayan, F.E.; Cantrell, C.L.; Duke, S.O. Natural products in crop protection. *Bioorg. Med. Chem.* **2009**, *17*, 4022–4034. [[CrossRef](#)] [[PubMed](#)]
205. Zanic, K.; Goreta, S.; Perica, S.; Sutik, J. Effects of alternative pesticides on greenhouse whitefly in protected cultivation. *J. Pest Sci.* **2008**, *81*, 161–166. [[CrossRef](#)]
206. Seyran, M.; Brenneman, T.B.; Stevenson, K.L. In vitro toxicity of alternative oxidase inhibitors salicylhydroxamic acid and propyl gallate on *Fusicladium effusum*. *J. Pest Sci.* **2010**, *83*, 421–427. [[CrossRef](#)]
207. Yangui, T.; Sayadi, S.; Rhouma, A.; Dhoubi, A. Potential use of hydroxytyrosol-rich extract from olive mill wastewater as a biological fungicide against *Botrytis cinerea* in tomato. *J. Pest Sci.* **2010**, *83*, 437–445. [[CrossRef](#)]
208. Varejao, E.V.V.; Demuner, A.J.; Barbosa, L.C.A.; Barreto, R.W. The search for new natural herbicides—Strategic approaches for discovering fungal phytotoxins. *Crop Prot.* **2013**, *48*, 41–50. [[CrossRef](#)]
209. Douda, O.; Zouhar, M.; Mazáková, J.; Nováčková, E.; Pavela, R. Using plant essence as alternatives mean for northern root-knot nematode (*Meloidogyne hapla*) management. *J. Pest Sci.* **2010**, *83*, 217–221. [[CrossRef](#)]
210. Batish, D.R.; Setia, N.; Singh, H.P.; Kohli, R.K. Phytotoxicity of lemon-scented eucalypt oil and its potential use as a bioherbicide. *Crop Prot.* **2004**, *23*, 1209–1214. [[CrossRef](#)]
211. Setia, N.; Batish, D.R.; Singh, H.P.; Kohli, R.K. Phytotoxicity of volatile oil from *Eucalyptus citriodora* against some weedy species. *J. Environ. Biol.* **2007**, *28*, 63–66. [[PubMed](#)]
212. Zhang, J.; An, M.; Wu, H. Chemical composition of EOs of four *Eucalyptus* species and their phytotoxicity on silver leaf nightshade (*Solanum elaeagnifolium* Cav.) in Australia. *Plant Growth Regul.* **2012**, *68*, 231–237. [[CrossRef](#)]
213. Zhang, J.; An, M.; Wu, H.; Liu, D.L.; Stanton, R. Phytotoxic activity and chemical composition of aqueous volatile fractions from *Eucalyptus* species. *PLoS ONE* **2014**, *9*, e93189. [[CrossRef](#)] [[PubMed](#)]

214. Qiu, X.; Yu, S.; Wang, Y.; Fang, B.; Cai, C.; Liu, S. Identification and allelopathic effects of 1,8-cineole from *Eucalyptus urophylla* on lettuce. *Allelopathy J.* **2010**, *26*, 255–264.
215. Vivan, G.A.; Barboza, F.S.; Luz, M.L.G.S.; Luz, C.A.S.; Pereira-Ramirez, O.; Gomes, M.C.; Soares, F.C. Estudo técnico e econômico de um sistema móvel de extração de óleo essencial de eucalipto. *Cerne* **2011**, *17*, 23–31. [[CrossRef](#)]
216. Coppen, J.J.W.; Hone, G.A. *Eucalyptus Oils—A Review of Production and Markets—Bulletin 56*; Natural Resources Institute, University of Greenwich: London, England, 1992.
217. Lassak, E.V. The Australian *Eucalyptus* oil industry, past and present. *Chem. Aust.* **1998**, *55*, 396–398.
218. Doran, J.C. Commercial sources, uses, formation, and biology. In *Eucalyptus Leaf Oils: Use, Chemistry, Distillation and Marketing*; Boland, D., Brophy, J., House, J.J., Eds.; Inkata: Melbourne, Australia, 1991; pp. 11–28.
219. Silva, J.C. Eucalipto: Pesquisa amplia usos: Perspectivas do setor florestal Brasileiro. *Rev. Madeira* **2003**, *13*, 4–6.
220. Coppen, J.J.W. Productions, trade and markets for *Eucalyptus* oil. In *Eucalyptus—The Genus Eucalyptus*; Coppen, J.J.W., Ed.; Taylor and Francis: London, UK, 2005; Chapter 17; pp. 365–383.



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